INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)

(Approved by AICTE | NAAC Accreditation with 'A++' Grade | Accredited by NBA | Affiliated to JNTUH)

Dundigal, Hyderabad - 500 043, Telangana

OUTCOME BASED EDUCATION
WITH
CHOICE BASED CREDIT SYSTEM

BACHELOR OF TECHNOLOGY
ELECTRICAL AND ELECTRONICS ENGINEERING

ACADEMIC REGULATIONS, COURSE CATALOGUE and SYLLABUS
BT25

B.Tech Regular Four Year Degree Program
(for the batches admitted from the academic year 2025 - 2026)

&

B.Tech (Lateral Entry Scheme)
(for the batches admitted from the academic year 2026 - 2027)

These rules and regulations may be altered / changed from time to time by the academic council
FAILURE TO READ AND UNDERSTAND THE RULES IS NOT AN EXCUSE

VISION

To bring forth students, professionally competent and socially progressive, capable of working across cultures meeting the global standards ethically.

MISSION

To provide students with an extensive and exceptional education that prepares them to excel in their profession, guided by dynamic intellectual community and be able to face the technically complex world with creative leadership qualities.

Further, be instrumental in emanating new knowledge through innovative research that emboldens entrepreneurship and economic development for the benefit of wide spread community.

QUALITY POLICY

Our policy is to nurture and build diligent and dedicated community of engineers providing a professional and unprejudiced environment, thus justifying the purpose of teaching and satisfying the stake holders.

A team of well qualified and experienced professionals ensure quality education with its practical application in all areas of the Institute.

PROGRAM OUTCOMES (PO's)
Engineering Graduates will be able to:
PO1: **Engineering Knowledge:** Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop to the solution of complex engineering problem.
PO2: **Problem Analysis:** Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4)
PO3: **Development of Solutions:** Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required. (WK5).
PO4: **Conduct Investigations of Complex Problems:** Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8).
PO5: **Engineering Tool Usage:** Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling recognizing their limitations to solve complex engineering problems. (WK2 and WK6).
PO6: **The Engineer and The World:** Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7).
PO7: **Ethics:** Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9)
PO8: **Individual and Collaborative Team work:** Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams
PO9: **Communication:** Communicate effectively and inclusively within the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences
PO10: **Project Management and Finance:** Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects and in multidisciplinary environments.
PO11: **Life-Long Learning:** Recognize the need for, and have the preparation and ability for i) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change. (WK8).

CONTENTS

> **"Take up one idea.**
> **Make that one idea your life-think of it, dream of it, live on that idea.**
> **Let the brain muscles, nerves, every part of your body be full of that idea and just leave every other idea alone. This is the way to success"**
>
> **Swami Vivekananda**

PRELIMINARY DEFINITIONS AND NOMENCLATURES

AICTE: Means All India Council for Technical Education, New Delhi.

Autonomous Institute: Means an institute designated as Autonomous by University Grants Commission (UGC), New Delhi in concurrence with affiliating University (Jawaharlal Nehru Technological University, Hyderabad) and State Government.

Academic Autonomy: Means freedom to an institute in all aspects of conducting its academic programs, granted by UGC for Promoting Excellence.

Academic Council: The Academic Council is the highest academic body of the institute and is responsible for the maintenance of standards of instruction, education and examination within the institute. Academic Council is an authority as per UGC regulations and it has the right to take decisions on all academic matters including academic research.

Academic Year: It is the period necessary to complete an actual course of study within a year. It comprises two main semesters i.e., (one odd + one even) and one supplementary semester.

Branch: Means specialization in a program like B.Tech degree program in Aeronautical Engineering, B.Tech degree program in Computer Science and Engineering etc.

Board of Studies (BOS): BOS is an authority as defined in UGC regulations, constituted by Head of the Organization for each of the departments separately. They are responsible for curriculum design and updation in respect of all the programs offered by a department.

Backlog Course: A course is considered to be a backlog course, if the student has obtained a failure grade (F) in that course.

Basic Sciences: The courses offered in the areas of Mathematics, Physics, Chemistry etc., are considered to be foundational in nature.

Betterment: Betterment is a way that contributes towards improvement of the students' grade in any course(s). It can be done by either (a) re-appearing or (b) re-registering for the course.

Commission: Means University Grants Commission (UGC), New Delhi.

Choice Based Credit System: The credit based semester system is one which provides flexibility in designing curriculum and assigning credits based on the course content and hours of teaching along with provision of choice for the student in the course selection.

Certificate Course: It is a course that makes a student to have hands-on expertise and skills required for holistic development in a specific area/field.

Compulsory course: Course required to be undertaken for the award of the degree as per the program.

Continuous Internal Examination: It is an examination conducted towards sessional assessment.

Core: The courses that are essential constituents of each engineering discipline are categorized as professional core courses for that discipline.

Course: A course is offered by a department for learning in a particular semester.

Course Outcomes: The essential skills that need to be acquired by every student through a course.

Credit: A credit is a unit that gives weight to the value, level or time requirements of an academic course. The number of 'Contact Hours' in a week of a particular course determines its credit value. One credit is equivalent to one lecture/tutorial hour per week.

Credit point: It is the product of grade point and number of credits for a course.

Cumulative Grade Point Average (CGPA): It is a measure of cumulative performance of a student over all the completed semesters. The CGPA is the ratio of total credit points secured by a student in various courses in all semesters and the sum of the total credits of all courses in all the semesters. It is expressed up to two decimal places.

Curriculum: Curriculum incorporates the planned interaction of students with instructional content, materials, resources, and processes for evaluating the attainment of Program Educational Objectives.

Department: An academic entity that conducts relevant curricular and co-curricular activities, involving both teaching and non-teaching staff, and other resources in the process of study for a degree.

Detention in a Course: Student who does not obtain minimum prescribed attendance in a course shall be detained in that particular course.

Dropping from Semester: Student who doesn't want to register for any semester can apply in writing in prescribed format before the commencement of that semester.

Elective Course: A course that can be chosen from a set of courses. An elective can be Professional Elective and / or Open Elective.

Evaluation: Evaluation is the process of judging the academic performance of the student in her/his courses. It is done through a combination of continuous internal assessment and semester end examinations.

Experiential Engineering Education (ExEEd): Engineering entrepreneurship requires strong technical skills in engineering design and computation with key business skills from marketing to business model generation. Our students require sufficient skills to innovate in existing companies or create their own.

Grade: It is an index of the performance of the students in a said course. Grades are indicated by alphabets.

Grade Point: It is a numerical weight allotted to each letter grade on a 10 - point scale.

Honours: An Honours degree typically refers to a higher level of academic achievement at an undergraduate level.

Institute: Means Institute of Aeronautical Engineering, Hyderabad unless indicated otherwise by the context.

Massive Open Online Courses (MOOC): MOOC courses inculcate the habit of self-learning. MOOC courses would be additional choices in all the elective group courses.

Minor: Minor are coherent sequences of courses which may be taken in addition to the courses required for the B.Tech degree.

Pre-requisite: A specific course, the knowledge of which is required to complete before student register another course at the next grade level.

Professional Elective: It indicates a course that is discipline centric. An appropriate choice of minimum number of such electives as specified in the program will lead to a degree with specialization.

Program: Means, UG degree program: Bachelor of Technology (B.Tech); PG degree program: Master of Technology (M.Tech) / Master of Business Administration (MBA).

Program Educational Objectives: The broad career, professional and personal goals that every student will achieve through a strategic and sequential action plan.

Project work: It is a design or research-based work to be taken up by a student during his/her final year to achieve a particular aim. It is a credit based course and is to be planned carefully by the student.

Re-Appearing: A student can reappear only in the semester end examination for theory component of a course to the regulations contained herein.

Registration: Process of enrolling into a set of courses in a semester of a program.

Regulations: The regulations, common to all B.Tech programs offered by Institute, are designated as "BT23" and are binding on all the stakeholders.

Semester: It is a period of study consisting of 16 weeks of academic work equivalent to normally minimum of 90 working days. Odd semester commences usually in July and even semester in December of every year.

Semester End Examinations: It is an examination conducted for all courses offered in a semester at the end of the semester.

S/he: Means "she" and "he" both.

Student Outcomes: The essential skill sets that need to be acquired by every student during her/his program of study. These skill sets are in the areas of employability, entrepreneurial, social and behavioral.

University: Means Jawaharlal Nehru Technological University Hyderabad (JNTUH), Hyderabad, is an affiliating University.

Withdraw from a Course: Withdrawing from a course means that a student can drop from a course within the first two weeks of odd or even semester (deadlines are different for summer sessions). However, s/he can choose a substitute course in place of it, by exercising the option within 5 working days from the date of withdrawal.

PREFACE

Dear Students,

The focus at IARE is to deliver value-based education with academically well qualified faculty and infrastructure. It is a matter of pride that IARE continues to be the preferred destination for students to pursue an engineering degree.

In the year 2015, IARE was granted academic autonomy status by University Grants Commission, New Delhi under Jawaharlal Nehru Technology University Hyderabad. From then onwards, our prime focus is on developing and delivering a curriculum which caters to the needs of various stakeholders. The curriculum has unique features enabling students to develop critical thinking, solve problems, analyze socially relevant issues, etc. The academic cycle designed on the basis of Outcome Based Education (OBE) strongly emphasizes continuous improvement and this has made our curriculum responsive to current requirements.

The curriculum at IARE has been developed by experts from academia and industry and it has unique features to enhance problem solving skills apart from academic enrichment. The curriculum of B.Tech program has been thoroughly revised as per AICTE / UGC / JNTUH guidelines and have incorporated unique features such as competency training / coding, industry driven elective, internship and many more. The curriculum is designed in a way so as to impart engineering education in a holistic approach towards Excellence.

I hope you will have a fruitful stay at IARE.

Dr. L V Narasimha Prasad
Principal

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)

ACADEMIC REGULATIONS – BT25

B.Tech. Regular Four-Year Degree Program
(for the batches admitted from the academic year 2025 - 2026)
&
B.Tech. (Lateral Entry Scheme)
(for the batches admitted from the academic year 2026 - 2027)

For pursuing Four-year undergraduate Bachelor of Technology (B.Tech) degree program of study in engineering offered by Institute of Aeronautical Engineering under Autonomous status.

A student after securing admission shall complete the B.Tech. program in a minimum period of four academic years and a maximum period of eight academic years starting from the date of commencement of first semester, failing which student shall forfeit seat in B.Tech. course. Each student has to secure a minimum of 160 credits out of 164 credits for successful completion of the undergraduate program and award of the B.Tech. degree. Additional 20/18 credits can be acquired for the degree of B.Tech with **Honours or Minor in Engineering**. Separate certificate will be issued in addition to major degree program mentioning that the student has cleared Honours / Minor specialization in respective courses.

1. CHOICE BASED CREDIT SYSTEM

The credit-based semester system provides flexibility in designing program curriculum and assigning credits based on the course content and hours of teaching. The Choice Based Credit System (CBCS) provides a 'cafeteria' type approach in which the students can take courses of their choice, learn at their own pace, undergo additional courses and acquire more than the required credits, and adopt an interdisciplinary approach to learning.

A course defines learning objectives and learning outcomes and comprises lectures / tutorials / laboratory work / field based research work / capstone project / seminars / internship / assignments / MOOCs / alternative assessment tools / presentations / self-study etc., or a combination of some of these. Under the CBCS, the requirement for awarding a degree is prescribed in terms of number of credits to be completed by the students.

2. MEDIUM OF INSTRUCTION

The medium of instruction shall be **English** for all courses, examinations, seminar presentations and project work. The program curriculum will comprise courses of study as given in course structure, in accordance with the prescribed syllabi.

3. PROGRAMS OFFERED

Presently, the institute is offering Bachelor of Technology (B.Tech) degree programs in Nine disciplines. The various programs and their two-letter unique codes are given in Table 1.

Table 1: B.Tech programs offered

S.No	Name of the Program	Title	Code
1	Aeronautical Engineering	AE	07
2	Computer Science and Engineering	CS	05
3	Computer Science and Engineering (AI&ML)	CA	34
4	Computer Science and Engineering (Data Science)	CD	35
5	Information Technology	IT	06
6	Electronics and Communication Engineering	EC	04
7	Electrical and Electronics Engineering	EE	02

8	Mechanical Engineering	ME	03
9	Civil Engineering	CE	01

4. SEMESTER STRUCTURE

The undergraduate program is of four academic years and there shall be two semesters in each academic year. There shall be a minimum of 15 weeks of instruction weeks, excluding the mid-term and semester-end exams. Around 15 instruction hours, 30 instruction hours and 45 hours of learning need to be followed per one credit of theory course, practical course and project/field-based learning respectively. All second Saturday's are observed as holiday.

Readmitted students and those admitted on transfer from JNTUH-affiliated institutes, universities, or other institutions are required to pursue the prescribed courses and earn credits on par with regular students, as prescribed by the respective Board of Studies.

5 REGISTRATION / DROPPING / WITHDRAWAL

The academic calendar includes important academic activities to assist the students and the faculty. These includes commencement of class work, continuous internal examinations, preparation holidays and semester end examinations. This enables the students to be well prepared and take full advantage of the flexibility provided by the credit system.

5.1. Each student has to compulsorily register for course work at the beginning of each semester as per the schedule mentioned in the academic calendar. It is compulsory for the student to register for courses in time. The registration will be organized departmentally under the supervision of the Head of the department.

5.2. In ABSENTIA, registration will not be permitted under any circumstances.

5.3. At the time of registration, students should have cleared all the dues of Institute and Hostel for the previous semesters, paid the prescribed fees for the current semester and not been debarred from the institute for a specified period on disciplinary or any other ground.

5.4. In the first two semesters, the prescribed course load per semester is fixed and is mandated to register all the courses. Withdrawal / Dropping of courses in the first and second semester is not allowed.

5.5. In all semesters, the average load is 20 credits / semester, with its minimum and maximum limits being set at 16 and 24 credits. This flexibility enables students (**from IV semester onwards**) to cope with the course work considering the academic strength and capability of student.

5.6. **Dropping of Courses:**
Within one week after the last date of first continuous internal examination, the student may in consultation with his / her faculty mentor / adviser, drop one or more courses without prejudice to the minimum number of credits as specified in clause 5.5. The dropped courses are not recorded in the memorandum of grades. Student must complete the dropped course(s) by registering in the forthcoming semester in order to earn the required credits.

5.7. **Withdrawal from Courses:**
A student is permitted to withdraw from a course before commencement first continuous internal examination. Such withdrawals will be permitted without prejudice to the minimum number of credits as specified in clause 5.5. A student cannot withdraw a course more than once and withdrawal of reregistered courses is not permitted.

6. CREDIT SYSTEM

The B.Tech program shall consist of a number of courses and each course shall be assigned with credits. The curriculum shall comprise Foundation Courses (FC), Professional Core (PC), Professional Electives (PE), Open Electives (OE), Laboratory Courses, Skill Development Courses, Other Courses and Mandatory Courses (MC) / Value Added Courses (VAC).

Depending on the complexity and volume of the course, the number of contact periods per week will be assigned. Each theory and laboratory course carries credits based on the number of hours/weeks.

- Contact classes (Theory): 1 credit per lecture hour per week, 1 credit per tutorial hour per week.
- Laboratory hours (Practical): 1 credit for 2 practical hours per week.
- Project work: 1 credit for 4 hours in a semester for Project/Mini-Project session per week.
- Skill Development Courses: 1 credit for 2 hours
- Mandatory courses / Value added courses : 1 credit is awarded.

Category wise distribution of Credits is shown in Table 2.

Table 2: Category Wise Distribution of Credits

S.No	Category	Number of courses	Credits per course(s)	Total Credits	
1	BS - Basic Science (1 - 4 credits, 4 - 3 Credits)	5	4/3	16	18
	BS - Basic Science Laboratories	2	1	2	
2	ES - Engineering Science	3	3	9	20
	ES - Engineering Science Laboratories	2	1	2	
	MEC Courses	2	3/1	4	
	CSC Courses	3	3/1	5	
3	HS - Humanities and Social Sciences	1	3	3	6
	HS - Humanities and Social Sciences Laboratories	3	1	3	
4	Professional Core - Theory	16	3	-	48
	Professional Core - Laboratories	15	1	-	15
5	Professional Electives	6	3		18
6	Open Electives	3	2		6
7	Project Work	1	14		14
8	Skill Development Courses	4	1		4
9	Industry Oriented Mini Project/ Summer Internship	1	2		2
10	Field-Based Project / Internship	1	2		2
11	Mandatory Courses / Value Added Course	3	1		3
12	Innovation and Entrepreneurship	1	2		2
13	Business Economics and Financial Analysis	1	3		3
14	Fundamentals of Management	1	3	-	3
	Total		--	-	**164**

Major benefits of adopting the credit system are listed below:

- Quantification and uniformity in the listing of courses for all programs at institute, like program core, electives and project work.
- Ease of allocation of courses under different heads by using their credits to meet national /international practices in technical education.
- Convenience to specify the minimum / maximum limits of course load and its average per semester in the form of credits to be earned by a student.
- Flexibility in program duration for students by enabling them to pace their course load within minimum/maximum limits based on their preparation and capabilities.
- Wider choice of courses available from any department of the same institute or even from other similar institute, either for credit or for audit.
- Improved facility for students to optimize their learning by availing of transfer of credits earned by them from one College to another.

7. CURRICULAR COMPONENTS

Courses in a curriculum may be of three kinds: **Foundation courses, Core courses, Elective courses, Project core, Other core courses, Skill development courses and Value added courses.**

Foundation course:

Foundation courses include the basic science and engineering science course based upon the content leads to enhancement of skill and knowledge as well as value based and are aimed at man making education.

Professional core (PC):

There may be a professional core course in every semester. These courses are to be compulsorily studied by a student as a core requirement to complete the requirement of a program in the said discipline of study.

Professional electives (PE) / Open electives (OE):

Electives provide breadth of experience in respective branch and application areas. The program elective(s) is a course which can be chosen from a pool of courses. An elective may be professional elective, is a discipline centric focusing on those courses which add generic proficiency to the students or may be Open elective course, chosen from unrelated disciplines.

There are six professional elective tracks (PE-1 to PE-VI). Students can choose not more than two courses from each track. Overall, students can opt for six professional electives which suit their capstone project in consultation with the faculty advisor/mentor. Nevertheless, one course from each of the three open electives has to be selected. A student may also opt for more elective courses in his/her area of interest.

Students have the flexibility to choose from the list of professional electives offered by the Institute or opt to register for the equivalent MOOCS courses as listed from time to time by the institute.
It may be:
- Supportive to the discipline of study
- Providing an expanded scope
- Enabling an exposure to some other discipline / domain
- Nurturing student's proficiency / skill.

Provision for Early Registration of MOOCs:

- For a professional elective in a semester, students are allowed to register for an equivalent MOOCs course listed from time to time.
- For example, a Professional Elective of VI semester shall be allowed to register under MOOCs platform in V semester.
- The credits earned in one semester in advance can be submitted in the subsequent semester for the assessment.
- The student who has registered in advance in an equivalent MOOCs course and fails to secure any pass grade in the MOOCs course, can register for the regular course offered in the following semester of their course catalogue.

Note: MOOCS courses are allowed only for professional electives.

Skill development courses are structured training courses which help students to acquire **practical abilities, competencies, and soft skills** which are essential for academic, professional, and personal growth.

Value Added Course (VAC):

Value-added courses that focus on professional values, traditional knowledge, and the sensitization of societal issues are short, skill-oriented programs designed to help students grow ethically, culturally, and socially beyond technical skills. The evaluation of value added courses shall be similar to theory courses. However, the scheduling of these CIA and SEE may not be combined with regular SEE examinations.

Semester wise course break-up

Following are the **TWO** models of course catalogue out of which any student shall choose or will be allotted with one model based on their academic performance.

i. Full Semester Internship (FSI) Model and
ii. Non Full Semester Internship (NFSI) Model

A student with **no current arrears** upto IV semester shall be eligible to opt for FSI. Students can opt full semester internship (FSI) in VIII semester. In Non-FSI Model, all the selected students shall carry out the course work and capstone project as specified in the course cataloge.

8. EVALUATION METHODOLOGY

Total marks for each course shall be based on Continuous Internal Assessment (CIA) and Semester End Examination (SEE). There shall have a uniform pattern of 40:60 for CIA and SEE of both theory and practical courses. The institute shall conduct multiple CIA for theory courses. All the performances of a student shall be considered for CIA marks distribution is shown in Table 3.

Table 3: Outline for Continuous Internal Assessments (CIA-1 and CIA-2) and SEE:

Activities	CIA-1	CIA-2	SEE	Total Marks
Continuous Internal Examination (CIE)	10 marks	10 marks		20 marks
Objective / Quiz / Complex Engineering Problem Solving / Case Studies	05 marks	05 marks		10 marks
AAT	05 marks	05 marks		10 marks
Semester End Examination (SEE)			60 marks	60 marks
Total	--	--		100 marks

8.1 Continuous Internal Assessments (CIA-1 and CIA-2)

Assessment is an ongoing process that begins with establishing clear and measurable expected outcomes of student learning, provides students with sufficient opportunities to achieve those outcomes, and concludes with gathering and interpreting evidence to determine how well students' learning matches expectations. The first component CIA-1 of assessment is for 20 marks. This assessment and score process should be completed after completing of first 50% of syllabus ($2^{1/2}$) of the course/s and within 45 working days of semester program.

The second component CIA-2 of assessment is for 20 marks, this assessment and score process should be completed after completing of remaining 50% of syllabus ($2^{1/2}$) of the course/s and within 45 working days of semester program.

In case of a student who has failed to attend the CIA1 or CIA2 on a scheduled date, shall be deemed that the student has dropped the examination. However, in case a student could not take the test on scheduled date due to genuine reasons, may appeal to the HOD / Principal. The HOD / Principal in consultation with the class in-charge shall decide about the genuineness of the case and decide to conduct Make-Up examination to such candidate on the date fixed by the Examinations Control Office but before commencement of the concerned semester end examinations.

Alternative Assessment Tool (AAT) In order to encourage innovative methods while delivering a course, the faculty members are encouraged to use the Alternative Assessment Tool (AAT). If properly applied, the AAT converts the classroom into an effective learning centre. The AAT may include tech talk, tutorial hours/classes, seminars, assignments, term paper, open ended experiments, concept videos, partial reproduction of research work, oral presentation of research work, developing a generic tool-box for problem solving, report based on participation in create-a-thon, makea-thon, code-a-thon, hack-a-thon conducted by reputed organizations / any other. etc.

The performance of a student in every course including value added courses, skill development courses, laboratory courses, capstone project work will be evaluated for 100 marks each, with 40 marks allotted for CIA and 60 marks for SEE, irrespective of the credits allocated.

8.2 Semester End Examination (SEE)

The semester end examinations, for theory courses, will be conducted for 60 marks consisting of two parts viz. i) Part- A for 10 marks and ii) Part - B for 50 marks.

Part-A is compulsory, consists of five short answer questions; each question carries two marks.

Part-B consists of five questions carrying 10 marks each. There shall be two questions asked in the question paper from each module with either-or choice and the student should answer either of the two questions. The student shall answer one question from each of five modules.

The duration of SEE is 3 hours.

8.3 Passing Criteria:

To maintain high standards in all aspects of examinations at the institute, the institute shall follow the standards of passing at CIA and SEE for each course.

a) A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each course, if the student secures not less than 35% (21 marks out of 60 marks) in the semester end examinations, and a minimum of 40% (40 marks out of 100 marks) in the sum total of the Continuous Internal Assessment and Semester End Examination taken together; in terms of letter grades, this implies securing 'C' grade or above in that course.

b) A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to Engineering Design Project / Engineering Development Project / Summer Internship, if the student secures not less than 40% marks (i.e. 40 out of 100 allotted marks) in each of them. The student is deemed to have failed, if he/she (i) does not submit a report on Engineering Design Project / Engineering Development Project / Summer Internship or (ii) not make a presentation of the same before the evaluation committee as per schedule, or (iii) secures less than 40% marks in Field-Based Research Project / Industry Oriented Mini Project / Internship evaluations.

c) A student eligible to appear in the SEE for any course, is absent from it or failed (thereby failing to secure 'C' grade or above) may re-appear for that course in the supplementary examination as and when it is conducted. In such cases, internal marks (CIA) assessed earlier for that course will be carried over, and added to the marks obtained in the SEE supplementary examination. If the student secures sufficient marks for passing, 'C' grade or above shall be awarded as specified in clause 11.3.

8.4 Supplementary examinations

Supplementary examinations for the odd semester shall be conducted with the regular examinations of even semester and vice versa. In case of failure in any course, a student may be permitted to register for the same course when offered.

Advanced supplementary examinations in VIII semester courses may be conducted for those who failed in any course offered in VIII semester. It may enable the students to receive their B.Tech provisional certificate at an early date.

There shall be no supplementary examination in the successive semester. The students who could not secure any pass grade in advance supplementary examinations have to wait for regular series examination of next batch to write their backlog examination.

8.5 Laboratory Course

Evaluation methodology of laboratory course (CIA)

Each laboratory courses there shall be a CIA during the semester for 40 marks and 60 marks for SEE. The 40 marks for internal evaluation marks are awarded as follows:

1. A write-up on day-to-day experiment in the laboratory (in terms of aim, components / procedure, expected outcome) which shall be evaluated for **20 marks.**
2. Internal practical examination conducted by the laboratory teacher concerned shall be evaluated for **10 marks.**
3. The remaining **10 marks** will be awarded for the project report submission and evaluation.

Evaluation methodology of laboratory course (SEE)

The SEE shall be conducted by an external examiner along with the laboratory handling faculty. The external examiner shall be appointed from other institutions and will be selected from the panel by the Principal.

The SEE held for 3 hours. Total 60 marks are divided and allocated as shown below:

1. 10 marks for write-up
2. 10 for experiment / program
3. 10 for evaluation of results
4. 10 marks for viva-voce on concerned laboratory course.
5. 20 marks will be awarded for the solving Complex Tasks Descriptions (CTDs) / take-home project identified by department advisory committee which will be announced at the beginning of the semester.

8.6 Evaluation of Engineering Design Project and Engineering Development Project

Engineering Design and Development Projects is the high point of degree studies in engineering. The transition of students to industry is still not optimal, and there is a disparity between the needs of industry and the actual ability of academia to meet these needs. Each project is carried out under the supervision of academic faculty and where appropriate an industry partner.

The **Engineering Design Project and Engineering Development Project** shall be evaluated for 100 marks each. out of which 40 marks for CIA and 60 marks for SEE. The evaluation committee shall consist of a Head of the Department, Supervisor of the Project and a Senior Faculty Member of the department. Student shall have to earn 40% marks, i.e 40 marks out of 100 marks. The student is deemed to have failed, if he (i) does not submit a report on the project, or (ii) does not make a presentation of the same before the internal committee as per schedule, or (iii) secures less than 40% marks in this course.

8.7 Evaluation of Summer Internship

A Summer Internship shall be undertaken in collaboration with an industry relevant to the student's area of specialization. Students must register for the internship immediately after the completion of their V semester examinations and pursue it during the summer vacation. The internship, preferably at a reputed organization, must be documented in the form of a report and presented before a committee during the VII semester, prior to the semester-end examinations.

The internship shall be evaluated for 100 external marks, out of which 40 marks for CIA and 60 marks for SEE. The evaluation committee shall consist of an external examiner, the Head of the Department, supervisor, and a senior faculty member from the department.

8.8 Additional Mandatory Courses for lateral entry B.Tech students

In addition to the non-credit mandatory courses for regular B.Tech students, the lateral entry students shall take up the following three non-credit mandatory bridge courses (one in III semester, one in IV semester and one in V semester) as listed in Table 4. The student shall pass the following non-credit mandatory courses for the award of the degree and must clear these bridge courses before advancing to the VII semester of the program.

Table-4: Additional Mandatory Courses for lateral entry students

S.No	Additional mandatory courses for lateral entry students
1	Dip - Object Oriented Programming
2	Dip - Data Structures
3	Dip - Front-End Web Development

8.9 Innovation and Entrepreneurship

Innovation and entrepreneurship course offered in III semester and its requires strong technical skills in engineering design and computation with key business skills from marketing to business model generation. Students require sufficient skills to innovate in existing companies or create their own.

This course will be evaluated for a total of 100 marks consisting of 40 marks for CIA and 60 marks for SEE. Out of 40 marks of internal assessment, students has to submit Innovative Idea in a team of three / four members in the given format. The SEE for 60 marks shall be conducted internally, students has to present the Innovative Idea and it will be evaluated by internal course handling faculty with at least one faculty member as examiner from the industry, both nominated by the Principal.

8.10 Capstone Project

The capstone project shall be initiated at the beginning of the VIII semester and the duration is one semester. The student must present in consultation with his/her supervisor, the title, objective and plan of action of his/her to the departmental committee for approval within two weeks from the commencement of VIII semester. Only after obtaining the approval of the departmental committee, the student can start his/her capstone project.

Student has to submit report of capstone project at the end of VIII semester. It shall be evaluated for 100 marks. Out of which 40 marks and 60 marks are allocated for CIA and SEE respectively. Evaluation shall be done by a committee comprising the supervisor, Head of the department, and an external examiner nominated by the Principal.

The external examiner shall evaluate the capstone project for 60 marks and the internal committee shall evaluate it for 40 marks. The departmental committee consisting of Head of the department, supervisor and a senior faculty member shall evaluate for 20 marks and supervisor shall evaluate for 20 marks.

The topics for the capstone project shall be different from the topics of Engineering design project / Engineering development project / Summer Internship. The student is deemed to have failed, if he (i) does not submit a capstone project, or (ii) does not make a presentation of the same before the external examiner as per schedule, or (iii) secures less than 40% marks in the sum total of the CIE and SEE taken together.

The external examiner will be selected for conducting viva-voce examination from the list of experts selected by the Principal of the institute.

This gives students a platform to experience a research driven career in engineering, while developing a device / systems and publishing in reputed SCI / SCOPUS indexed journals and/or filing an **Intellectual Property** (IPR-Patent/Copyright) to aid communities around the world.   Students should work individually as per the guidelines issued by head of the department concerned. The benefits to students of this mode of learning include increased engagement, fostering of critical thinking and greater independence.

A student who has failed, may re-appear once for the above evaluation, when it is scheduled again; if student fails in such 'one re-appearance' evaluation also, he/she has to appear for the same in the next subsequent year, as and when it is scheduled.

A minimum of 50% of maximum marks shall be obtained to earn the corresponding credits.

8.11 Skill Development Courses

There are four skill development courses included in the curriculum in III, IV, V and VI semesters. Each skill development course carries one credit. The evaluation pattern will be the same as that for a laboratory course including internal and external assessments.

The objective of skill courses is to develop the cognitive skills as well as the psycho-motor skills.

8.12 Full Semester Internship (FSI)

FSI is a full semester internship program carry 14 credits. The FSI shall be opted in VIII semester. During the FSI, student has to spend one full semester in an identified industry / firm / R&D organization or another academic institution/University where sufficient facilities exist to carry out the project work.

The selection procedure is:
- Choice of the students.
- CGPA (> 7.5) upto IV semester having no credit arrears.
- Competency Mapping / Allotment.

It is recommended that the FSI Project work leads to a research publication in a reputed Journal / Conference or the filing of patent / design with the patent office, or, the start-up initiative with a sustainable and viable business model accepted by the incubation center of the institute together with the formal registration of the startup.

9. ATTENDANCE REQUIREMENTS AND DETENTION POLICY

9.1   A student shall be eligible to appear for the semester end examinations, if the student acquires a minimum of 75% of attendance in aggregate of all the courses for that semester.

9.2   Shortage of attendance in aggregate upto 10% (65% and above, and below 75%) in each semester may be condoned by the college academic committee on genuine and valid grounds, based on the student's representation with supporting evidence.

9.3   A stipulated fee shall be payable for condoning of shortage of attendance.

9.4   Shortage of attendance below 65% in aggregate shall in NO case be condoned.

9.5   Students whose shortage of attendance is not condoned in any semester are not eligible to take their semester end examinations of that semester. They get detained and their registration for that semester shall stand cancelled, including all academic credentials (internal marks etc.) of that semester. They will not be promoted to the next semester. They may seek re-registration for that semester in the next academic year.

9.6   A student fulfilling the attendance requirement in the present semester shall not be eligible for readmission into the same semester / class.

9.7   A student detained in a semester due to shortage of attendance may be re-admitted in the same semester in the next academic year for fulfillment of academic requirements. The academic regulations under which a student has been re-admitted shall be applicable. Further, no grade allotments or SGPA/ CGPA calculations will be done for the entire semester in which the student has been detained.

9.8   A student detained due to lack of credits, shall be promoted to the next academic year only after acquiring the required number of academic credits. The academic regulations under which the student has been readmitted shall be applicable to him.

10. CONDUCT OF SEMESTER END EXAMINATIONS AND EVALUATION

10.1 Semester end examination shall be conducted by the Controller of Examinations (COE) by inviting question papers from the external examiners.

10.2 The Controller of Examinations (COE) shall invite external examiners to evaluate all semester end examination answer scripts on the scheduled dates. Similarly, practical laboratory examinations shall be conducted in the presence of external examiners to ensure transparency and fair evaluation.

10.3 Examinations control office shall consolidate the marks awarded by examiner/s and award the grades.

11. LETTER GRADES AND GRADE POINTS

11.1 ABSOLUTE Grading system is followed for awarding the grade to each course.

11.2 Performance of students in each course, Theory, Laboratory, Industry-Oriented Mini Project/ Internship/ Skill development course and Project Work are expressed in terms of marks as well as in Letter Grades based on absolute grading system.

11.3 To measure the performance of a student, a 10-point grading system is followed. The mapping between the percentage of marks secured and the corresponding letter grade is as shown in the below Table 5.

Table-5: Grade Points Scale (Absolute Grading)

Range of % of Marks Secured in a Course	Letter Grade	Grade Point
Greater than or equal to 90	O (Outstanding)	10
80 and less than 90	A+ (Excellent)	9
70 and less than 80	A (Very Good)	8
60 and less than 70	B+ (Good)	7
50 and less than 60	B (Average)	6
40 and less than 50	C (Pass)	5
Below 40	F (Fail)	0
Absent	AB (Absent)	0

11.3 A student is deemed to have passed and acquired to correspondent credits in particular course if s/he obtains any one of the following grades: "O", "A+", "A", "B+", "B", "C".

11.4 A student who has obtained an 'F' grade in any course shall be deemed to have **'failed'** and is required to reappear for a supplementary exam as and when conducted. In such cases, internal marks in those courses will remain the same as those obtained earlier.

11.5 A student who has not appeared for an examination in any course, 'Ab' grade will be allocated in that course, and he/she is deemed to have 'Failed'. Such student will be required to reappear for supplementary/make-up exam as and when conducted. The internal marks in those courses will remain the same as those obtained earlier.

11.6 The students earn a Grade Point (GP) in each course, on the basis of letter grade secured in that course. Every student who passes a course will receive grade point GP $\geq$ 5 ('C' grade or above).

11.7 At the end of each semester, the institute issues grade sheet indicating the SGPA and CGPA of the student. However, grade sheet will not be issued to the student if s/he has any outstanding dues.

11.8 If a student earns more than 160 credits, only the courses corresponding to the best 160 credits shall be considered for the computation of CGPA of B.Tech. degree.

12. COMPUTATION OF SGPA AND CGPA

The UGC recommends to compute the Semester Grade Point Average (SGPA) and Cumulative Grade Point Average (CGPA). The credit points earned by a student are used for calculating the Semester Grade Point Average (SGPA) and the Cumulative Grade Point Average (CGPA), both of which are important performance indices of the student.

The Semester Grade Point Average (SGPA) is calculated only when all the courses offered in a semester are cleared by a student. It is calculated by dividing the sum of credit points secured from all courses registered in a semester, by the total number of credits registered during that semester. SGPA is rounded off to two decimal places. SGPA for each semester is thus computed as

$$SGPA = \{ \sum_{i=1}^{N} C_i \, G_i \} / \{ \sum_{i=1}^{N} C_i \}$$

where 'i' is the course indicator index (considering all courses in a semester), 'N' is the no. of courses registered for the semester (as listed under the course structure of the branch), C_i is the no. of credits allotted to the ith course, and G_i represents the grade points corresponding to the letter grade awarded for that i^{th} course.

The Cumulative Grade Point Average (CGPA) is a measure of the overall cumulative performance of a student in all semesters considered for registration. The CGPA is the ratio of the total credit points secured by a student for the courses correspond to best 160 credits out of all registered courses in all semesters, and the total number of credits correspond to those selected courses. CGPA is rounded off to two decimal places. CGPA is thus computed at the end of each semester, from the I year II semester onwards, as per the formula.

$$CGPA = \{ \sum_{j=1}^{M} C_j \ G_j \} / \{ \sum_{j=1}^{M} C_j \}$$

where 'M' is the total no. of courses corresponding to the best 160 credits from the courses registered in all eight semesters, 'j' is the course indicator index (takes into account all courses from 1 to 8 semesters), C_j is the no. of credits allotted to the jth course, and G_j represents the grade points (GP) corresponding to the letter grade awarded for that j^{th} course.

The SGPA and CGPA shall be rounded off to 2 decimal points and reported in the transcripts.

13.0 ILLUSTRATION OF COMPUTATION OF SGPA AND CGPA
13.1 Illustration for SGPA

Course Name	Course Credits	Grade letter	Grade point	Credit Point (Credit x Grade)
Course 1	4	A	8	4 x 8 = 32
Course 2	3	O	10	3 x 10 = 30
Course 3	3	C	5	3 x 5 = 15
Course 4	3	B	6	3 x 6 = 18
Course 5	3	A	8	3 x 8 = 24
Course 6	2	A+	9	2 x 9 = 18
Course 7	1	C	5	1 x 5 = 15
Course 8	1	O	10	1 x 10 = 10
	20			**152**

Thus, SGPA = 152 / 20= 7.6

13.2. The CGPA of the entire B.Tech. program shall be calculated considering the best 160 credits earned by the student.

13.3 For merit ranking or comparison purposes or any other listing, only the 'rounded off' values of the CGPAs will be used.

13.4 SGPA of a semester will be mentioned in the semester Memorandum of Grades if all courses of that semester are passed in first attempt. Otherwise, the SGPA shall be mentioned only on the Memorandum of Grades in which sitting he passed his last exam in that semester.

14. REVALUATION
If the examinee is not satisfied with the marks awarded, s/he may apply for revaluation of answer booklets in prescribed format online within three (3) working days from the date of declaration of result of the examination or issue of the statement of marks, whichever is earlier. The revaluation facility shall be for theory papers only. The revaluation of answer booklets shall not be permitted in respect of the marks awarded to the scripts of practical examination / project work (including theory part) and in viva voce / oral / comprehensive examinations.

15. PROMOTION POLICIES

The following academic requirements have to be satisfied in addition to the attendance requirements mentioned in item no. 9.

S.No	Promotion	Conditions to be Fulfilled
1	First year first semester to first year second semester	Regular course of study of first year first semester and fulfilment of attendance requirement.
2	First year second semester to Second year first semester	(i) Regular course of study of first year second semester and fulfilment of attendance requirement (ii) Must have secured at least 25% of the total credits up to first year second semester from all the relevant regular and supplementary examinations, whether the student takes those examinations or not.
3	Second year first semester to Second year second semester	Regular course of study of second year first semester and fulfilment of attendance requirement.
4	Second year second semester to Third year first semester	(i) Regular course of study of second year second semester and fulfilment of attendance requirement. (ii) Must have secured at least 25% of the total credits up to second year second semester from all the relevant regular and supplementary examinations, whether the student takes those examinations or not.
5	Third year first semester to Third year second semester	Regular course of study of third year first semester and fulfilment of attendance requirement.
6	Third year second semester to Fourth year first semester	Regular course of study of third year second semester and fulfilment of attendance requirement
7	Fourth year first semester to Fourth year second semester	Regular course of study of fourth year first semester and fulfilment of attendance requirement

16. CREDIT EXEMPTION

A student (i) shall register for all courses covering 164 credits as specified and listed in the course catalogue and (ii) earn 160 or more credits to successfully complete the undergraduate Program.

- Best 160 credits shall be considered for CGPA computation. The student can avail exemption of courses *totalling upto 4 credits* other than professional core courses, laboratory courses, seminars, capstone project, engineering design project / engineering development project / summer internship, for optional drop out from these 164 credits registered.

- The Semester Grade Point Average (SGPA) of each semester shall be mentioned at the bottom of the grade card, when all the subjects in that semester have been passed by the student.

- Credits earned by the student in either a Minor or Honors program cannot be counted towards the required 160 credits for the award of the B.Tech. degree.

17. AWARD OF DEGREE

17.1 A student who registers for all the specified courses as listed in the course catalogue and secures the required number of 160 credits within 8 academic years from the date of commencement of the first academic year, shall be declared to have 'qualified' for the award of B.Tech. degree in the branch of Engineering selected at the time of admission.

17.2 A student who qualifies for the award of the degree as listed in item 17.1 shall be placed in the following classes.

17.3 A student with final CGPA (at the end of the undergraduate program) ≥ 7.5, and fulfilling the following conditions - shall be placed in '**first class with distinction'**. However,

    a. Should have passed all the courses in '**first appearance'** within the first 4 academic years (or 8 sequential semesters) from the date of commencement of first semester.

    b. Should not have been detained or prevented from writing the semester end examinations in any semester due to shortage of attendance or any other reason.

c. A student not fulfilling any of the above conditions with final CGPA ≥ 7.5 shall be placed in **'first class'.**

17.4 Students with final CGPA (at the end of the undergraduate program) ≥ 6.5 but < 7.5 shall be placed in **'first class'.**

17.5 Students with final CGPA (at the end of the undergraduate program) ≥ 5.5 but < 6.5, shall be placed in '**second class**'.

17.5 All other students who qualify for the award of the degree (as per item 17.1), with final CGPA (at the end of the B.Tech program) ≥ 5.00 but < 5.5, shall be placed in **'pass class'.**

17.6 A student with final CGPA (at the end of the B.Tech program) <5.0 will not be eligible for the award of the degree.

17.7 Students fulfilling the conditions listed under item 17.3 alone will be eligible for award of '**Gold Medal**'.

17.8 If more than one student secures the same highest CGPA, then the following tie resolution criteria, in the same order of preference shall be followed for selecting the Gold Medal winner, until the tie is resolved: 1) more number of times secured highest SGPAs, ii) more number of O and A+ grades in that order and iii) highest SGPA in the order of first semester to eight semester.

17.9 Grace Marks

Grace marks shall be given to those students who complete the course work of four year B.Tech. degree, not secured pass grade in not more than three courses and adding a specified grace marks enables the student to pass the course(s) as well as gets eligibility to receive the provisional degree certificate.

Grace marks for students admitted under the R25 Academic Regulations should not exceed 0.15% of the total maximum marks in all eight semesters (excluding the marks allocated for value added courses and skill development courses). The grace marks shall only be added if a student fails in a maximum of three courses and adding the above grace marks make the student eligible to receive the provisional degree certificate.

All the candidates who register for the SEE will be issued a memorandum of grades sheet by the institute. Apart from the semester wise memorandum of grades sheet, the institute will issue the provisional certificate and consolidated grades memorandum certificate to the fulfilment of all the academic requirements.

18. CONVERSION OF CGPA INTO EQUIVALENT PERCENTAGE OF MARKS

The following formula shall be used for the conversion of CGPA into equivalent marks, whenever it is necessary.

Percentage (%) of Marks = (Final CGPA – 0.5) x 10

The Table 06 shows the Percentage Equivalence of Grade Points (for a 10 – Point Scale).

Table 06: Percentage Equivalence of Grade Points (for a 10 – Point Scale)

Grade Point	Percentage of Marks / Class
5.5	50
6.0	55
6.5	60
7.0	65
7.5	70
8.0	75

19. B.TECH WITH HONOURS OR MINOR IN ENGINEERING

Students acquiring 160 credits or more are eligible to get B.Tech degree in Engineering. A student will be eligible to get B.Tech degree with Honours or Minor in Engineering, if s/he completes an additional 20/18 credits (3/4 credits per course). These could be acquired through MOOCs from SWAYAM / NPTEL only. The list for MOOCs will be a dynamic one, as new courses are added from time to time. Few essential skill sets required for employability are also identified year wise. Students interested in doing MOOC courses shall register the course title at their department office at the start of the semester against the courses that are announced by the department. Any expense incurred for the MOOC course / summer program should be met by the students.

Students having no credit arrears and a CGPA of 7.5 or above at the end of the fourth semester are eligible to register for B.Tech (Honours / Minor). After registering for the B.Tech (Honours / Minor) program, if a student fails in any course, s/he will not be eligible for B.Tech (Honours / Minor).

Honours Certificate for Vertical in his/her OWN Branch for Research orientation; Minor in any other branch for Improving Employability.

Honours will be reflected in the degree certificate as "B.Tech (Honours) in XYZ Engineering". Similarly, Minor as "B.Tech in XYZ Engineering with Minor in ABC".

19.1. B.Tech with Honours

The key objectives of offering B.Tech with Honors program are:

- To expand the domain knowledge of the students laterally and vertically.
- To increase the employability of undergraduate students with expanded knowledge in one of the core engineering disciplines.
- To provide an opportunity to students to pursue their higher studies in wider range of specializations.

Academic Regulations for B. Tech. Honours degree

1. The weekly instruction hours, internal and external evaluation and award of grades are on par with regular 4-Years B. Tech. program.

2. For B. Tech with Honors program, a student needs to earn additional 20 credits (over and above the required 160 credits for B.Tech degree). All these 20 credits required to be attained for B.Tech Honors degree credits are distributed from V semester to VII semester.

3. After registering for the Honors program, if a student is unable to pass all courses in first attempt and earn the required 20 credits, he/she shall not be awarded Honours degree. However, if the student earns all the required 160 credits or more of B.Tech., he/she will be awarded only B.Tech degree in the concerned branch.

4. There is no transfer of credits from courses of Honors program to regular B.Tech. degree course & vice versa.

5. These **20 credits** are to be earned from the additional courses offered by the host department in the institute or from closely related departments in the institute as well as from the MOOCS platform (NPTEL only).

6. The choice to opt/take the Honors program is purely on the choice of the students.

7. The student shall be given a choice of withdrawing all the courses registered and/or the credits earned for Honours program at any time; and in that case the student will be awarded only B.Tech. degree in the concerned branch on earning the required credits of 160.

8. The students of every branch can choose Honours program in their respective branches if they are eligible for the Honors program. A student who chooses an **Honors program is not eligible to choose a Minor program and vice-versa.**

9. A student can graduate with Honors if he/she fulfils the requirements for his/her regular B.Tech. program as well as fulfills the requirements for Honours program.

10. The institute shall maintain a record of students registered and pursuing their Honors programs branch-wise.

Eligibility conditions of the students for the B.Tech Honors degree

a) A student can opt for B.Tech. degree with Honors, if she/he passed all courses in first attempt in all the semesters till the results announced and maintaining **7.5 or more CGPA.**

b) If a student fails in any registered course of either B.Tech or Honours in any semester of four years program, he/she will not be eligible for obtaining Honors degree. He will be eligible for only

c) Prior approval of mentor and Head of the Department for the enrolment into Honors program, before commencement of V Semester, is mandatory.

d) If more than **30% of the students** in a branch fulfill the eligibility criteria (as stated above), the number of students given eligibility should be limited to 30%. The criteria to be followed for choosing 30% candidates in a branch may be the CGPA secured by the students till **III** semester.

e) Successful completion of **20 credits** earmarked for Honours program with at least 7.5 CGPA along with successful completion of 160 credits earmarked for regular B. Tech. Program with at least 7.5 CGPA and passing all courses in first attempt gives the eligibility for the award of B.Tech (Honors) degree.

f) For CGPA calculation of B.Tech. course, the **20 credits** of Honours program will not be considered.

Following are the details of such Honors which include some of the most interesting areas in the profession today:

S.No	Department	Honors scheme
1	Aeronautical Engineering	Aerospace Engineering / Space Science etc.
2	Computer Science and Engineering / Information Technology	Big data and Analytics / Cyber Physical Systems, Information Security / Cognitive Science / Artificial Intelligence/ Machine Learning / Data Science / Internet of Things (IoT) / Cyber Security etc.
3	Electronics and Communication Engineering	Digital Communication / Signal Processing / Communication Networks / VLSI Design / Embedded Systems etc.
4	Electrical and Electronics Engineering	Renewable Energy systems / Energy and Sustainability / IoT Applications in Green Energy Systems etc.
5	Mechanical Engineering	Industrial Automation and Robotics / Manufacturing Sciences and Computation Techniques etc.
6	Civil Engineering	Structural Engineering / Environmental Engineering etc.

19.2 B.Tech with Minor in Engineering

The key objectives of offering B.Tech with Minor program are:

- To expand the domain knowledge of the students in one of the other branches of engineering.
- To increase the employability of undergraduate students keeping in view of better opportunity in interdisciplinary areas of engineering & technology.
- To provide an opportunity to students to pursue their higher studies in the inter-disciplinary areas in addition to their own branch of study.
- To offer the knowledge in the areas which are identified as emerging technologies/thrust areas of Engineering.

Academic Regulations for B.Tech Degree with Minor programs

1. The weekly instruction hours, internal & external evaluation and award of grades are on par with regular 4-Years B. Tech. program.

2. For B. Tech. with Minor, a student needs to earn additional 18 credits (over and above the required 160 credits for B. Tech degree). The courses are offered from V semester to VII semester only, to obtain minor degree students required to obtain 18 credits.

3. After registering for the Minor program, if a student is unable to earn all the required 18 credits in a specified duration (twice the duration of the course), he/she shall not be awarded Minor degree. However, if the student earns all the required 160 credits of B.Tech, he/she will be awarded only

B. Tech degree in the concerned branch.

4. There is no transfer of credits from Minor program courses to regular B. Tech. degree course & vice versa.

5. These 18 credits are to be earned from the additional courses offered by the host department in the institute as well as from the MOOCs platform.

6. For the course selected under MOOCs platform (NPTEL) following guidelines may be followed:

   a) Prior to registration of MOOCs courses, formal approval of the courses, by the institute is essential, before the issue of approval considers the parameters like the institute / agency which is offering the course, syllabus, credits, duration of the program and mode of evaluation etc.

   b) Minimum credits for MOOCs course must be equal to or more than the credits specified in the Minor course structure provided by the institute.

   c) Only Pass-grade / marks or above shall be considered for inclusion of grades in minor grade memo.

   d) Any expenses incurred for the MOOCs courses are to be met by the students only.

7. The choice to opt / take a Minor program is purely on the choice of the students.

8. The student shall be given a choice of withdrawing all the courses registered and / or the credits earned for Minor program at any time; and in that case the student will be awarded only B. Tech. degree in the concerned branch on earning the required credits of 160.

9. The student can choose only one Minor program along with his / her basic engineering degree. A student who chooses an **Honors program is not eligible to choose a Minor program and vice-versa.**

10. The institute shall maintain a record of students registered and pursuing their Minor programs, minor program-wise and parent branch-wise.

11. The institute / department shall prepare the time-tables for each Minor course offered at their respective institutes without any overlap/clash with other courses of study in the respective semesters.

Eligibility conditions for the student to register for Minor course

   a) A student can opt for B.Tech. degree with Minor program if she/he has no active backlogs till III semester at the time of entering into V semester.

   b) Prior approval of mentor and Head of the Department for the enrolment into Minor program, before commencement of V Semester, is mandatory.

   c) If more than 50% of the students in a branch fulfill the eligibility criteria (as stated above), the number of students given eligibility should be limited to 50%.

20.0 TEMPORARY BREAK OF STUDY FROM THE PROGRAM

20.1 A candidate is normally not permitted to take a break from the study. However, if a candidate intends to temporarily discontinue the program in the middle for valid reasons (such as accident or hospitalization due to prolonged ill health) and to rejoin the program in a later respective semester, s/he shall seek the approval from the Principal in advance. Such application shall be submitted before the last date for payment of examination fee of the semester and forwarded through the Head of the Department stating the reasons for such withdrawal together with supporting documents and endorsement of his / her parent / guardian.

20.2 The institute shall examine such an application and if it finds the case to be genuine, it may permit the student to temporarily withdraw from the program. Such permission is accorded only to those who do not have any outstanding dues / demand at the College / University level including tuition fees, any other fees, library materials etc.

20.3 The candidate has to rejoin the program after the break from the commencement of the respective semester as and when it is offered.

20.4 The total period for completion of the program reckoned from the commencement of the semester to which the candidate was first admitted shall not exceed the maximum period specified in clause 17. The maximum period includes the break period.

20.5 If any candidate is detained for any reason, the period of detention shall not be considered as 'Break of Study'.

21. TERMINATION FROM THE PROGRAM

The admission of a student to the program may be terminated and the student is asked to leave the institute in the following circumstances:

a. The student fails to satisfy the requirements of the program within the maximum period stipulated for that program.
b. A student shall not be permitted to study any semester more than three times during the entire program of study.
c. The student fails to satisfy the norms of discipline specified by the institute from time to time.

22. WITH-HOLDING OF RESULTS

If the student has not paid the fees to the institute at any stage, or has dues pending due to any reason whatsoever, or if any case of indiscipline is pending, the result of the student may be withheld, and the student will not be allowed to go into the next higher semester. The award or issue of the degree may also be withheld in such cases.
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23. GRADUATION DAY

The institute shall have its own annual Graduation Day for the award of degrees to the students completing the prescribed academic requirements in each case, in consultation with the University and by following the provisions in the Statute. The college shall award prizes and medals to meritorious students and award them annually at the Graduation Day. This will greatly encourage the students to strive for excellence in their academic work.

24. DISCIPLINE

Every student is required to observe discipline and decorum both inside and outside the institute and are expected not to indulge in any activity which will tend to bring down the honour of the institute. If a student indulges in malpractice in any of the theory / practical examination, continuous assessment examinations, he/she shall be liable for punitive action as prescribed by the institute from time to time.

25. GRIEVANCE REDRESSAL COMMITTEE

The institute shall form a Grievance Redressal Committee for each course in each department with the Course Teacher and the HOD as the members. The committee shall solve all grievances related to the course under consideration.

26. MULTIPLE ENTRY MULTIPLE EXIT SCHEME (MEME)

26.1 Exit option after Second Year:

Students enrolled in the 4-Year B.Tech. program are permitted to exit the program after successful completion of the second year (B.Tech. IV Semester). The students who desire to exit after the IV year shall formally inform the exit plan one semester in advance i.e. at the commencement of II Semester itself. Such students need to fulfil the additional requirements as specified in Clause 27 described below.

Upon fulfilling the requirements like earning all the credits up to IV semester and successfully completing the additional requirements, the students will be awarded a 2-year undergraduate (UG) diploma in the concerned engineering branch.

27. ADDITIONAL REQUIREMENTS FOR DIPLOMA AWARD

To qualify for the diploma under the exit option, students must also complete 2 additional credits through one of the following institute-prescribed pathways.

Work-based Vocational Course:

Participation in a practical, hands-on vocational training program relevant to the engineering field, typically conducted during the summer term.

Internship / Apprenticeship:

Completion of a minimum 8-week internship or apprenticeship in their related field to gain practical industry exposure.

In addition, students must clear any associated course(s) or submit the internship/apprenticeship report as per the institute schedule and guidelines.

28. RE-ENTRY INTO THE B.TECH PROGRAM

Students who have exited the B.Tech. program with a 2 Year UG Diploma may apply for re-entry into the Fifth Semester of the B.Tech. program. Re-entry is subject to the following conditions.

- The student must surrender the awarded UG Diploma Certificate.
- Students who wish to rejoin in V semester must join the same B.Tech. program and same college from which the student exited. Before rejoining, students should check for continuation of the same branch at the college. If the specific branch is closed in that particular college, then student should consult the University for the possible alternative solutions.
- Re-registered students will be governed by the academic regulations in effect at the time of re-entry, regardless of the original regulations under which they were admitted.
- If a student opts to continue their studies without a gap after being awarded the diploma, they must register for the third-year courses before the commencement of classwork.

29. BREAK IN STUDY AND MAXIMUM DURATION

Students are allowed to take a break of up to four years after completion of IV Semester with prior University permission through the Principal of the college.

Re-entry after such a break is subject to the condition that the student completes all academic requirements within twice the duration of the program (i.e., within 8 years for a 4-year B.Tech. program).

30. TRANSITORY REGULATIONS TO THE STUDENTS RE-ADMITTED IN BT25 REGULATIONS:

30.1 Transitory regulations are applicable to the students detained due to shortage of attendance as well as detained due to the shortage of credits and seeks permission to re-join the B.Tech program, where BT25 regulations are in force.

30.2 A student detained due to shortage of attendance and re-admitted in BT25 regulations: Such students shall be permitted to join the same semester, but in BT25 Regulations.

30.3 A student detained due to shortage of credits and re-admitted in BT25 regulations: Such students shall be promoted to the next semester in BT25 regulations, only after acquiring the required number of credits as per the corresponding regulations of his/her previous semester.

30.4 A student who has failed in any course in a specific regulation has to pass those courses in the same regulations.

30.5 If a student is readmitted to BT25 Regulations and has any course with 80% of syllabus common with his/her previous regulations, that particular course in BT25 Regulations will be substituted by an equivalent course of BT23 regulations by the institute. All these details are summarized in a set of look-up Table; one set for each B. Tech. branch.

30.6 Look Up Table of equivalence courses

A lookup table will be provided for the benefit of students and Principals. This lookup table will include all the courses to be registered by students who have been re-admitted under the BT25 academic regulations from the BT23 academic regulations. Separate lookup tables will be provided for the following categories of students:

a. Students re-admitted into the II Semester of the R25 Regulations
b. Students re-admitted into the III Semester of the R25 Regulations
c. Students re-admitted into the IV Semester of the R25 Regulations,
d. Students re-admitted into the V Semester of the R25 Regulations
e. Students re-admitted into the VI Semester of the R25 Regulations
f. Students re-admitted into the VII Semester of the R25 Regulations
g. Students re-admitted into the VIII Semester of the R25 Regulations

For every B.Tech. branch there shall be separate set of seven lookup tables

Applicability of Look-up Table: The above look-up table shall be applicable for i) students who seek readmission from BT23 regulations to BT25 regulation and are going to be re-admitted in the same college and ii) detained students of one JNTUH affiliated non-autonomous college who seek admission into another JNTUH affiliated non-autonomous college.

For these two categories of students, the Principals of the affiliated colleges need not consult the University for the equivalence courses. However the Principals need to inform in the specified format, the list of such students and equivalences derived from the transitory regulations.

30.7 These look-Up tables are not applicable for i) the students who seek transfer from other Universities to JNTUH affiliated colleges, autonomous to non-autonomous and non-autonomous to autonomous colleges under JNTUH. Such students should consult the University regarding equivalent courses, as was in previous practice.

30.8 The BT25 Academic Regulations are applicable to a student from the year of re-admission. However, the student is required to complete the study of B.Tech. degree within the stipulated period of eight academic years from the year of first admission.

31. STUDENT TRANSFERS

31.1 There shall be no branch transfers after the completion of admission process.

32.2 There shall be no transfers from one college to another within the constituent colleges and units of Jawaharlal Nehru Technological University Hyderabad.

33.3 The students seeking transfer to colleges affiliated to JNTUH from various other universities / institutions have to pass the failed courses which are equivalent to the courses of JNTUH in JNTUH system, and also pass the additional courses of JNTUH which the students have not studied at the earlier institution.

34.4 The transferred students from other Universities/Institutions to JNTUH affiliated colleges, shall be given a chance to write CBTs for getting CIE component in the equivalent course(s) as per the clearance letter issued by the University.

32. ACADEMIC REGULATIONS FOR B.TECH. (LATERAL ENTRY SCHEME) FROM THE ACADEMIC YEAR: 2026-27

Eligibility for the award of B.Tech. Degree (LES):

1. The LES students after securing admission shall pursue a course of study for not less than three academic years and not more than six academic years.
2. The student shall register for 123/124 credits and secure 120 credits with CGPA ≥ 5 from III semester to VIII semester, B.Tech. program (LES) for the award of B.Tech. degree.
3. The student can avail exemption of courses totaling up to 3/4 credits other than Professional core courses, Laboratory Courses, Seminars, Project Work and Field Based Research Project Industry Oriented Mini Project / Internship, for optional drop out.
4. The students, who fail to fulfil the requirement for the award of the degree in six academic years from the year of admission, shall forfeit their seat in B.Tech.
5. The attendance requirements of B.Tech. (Regular) shall be applicable to B.Tech. (LES).

6. **Promotion Rules**

The following academic requirements have to be satisfied in addition to the attendance requirements mentioned in item no. 9.

S.No	Promotion	Conditions to be Fulfilled
1	Second year first semester to Second year second semester	Regular course of study of second year first semester and fulfilment of attendance requirement.
2	Second year second semester to Third year first semester	(i) Regular course of study of second year second semester and fulfilment of attendance requirement. (ii) Must have secured at least 25% of the total credits up to second year second semester from all the relevant regular and supplementary examinations, whether the student takes those examinations or not.
3	Third year first semester to Third year second semester	Regular course of study of third year first semester and fulfilment of attendance requirement.
4	Third year second semester to Fourth year first semester	Regular course of study of third year second semester and fulfilment of attendance requirement
5	Fourth year first semester to Fourth year second semester	Regular course of study of fourth year first semester and fulfilment of attendance requirement

7. All the other regulations as applicable to B.Tech. 4-year degree course (Regular) will hold good for B.Tech. (Lateral Entry Scheme).
8. LES students are not permitted to exit the B.Tech. program after completion of second year (B.Tech. IV Semester).

33. REVISION OF REGULATIONS AND CURRICULUM

The Institute from time to time may revise, amend or change the regulations, scheme of examinations and syllabi if found necessary and on approval by the Academic Council and the Governing Body shall be binding on the students, faculty, staff, all authorities of the Institute and others concerned.

FAILURE TO READ AND UNDERSTAND THE REGULATIONS IS NOT AN EXCUSE

INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

COURSE CATALOGUE - REGULATIONS: BT25
ELECTRICAL AND ELECTRONICS ENGINEERING

I SEMESTER

Course Code	Course Name	Subject Area	Category	Periods Per Week			Credits	Scheme of Examination Max. Marks		
				L	T	P		CIA	SEE	Total
INDUCTION PROGRAM										
THEORY										
AHSE01	Matrices and Calculus	BSC	Foundation	3	1	0	4	40	60	100
AHSE02	Engineering Physics	BSC	Foundation	3	0	0	3	40	60	100
AHSE04	English for Skill Enhancement	HSC	Foundation	3	0	0	3	40	60	100
AEEE02	Electrical Circuits	ESC	Foundation	3	0	0	3	40	60	100
ACSE01	Object Oriented Programming	CSC	Foundation	3	0	0	3	40	60	100
PRACTICAL										
AHSE07	English Language and Communication Skills Laboratory	HSC	Foundation	0	0	2	1	40	60	100
ACSE03	Object Oriented Programming Laboratory	CSC	Foundation	0	0	2	1	40	60	100
AHSE05	Engineering Physics Laboratory	BSC	Foundation	0	0	2	1	40	60	100
AMEE02	Engineering workshop	MEC	Foundation	0	0	2	1	40	60	100
TOTAL				**15**	**01**	**8**	**20**	**360**	**540**	**900**

II SEMESTER

Course Code	Course Name	Subject Area	Category	Periods Per Week			Credits	Scheme of Examination Max. Marks		
				L	T	P		CIA	SEE	Total
THEORY										
AHSE03	Engineering Chemistry	BSC	Foundation	3	0	0	3	40	60	100
AHSE08	Ordinary Differential Equations and Vector Calculus	BSC	Foundation	3	0	0	3	40	60	100
AEEE04	Network Analysis and Synthesis	ESC	Foundation	3	0	0	3	40	60	100
ACSE02	Essentials of Problem Solving	CSC	Foundation	3	0	0	3	40	60	100
ACSE05	Data Structures	CSC	Foundation	3	0	0	3	40	60	100
PRACTICAL										
AHSE06	Engineering Chemistry Laboratory	BSC	Foundation	0	0	2	1	40	60	100
AEEE05	Network Analysis and Synthesis Laboratory	ESC	Foundation	0	0	2	1	40	60	100
ACSE07	Programming for Problem Solving Laboratory	CSC	Foundation	0	0	2	1	40	60	100
AMEE03	Computer Aided Engineering Graphics	MEC	Foundation	1	0	2	2	40	60	100
ACSE08	Data Structures Laboratory	CSC	Foundation	0	0	2	1	40	60	100
TOTAL				**16**	**00**	**10**	**21**	**400**	**600**	**1000**

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

MATRICES AND CALCULUS							
I Semester: AE / ME / CE / ECE / EEE / CSE / CSE (AI & ML) / CSE (DS) / IT							

Course Code	Category	Hours/Week			Credits	Maximum Marks		
		L	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
AHSE01	**Foundation**	3	1	-	4	40	60	100
Contact Classes: 48	**Tutorial Classes: 16**	**Practical Classes: Nil**				**Total Classes: 64**		
Prerequisite: Basic Principles of Algebra and Calculus								

I. COURSE OVERVIEW:

This course Matrices and Calculus is a foundation course of mathematics for all engineering branches. The concepts of Matrices, Eigen Values, Eigen Vectors, Functions of Single and Several Variables, Fourier Series and Multiple Integrals. This course is applicable for simulations, colour imaging process, finding optimal solutions in all fields of industries.

II. COURSE OBJECTIVES:

The students will try to learn:

I	The concept of the rank of a matrix, solve the system of linear equations, eigen values, eigen vectors.
II	The geometrical approach to the mean value theorems and their application to the mathematical problems.
III	The Fourier series expansion in standard intervals as well as arbitrary intervals.
IV	The evaluation of multiple integrals and their applications.

III. COURSE OUTCOMES:

At the end of the course students should be able to:

CO 1	Determine the rank and solutions of linear equations with elementary operations.
CO 2	Utilize the Eigen values, Eigen vectors for developing spectral matrices.
CO 3	Make use of Cayley-Hamilton theorem for finding powers of the matrix.
CO 4	Apply the mean value theorems for finding analytical problems involving derivatives.
CO 5	Interpret the maxima and minima of given functions by finding the partial derivates.
CO 6	Determine the area of solid bounded regions by using the integral calculus.

IV. COURSE CONTENT:

MODULE - I: MATRICES (09)
Rank of a matrix by Echelon form and Normal form, Inverse of non-singular matrices by Gauss-Jordan method, system of linear equations: Solving system of homogeneous and non-homogeneous equations. Gauss Seidel iteration method.

MODULE - II: EIGEN VALUES AND EIGEN VECTORS (10)
Linear transformation and orthogonal transformation: Eigen values, Eigen vectors and their properties, diagonalization of a matrix, Cayley-Hamilton theorem (without proof), finding inverse and power of a matrix by Cayley-Hamilton theorem, Quadratic forms and nature of the Quadratic forms, reduction of Quadratic form to canonical form by orthogonal transformation

MODULE - III: SINGLE VARIABLE CALCULUS (10)
Limit and continuous of functions and its properties. mean value theorems: Rolle's theorem, Lagrange's mean value theorem with their geometrical interpretation and applications.

Cauchy's mean value theorem, Taylor's series (all the theorems without proof).

Curve Tracing: Curve tracing in cartesian coordinates.

MODULE - IV: MULTIVARIABLE CALCULUS (9)
Definitions of limit and continuity, partial differentiation: Euler's theorem, total derivative, Jacobian, functional dependence & independence. Applications: maxima and minima of functions of two variables and three variables using method of Lagrange multipliers

MODULE - V: MULTIPLE INTEGRALS (10)
Evaluation of double integrals (cartesian and polar coordinates), change of order of integration (only cartesian form), change of variables for double integrals (cartesian to polar). evaluation of triple integrals, change of variables for triple integrals (cartesian to spherical and cylindrical polar coordinates). Applications: areas by double integrals and volumes by triple integrals.

V. TEXT BOOKS:
I. B. S. Grewal, *Higher Engineering Mathematics*, 44/e, Khanna Publishers, 2017.
II. Erwin Kreyszig, *Advanced Engineering Mathematics*, 10/e, John Wiley & Sons, 2011.

VI. REFERENCE BOOKS:
I. R. K. Jain and S. R. K. Iyengar, *Advanced Engineering Mathematics*, 3/ed, Narosa Publications, 5th Edition, 2016.
II. George B. Thomas, Maurice D. Weir and Joel Hass, Thomas, *Calculus*, 13/e, Pearson Publishers, 2013.
III. N.P. Bali and Manish Goyal, *A text book of Engineering Mathematics*, Laxmi Publications, Reprint, 2008.
IV. Dean G. Duffy, *Advanced Engineering Mathematics with MATLAB*, CRC Press.
V. Peter O'Neil, *Advanced Engineering Mathematics*, Cengage Learning.
VI. B.V. Ramana, *Higher Engineering Mathematics*, McGraw Hill Education.

VII. ELECTRONIC RESOURCES:
I. Engineering Mathematics - I, By Prof. Jitendra Kumar | IIT Kharagpur
   https://onlinecourses.nptel.ac.in/noc23_ma88/preview
II. Advanced Calculus for Engineers, By Prof. Jitendra Kumar, Prof. Somesh Kumar | IIT Kharagpur
   https://onlinecourses.nptel.ac.in/noc23_ma86/preview
III. http://www.efunda.com/math/math_home/math.cfm
IV. http://www.ocw.mit.edu/resourcs/#Mathematics
V. http://www.sosmath.com
VI. http://www.mathworld.wolfram.com

VIII. MATERIAL ONLINE:

1. Course template
2. Tutorial question bank
3. Tech talk topics
4. Open end experiments
5. Definitions and terminology
6. Assignments
7. Model question paper – I
8. Model question paper - II
9. Lecture notes
10. E-learning readiness videos (ELRV)
11. Power point presentation

INSTITUTE OF AERONAUTICAL ENGINEERING
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COURSE CONTENT

ENGINEERING PHYSICS

I Semester: AE | ME | CE | ECE | EEE | CSE (AI & ML) | CSE (DS)
II Semester: CSE | IT

Course Code	Category	Hours / Week			Credits	Maximum Marks		
		L	T	P	C	CIA	SEE	Total
AHSE02	Foundation	3	-	-	3	40	60	100

Contact Classes: 48	Tutorial Classes: Nil	Practical Classes: Nil	Total Classes: 48

Prerequisite: Basic principles of physics

I. COURSE OVERVIEW:

The aim of this course is to enhance understanding of fundamental knowledge in physics needed for the future technological advances. The framework prepares students to engage in scientific questioning and extend thinking to investigations. The concepts cover current topics in the fields of solid state physics, modern physics, superconductors and nanotechnology. This knowledge helps to develop the ability to apply the principles in many technological sectors such as nanotechnology, optical fiber communication, quantum technology etc.

II. COURSES OBJECTIVES:

The students will try to learn

I. Fundamental concepts needed to explain a crystal structure in terms of atom positions, unit cells, and crystal symmetry.
II. Basic formulations in wave mechanics for the evolution of energy levels and quantization of energies for a particle in a potential box with the help of mathematical description.
III. The metrics of optoelectronic components, lasers, optical fiber communication and be able to incorporate them into systems for optimal performance.
IV. The appropriate magnetic, superconducting and basics of quantum computing required for various engineering applications.

III. COURSE OUTCOMES:

At the end of the course students should be able to:

CO1   Use the general rules of indexing of directions and planes in lattices to identify the crystal systems and the Bravais lattices.
CO2   Use the concepts of dual nature of matter and Schrodinger wave equation to a particle enclosed in simple systems.
CO3   Analyze the concepts of laser with normal light in terms of mechanism for applications in different fields and scientific practices.
CO4   Strengthen the knowledge on functionality of components in optical fiber communication system by using the basics of signal propagation, attenuation and dispersion.
CO5   Gain deeper understanding on properties of magnetic and superconducting materials suitable for engineering applications.
CO6   Review the basic principle, types, entanglement and the logic gates of quantum computers.

MODULE - I: CRYSTAL STRUCTURES

Introduction, space lattice, basis, unit cell, lattice parameter, Bravais lattices, crystal systems, structure and packing fractions of simple cubic, body centered cubic, face centered cubic crystals, directions and planes in crystals, Miller indices, separation between successive [h k l] planes.

MODULE –II: QUANTUM PHYSICS

Waves and particles, de Broglie hypothesis, matter waves, Davisson and Germer's experiment, Schrödinger's time independent wave equation, physical significance of the wave function, infinite square well potential.

MODULE –III: LASERS AND FIBER OPTICS

Characteristics of lasers, spontaneous and stimulated emission of radiation, population inversion, lasing action, Ruby laser, He-Ne laser, applications of lasers.

Principle and construction of an optical fiber, acceptance angle, numerical aperture, types of optical fibers (Single mode, multimode, step index, graded index), optical fiber communication system with block diagram, applications of optical fibers.

MODULE –IV: MAGNETIC AND SUPERCONDUCTING PROPERTIES

Permeability, field intensity, magnetic field induction, magnetization, magnetic susceptibility, origin of magnetic moment, Bohr magneton, classification of dia, para and ferro magnetic materials on the basis of magnetic moment, Hysteresis curve.

Superconductivity, general properties, Meissner effect, effect of magnetic field, type-I & type-II superconductors, BCS theory, applications of superconductors.

MODULE –V: QUANTUM COMPUTING

Introduction, linear algebra for quantum computation, Dirac's Bra and Ket notation and their properties, Hilbert space, Bloch's sphere, concept of quantum computer, classical bits, Qubits, multiple Qubit system, quantum computing system for information processing, evolution of quantum systems, quantum measurements, entanglement, quantum gates, challenges and advantages of quantum computing over classical computation.

V. TEXTBOOKS:

1. Arthur Beiser, Shobhit Mahajan and Rai Choudhary, *Concepts of Modern Physics*, Tata McGraw Hill, 7th Edition, 2017.
2. Thomas G. Wong, Introduction to Classical and Quantum Computing, Rooted Grove

VI. REFERENCE BOOKS:

1. H J Callister, *A Textbook of Materials Science and Engineering,* Wiley Eastern Edition, 8th Edition, 2013.
2. Halliday, Resnick and Walker, *Fundamentals of Physics,* John Wiley &Sons,11th Edition, 2018.
3. Charles Kittel, *Introduction to Solid State Physics,* Wiley Eastern, 2019.
4. S.L. Gupta and V. Kumar, *Elementary Solid State Physics,* Pragathi Prakashan, 2019.
5. Michael A. Nielsen & Isaac L. Chuang, *Quantum Computation and Quantum Information*, Cambridge University Press.

VII. ELECTRONICS RESOURCES:

1. NPTEL :: Physics - NOC:Quantum Mechanics I
2. NPTEL :: Physics - NOC:Introduction to Solid State Physics
3. NPTEL :: Physics - NOC:Solid State Physics
4. https://nptel.ac.in/courses/104104085
5. NPTEL :: Metallurgy and Material Science - NOC:Nanotechnology, Science and Applications

VIII. MATERIALS ONLINE

1. Course template
2. Tutorial question bank
3. Tech talk topics
4. Open end experiments
5. Definitions and terminology
6. Assignments

7. Model question paper – I
8. Model question paper - II
9. Lecture notes
10. E-learning readiness videos (ELRV)
11. Power point presentation

COURSE CONTENT

ENGLISH FOR SKILL ENHANCEMENT							
I Semester: AE / ME / CE / ECE / EEE / CSE (AI &ML) / CSE (DS) **II Semester:** CSE / IT							
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**	

Course Code	**Category**	**L**	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
AHSE04	**Foundation**	3	-	-	3	40	60	100

Contact Classes: 48	**Tutorial Classes: Nil**	**Practical Classes: Nil**	**Total Classes: 48**
Prerequisite:			

I. COURSE OVERVIEW:

The principle aim of the course is that the students will have awareness about the importance of English language in the contemporary times and also it emphasizes the students to learn this language as a skill (listening skill, speaking skill, reading skill and writing skill). Moreover, the course benefits the students how to solve their day-to-day problems in speaking English language. Besides, it assists the students to reduce the mother tongue influence and acquire the knowledge of neutral accent. The course provides theoretical and practical knowledge of English language and it enables students to participate in debates about informative, persuasive, didactic, and commercial purposes.

II. COURSE OBJECTIVES:
The students will try to learn:

I	Standard pronunciation, appropriate word stress, and necessary intonation patterns for effective communication towards achieving academic and professional targets.
II	Appropriate grammatical structures and also using the nuances of punctuation tools for practical purposes.
III	Critical aspect of speaking and reading for interpreting in-depth meaning between the sentences.
IV	Conceptual awareness on writing in terms of unity, content, coherence, and linguistic accuracy.

III. COURSE OUTCOMES:
After successful completion of the course, students should be able to:

CO 1	Demonstrate the essential listening and communication skills required for academic and non-academic purposes.
CO 2	Explain ideas and discuss issues effectively in spoken English with a high level of fluency and accuracy across different social contexts.
CO 3	Enhance language proficiency to strengthen life skills and effectively navigate challenges in a professional environment.
CO 4	Interpret grammatical and lexical forms of English and apply them in specific communicative contexts.
CO 5	Develop the ability to comprehend, analyze, and interpret a variety of texts, enhancing critical thinking, vocabulary, and the application of reading strategies for academic, professional, and personal growth.
CO 6	Improve the ability to produce clear, coherent, and well-structured written content and organization for academic, professional, and creative tenacities.

IV. COURSE CONTENT:

MODULE – I: PERSPECTIVES (13)

Lesson on 'The Generation Gap' by Benjamin M. Spock from the prescribed textbook titled *English for the Young in the Digital World* published by Orient Black Swan Pvt. Ltd.

Vocabulary: The Concept of Word Formation -The Use of Prefixes and Suffixes - Words Often Misspelt - Synonyms and Antonyms

Grammar: Identifying Common Errors in Writing with Reference to Parts of Speech particularly Articles and Prepositions – Degrees of Comparison

Reading: Reading and Its Importance- Sub Skills of Reading – Skimming and Scanning.

Writing: Sentence Structures and Types -Use of Phrases and Clauses in Sentences- Importance of Proper Punctuation- Techniques for Writing Precisely –Nature and Style of Formal Writing.

MODULE – II: DIGITAL TRANSFORMATION (13)

Lesson on '*Emerging Technologies*' from the prescribed textbook titled *English for the Young in the Digital World* published by Orient Black Swan Pvt. Ltd.

Vocabulary: Homophones, Homonyms and Homographs,

Grammar: Identifying Common Errors in Writing with Reference to Noun-pronoun Agreement and Subject-verb Agreement.

Reading: Reading Strategies-Guessing Meaning from Context – Identifying Main Ideas – Exercises for Practice,

Writing: Paragraph Writing – Types, Structures and Features of a Paragraph - Creating Coherence – Linkers and Connectives - Organizing Principles in a Paragraph – Defining- Describing People, Objects, Places and Events – Classifying- Providing Examples or Evidence - Essay Writing - Writing Introduction and Conclusion.

MODULE – III: ATTITUDE AND GRATITUDE (13)

Poems on '*Leisure*' by William Henry Davies   and '*Be Thankful*' - Unknown Author from the prescribed textbook titled *English for the Young in the Digital World* published by Orient Black Swan Pvt. Ltd.

Vocabulary: Words Often Confused - Words from Foreign Languages and their Use in English.

Grammar: Identifying Common Errors in Writing with Reference to Misplaced Modifiers and Tenses.

Reading: Sub-Skills of Reading – Identifying Topic Sentence and Providing Supporting Ideas - Exercises for Practice.

Writing: Format of a Formal Letter-Writing Formal Letters E.g.., Letter of Complaint, Letter of Requisition, Job Application with CV/Resume –Difference between Writing a Letter and an Email - Email Etiquette.

MODULE – IV: ENTREPRENEURSHIP (12)

Lesson on '*Why a Start-Up Needs to Find its Customers First*' by Pranav Jain from the prescribed textbook titled *English for the Young in the Digital World* published by Orient Black Swan Pvt. Ltd.

Vocabulary: Standard Abbreviations in English – Inferring Meanings of Words through Context – Phrasal Verbs – Idioms.

Grammar: Redundancies and Clichés in Written Communication – Converting Passive to Active Voice and Vice-Versa.

Reading: Prompt Engineering Techniques– Comprehending and Generating Appropriate Prompts - Exercises for Practice

Writing: Writing Practices- Note Making-Précis Writing.

MODULE – V: INTEGRITY AND PROFESSIONALISM (13)

Lesson on '*Professional Ethics*' from the prescribed textbook titled *English for the Young in the Digital World* published by Orient Black Swan Pvt. Ltd.

Lesson on '*Professional Ethics*' from the prescribed textbook titled *English

Vocabulary: Technical Vocabulary and their Usage– One Word Substitutes – Collocations.

Grammar: Direct and Indirect Speech **-** Common Errors in English (Covering all the other aspects of grammar which were not covered in the previous units)

Reading: Survey, Question, Read, Recite and Review (SQ3R Method) – Inferring the Meaning and Evaluating a Text- Exercises for Practice

Writing: Report Writing - Technical Reports- Introduction – Characteristics of a Report – Categories of Reports Formats- Structure of Reports (Manuscript Format) -Types of Reports - Writing a Technical Report.

V. TEXT BOOKS:

1. Board of Editors. 2025. English for the Young in the Digital World. Orient Black Swan Pvt. Ltd.

VI. REFERENCE BOOKS:

1. Swan, Michael. (2016). Practical English Usage. Oxford University Press. New Edition.
2. Karal, Rajeevan. 2023. English Grammar Just for You. Oxford University Press. New Delhi
3. 2024. Empowering with Language: Communicative English for Undergraduates. Cengage Learning India Pvt. Ltd. New Delhi
4. Sanjay Kumar & Pushp Lata. 2022. Communication Skills – A Workbook. Oxford University Press. New Delhi
5. Wood,F.T. (2007). Remedial English Grammar. Macmillan.
6. Vishwamohan, Aysha. (2013). English for Technical Communication for Engineering Students. Mc Graw-Hill Education India Pvt. Ltd

VII. ELECTRONICS RESOURCES:

1. https://akanksha.iare.ac.in/index?route=course/details&course_id=954
2. https://akanksha.iare.ac.in/index?route=course/details&course_id=10
3. https://akanksha.iare.ac.in/index?route=course/details&course_id=352
4. https://akanksha.iareac.in/index?route=publicprofile&id=5075

VIII. MATERIALS ONLINE

1. Course template
2. Tutorial question bank
3. Tech talk topics
4. Open end experiments
5. Definitions and terminology
6. Assignments
7. Model question paper – I
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INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

ELECTRICAL CIRCUITS

I Semester: EEE / ECE

Course Code	Category	Hours / Week			Credits	Maximum Marks		
		L	T	P	C	CIA	SEE	Total
AEEE02	Core	3	0	0	3	40	60	100
Contact Classes: 48	Tutorial Classes: Nil	Practical Classes: Nil				Total Classes: 48		
Prerequisite: Mathematics								

I. COURSE OVERVIEW:

This course introduces fundamental concepts of circuit laws, theorems, and various electrical elements. It covers steady-state analysis for both single-phase and three-phase circuits, along with concepts of resonance and power calculations. Students also explore network theorems and magnetic coupled circuits to enhance problem-solving skills. End the end of the course completion, learners will be able to analyze and design AC and DC electrical circuits using scientific and engineering principles

II. COURSE OBJECTIVES:
The students will try to learn:
I The fundamental circuit laws and transformations in electrical networks.
II The AC and DC circuits using network theorems and systematic methods like mesh and nodal analysis.
III The use of single-phase and three-phase circuits for balanced and unbalanced loads.
IV The resonance, power concepts, and mutual inductance in circuits with energy-storing elements

III. COURSE OUTCOMES:
At the end of the course students should be able to:
CO1 **Identify and classify** different electrical elements and apply Kirchhoff's laws, source, and Star-Delta transformations in network analysis.
CO2 **Analyze** AC single-phase circuits using phasor techniques and compute power, impedance, and resonance conditions.
CO3 **Evaluate** three-phase systems under balanced and unbalanced conditions and measure power using appropriate methods.
CO4 **Apply** various network theorems to simplify and solve complex AC and DC circuits.
CO5 **Interpret and solve** magnetic coupled circuits using concepts like mutual inductance, dot convention, and coefficient of coupling.

IV. COURSE CONTENT:

MODULE-I: NETWORK ELEMENTS & LAWS (09)
Network Elements: Active elements- Independent and dependent sources, Passive elements- R, L and C, Energy stored in Inductance and Capacitance, Laws: Kirchhoff's laws, Source transformation, Star-Delta transformation, Node voltage method, and Mesh current method.

MODULE-II: SINGLE-PHASE CIRCUITS (09)
Single-Phase Circuits: RMS and average values of periodic sinusoidal and non-sinusoidal waveforms, Phasor representation, j-Notation, Steady-state analysis of series, parallel circuits. Impedance, Admittance, Active and Reactive Powers, Complex Power.
Resonance: Series and parallel circuits, Bandwidth and Q-factor.

MODULE-III: THREE-PHASE CIRCUITS (10)
Three-phase Circuits: Analysis of balanced and unbalanced three-phase circuits, Star and delta connections,
Measurement of three-phase power for balanced and unbalanced loads.

MODULE-IV: NETWORK THEOREMS (10)
Network theorems: Superposition theorem, Thevenin's theorem, Norton's theorems, Maximum power transfer theorem, Tellegen's theorem, Compensation theorem, Millman's theorem and Reciprocity theorem. (AC & DC).

MODULE-V: MAGNETIC COUPLED CIRCUITS (10)
Magnetic Coupled circuits: Concept of self and mutual inductance, Dot convention, Coefficient of coupling, Analysis of circuits with mutual inductance.

V.   TEXT BOOKS:
1.   Van Valkenburg M.E, "Network Analysis", Prentice Hall of India, 3rd Edition, 2000.
2.   Ravish R Singh, "Network Analysis and Synthesis", McGraw Hill, 2nd Edition, 2019.

VI. REFERENCE BOOKS:
1.   B. Subramanyam, "Electric Circuit Analysis", Dreamtech Press & Wiley, 2021.
2.   James W.Nilsson, Susan A.Riedel, "Electric Circuits", Pearson, 11th Edition, 2020.
3.   A Sudhakar, Shyammohan S Palli, "Circuits and Networks: Analysis and Synthesis", McGraw Hill, 5th Edition, 2017.
4.   Jagan N.C, Lakshrninarayana C., "Network Analysis", B.S. Publications, 3rd Edition, 2014.
5.   William Hayt H, Kimmerly Jack E. and Steven Durbin M, "Engineering Circuit Analysis", McGraw Hill,
   6th Edition, 2002.
6.   Chakravarthy A., "Circuit Theory", Dhanpat Rai & Co., First Edition, 1999.

VII. ELECTRONIC RESOURCES:
1.   https://nptel.ac.in/courses/108/104/108104139/
2.   https://www.researchgate.net
3.   https://www.electrical4u.com
4.   https://www.iare.ac.in

VIII. MATERIALS ONLINE:
1.   Course template
2.   Tutorial question bank
3.   Tech talk topics
4.   Open end experiments
5.   Definitions and terminology
6.   Assignments
7.   Model question paper - I
8.   Model question paper - II
9.   Lecture notes
10.   E-learning readiness videos (ELRV)

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

OBJECT ORIENTED PROGRAMMING							
I Semester: AE / ME / CE / ECE / EEE / CSE / CSE (AI & ML) / CSE (DS) / IT							

Course Code	Category	Hours / Week			Credits	Maximum Marks		
ACSE01	**Foundation**	**L**	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
		3	0	0	3	40	60	100

Contact Classes: 48	Tutorial Classes: Nil	Practical Classes: Nil	Total Classes: 48

Prerequisites: There are no prerequisites to take this course.

I. COURSE OVERVIEW:

This course introduces the principles of Object-Oriented Programming (OOP) and its role in solving complex problems effectively. It provides a solid foundation in object-oriented concepts such as abstraction, encapsulation, inheritance, polymorphism, and collaboration. The course also extends into file handling, exception management, and concurrent execution, preparing students to design, develop, and manage robust real-world applications.

II. COURSES OBJECTIVES:

The students will try to learn

I. The fundamental concepts and principles of object-oriented programming in high-level programming languages.
II. The advanced concepts for developing well-structured and efficient programs that involve complex data structures, numerical computations, or domain-specific operations.
III. The design and implementation features such as inheritance, polymorphism, and encapsulation for tackling complex problems and creating well-organized, modular, and maintainable code.
IV. The usage of input/output interfaces to transmit and receive data to solve real-time computing problems.

III. COURSE OUTCOMES:

At the end of the course, students should be able to:

CO1 Identify appropriate programming approaches to manage complexity.

CO2 Design modular, reusable, and adaptable software systems.

CO3 Apply structured problem-solving techniques to build reliable and maintainable applications.

CO4 Demonstrate the ability to handle data, manage errors, and ensure smooth program execution.

CO5 Develop applications that are efficient, scalable, and suitable for real-world scenarios

CO6 Develop contemporary solutions to software design problems using object-oriented principles.

IV. COURSE CONTENT:

MODULE - I: Object-oriented concepts (10)
Complex systems: definition, characteristics, and five attributes (hierarchy, abstraction, emergence, encapsulation, modularity).
Evolution of problem-solving: procedural vs. object-oriented thinking.
Objects as fundamental building blocks: state, behavior, and identity.
Benefits of OOP in managing complexity, Applications of OOP in real-world systems.

MODULE II: Abstraction, Encapsulation and Object Collaboration (09)
Abstraction: forms of abstraction (procedural, data, control), abstraction layers, mechanisms.
Encapsulation: information hiding, boundary definition, modularity.
Objects and message passing: collaboration through responsibilities.
Relationships: association, aggregation, composition, dependency.

MODULE III: Inheritance and Generalization (10)
Classification and taxonomy in object-oriented programming, Concepts of generalization and specialization.
Types of inheritance: single, multiple, and hierarchical (conceptual).

Challenges in multiple inheritance: ambiguity and the diamond problem (conceptual).
Importance of generalization for adaptability and method reuse.

MODULE IV: Polymorphism and Interfaces (09)
Polymorphism: static vs dynamic polymorphism, Abstract classes, abstract operations, late binding, and dynamic dispatch.
Interfaces as behavioral contracts, difference between interfaces and abstract classes (conceptual), Multiple realizations of interfaces (role-based modeling).

MODULE V: File structures, Exception handling, Concurrent execution (09)
Working with Files: Files, need for file handling, types, modes, operations and error handling.
Exception handling: Detecting problems during execution and responding gracefully, preventing failures from crashing the system and ensuring smooth execution.
Concurrent execution: Allowing multiple tasks to run simultaneously within a system, co-ordinating tasks to avoid conflicts when sharing resources.

V. TEXTBOOKS:

1. Matt Weisfeld, *The Object-Oriented Thought Process*, Addison Wesley Object Technology Series, 4th Edition, 2013.
2. Grady Booch, *Object-Oriented Analysis and Design with Applications*, Addison-Wesley Professional, 3rd Edition, 2007.
3. Craig Larman, Applying UML and Patterns: An Introduction to Object-Oriented Analysis and Design and Iterative Development, Addison-Wesley Professional, 3rd Edition, 2004.

VI. REFERENCE BOOKS:

1. Timothy Budd, *Introduction to object-oriented programming*, Addison Wesley Object Technology Series, 3rd Edition, 2002.
2. Gaston C. Hillar, *Learning Object-Oriented Programming*, Packt Publishing, 2015.
3. Kingsley Sage, *Concise Guide to Object-Oriented Programming*, Springer International Publishing, 1st Edition, 2019.
4. Rudolf Pecinovsky**,** *OOP - Learn Object Oriented Thinking and Programming*, Tomas Bruckner, 2013.

VII. ELECTRONICS RESOURCES:

1. https://docs.oracle.com/javase/tutorial/java/concepts/
2. https://www.w3schools.com/cpp/
3. https://www.edx.org/learn/object-oriented-programming/
4. https://www.geeksforgeeks.org/introduction-of-object-oriented-programming/

VIII. MATERIALS ONLINE

1. Course template
2. Tutorial question bank
3. Tech talk topics
4. Open-ended experiments
5. Definitions and terminology
6. Assignments
7. Model question paper – I
8. Model question paper – II
9. Lecture notes
10. PowerPoint presentation
11. E-Learning Readiness Videos (ELRV)

COURSE CONTENT

ENGLISH LANGUAGE AND COMMUNICATION SKILLS LABORATORY									

I Semester: AE / ME / CE / ECE / EEE / CSE (AI &ML) / CSE (DS)
II Semester: CSE / IT

Course Code	Category	Hours / Week			Credits	Maximum Marks		
		L	T	P	C	CIA	SEE	Total
AHSE07	Foundation	-	-	2	1	40	60	100
Contact Classes: Nil	Tutorial Classes: Nil	Practical Classes: 45				Total Classes: 45		
Prerequisite: Nil								

I. COURSE OVERVIEW:

This laboratory course is designed to introduce students to create a wide exposure on language learning techniques of the basic elements of listening skills, speaking skills, reading skills and writing skills. In this laboratory, students are trained in communicative English language skills, phonetics, word accent, word stress, rhythm, intonation, oral presentations and extempore speeches. Students are also taught in terms of seminars, group-discussions, presenting techniques of writing, participating in role plays, telephonic etiquettes, asking and giving directions, information transfer, debates, description of persons, places and objects etc. The laboratory encourages students to work in a group, engage in peer-reviews and inculcate team spirit through various exercises on grammar, vocabulary, and pronunciation games etc. Students will make use of all these language skills in academic, professional and real time situations.

II. COURSES OBJECTIVES

The students will try to learn:

I	The computer-assisted multi-media instructions to make possible individualized and independent language learning.
II	The critical aspect of speaking and reading for interpreting in-depth meaning of the sentences.
III	The language techniques for social interactions such as public speaking, group discussions and interviews.
IV	English speech sounds, word accent, intonation and rhythm patterns for effective pronunciation.

III. COURSE OUTCOMES:

At the end of the course, students will be able to:

CO1 Discuss the prime necessities of listening skills for improving pronunciation in academic and non-academic purposes.

CO2 Summarize the significance of speaking skills by using phonetics knowledge and intonation patterns.

CO3 Express the usage of strong forms and weak forms in the connected speech.

CO4 Explain how writing skills fulfil the academic and non-academic requirements of various written communicative functions.

CO5 Generalize the activities of Interactive Communication Skills to overcome the day-to-day challenges.

CO6 Classify the roles of collaboration, risk-taking, multi-disciplinary awareness, and the imagination in achieving creative responses to problems.

Dos

1. Turn up in a neat and formal dress code regularly and maintain punctuality.
2. Bring observation books and worksheets for every laboratory session without fail.
3. Keep lab record book up to date.
4. Students must adhere to the acceptable use of ICT resources policy.
5. CD ROM 's, USB and other multimedia equipment are for college use only.
6. Replace headsets onto the monitor and rearrange your chairs back into their position as you leave laboratory.
7. Get your lab worksheets evaluated and upload online within the stipulated time for online evaluation by the faculty concerned.
8. Conduct yourself at the best to be a good learner.

Don'ts

1. Do not use the on/off switch to reboot the system.
2. Do not breach copyright regulations.
3. The not install or download any software or modify or delete any system files on any laboratory computer.
4. Do not read or modify other users' files.
5. Do not damage, remove, or disconnect any labels, parts, cables or equipment.
6. The not make undue noise in the laboratories. Be considerate of the other lab users- this is study area.
7. No food and the beverages are allowed into computer laboratories.

IV. COURSE CONTENT
Exercises for professional communication laboratory

Exercises –1   CALL LAB: Speech Sounds with Active Listening.
          ICS LAB: introducing self and introducing others and feedback.

    a. Common mispronunciations.
    b. Errors committed in self-introduction and introducing others.

Exercises –2   CALL LAB: Listening to Distinguish Speech Sounds (minimal pairs) – Testing Exercises.
          ICS LAB: Ice Breaking Activity.

    a. Difficulty in familiarizing with the sounds of English language, errors in using different kinds of sounds, vowels and consonants.
    b. supports a positive social climate; decreases in off task behaviors; improved social skills; improves student enjoyment; and raises participation levels.

Exercises –3   CALL LAB: Listening for General Information Followed by Multiple Questions.
          ICS LAB: Role Play Activity.

    a. Listening actively to understand the information to respond.
    b. Take on different roles and act out situations like ordering food in a restaurant, asking for directions, or even having a phone conversation.

Exercises –4   CALL LAB: Listening Comprehension Activity.
          ICS LAB: Social Etiquettes.

    a. Enhancing their language skills, academic performance, and social interactions.
    b. Positive social interactions, enhancing communication skills, and contributing to overall personal and academic success.

Exercises –5   CALL LAB: Neutralization of Mother Tongue Influence (MTI).
          ICS LAB: Describing Objects, Situations, Places, People and Events.

    a. Influence of Mother tongue in spoken communication.
    b. Strengthen the art of writing and spoken language.

Exercises – 6   CALL LAB: Techniques for Effective Listening.
          ICS LAB: Story Telling.

    a. actively engaging with the speaker to understand their message fully.
    b. enhancing their language skills, creativity, and overall learning experience.

Exercises –7   CALL LAB: Identifying the Literal and Implied Meaning.
          ICS LAB: Non-Verbal Communication

    a. Listening for evaluation – Write summary – Listening for evaluation – Listening comprehension exercises.
    b. Attention of non-verbal ques.

Exercises – 8   CALL LAB: Structure of syllables.
          ICS LAB: JAM Sessions using public address system.

    a. Practicing consonant clusters
    b. Practicing different methods of dividing the syllables
    c. Participating in just a minute session

Exercises –9   CALL LAB: Past tense and plural markers.
ICS LAB: Oral Presentations.

 a. Addition of suffixes to verbs.
 b. Confidence and fluency in delivering different oral presentations.

Exercises –10   CALL LAB: Minimal pairs.
ICS LAB: Debates.

 a. Difficulties in understanding and remembering various homonyms, homophones and homographs.
 b. Problems in understanding the difference between debates and discussions, participating and contributing.

Exercises –11   CALL LAB: Intonation.
ICS LAB: Group discussion.

 a. Inability in focused listening, understanding the accent, vocabulary and discourse markers in connected speech.
 b. Lack of confidence in participating and contributing to Group discussions.

Exercises –12   CALL LAB: Demonstration on how to write leaflets, messages and notices.
ICS LAB: Techniques and methods to write summaries and reviews of videos.

 a. Inadequacy and inappropriacy in writing leaflets, messages and notices.
 b. Lack of proficiency in writing summaries and reviews of videos.

Exercises –13   CALL LAB: Pronunciation practice.
ICS LAB: Information transfer.

 a. Influence of mother tongue in using English language.
 b. Problems in interpreting data from diagram to text and text to diagram.

Exercises –14   CALL LAB; Open Ended Experiments-Phonetics Practice.
ICS LAB: Picture Extempore.

 a. Persistent problems in identifying the phonetic symbols, remembering and using them.
 b. Execution while describing picture.

Exercises –15   CALL LAB: Open Ended experiments-Text to Speech.
ICS LAB: Writing slogan related to the image.

 a. Difficulties in writing text to Speech.
 b. Lack of fluency in writing slogans related to the images.

V. TEXT BOOKS:
1. Professional Communication laboratory manual

VI. REFERENCE BOOK
1. Meenakshi Raman, Sangeetha Sharma, *Technical Communication Principles and Practices*, Oxford University Press, New Delhi, 3rd Edition, 2015.
2. Rhirdion, Daniel, *Technical Communication*, Cengage Learning, New Delhi, 1st Edition, 2009.

VII. ELECTRONICS RESOURCES
1. Cambridge online pronunciation dictionary https://dictionary.cambridge.org/
2. Fluentu website https://www.fluentu.com/
3. Repeat after us https://brycs.org/clearinghouse/3018/
4. Language lab https://brycs.org/clearinghouse/3018/
5. Oxford online videos

VIII. MATERIALS ONLINE
1. Course template

COURSE CONTENT

OBJECT ORIENTED PROGRAMMING LABORATORY							
I Semester: AE / ME / CE / ECE / EEE / CSE / IT / CSE (AI&ML) / CSE (DS)							
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**	
ACSE03	**Foundation**	L	T	P	C	CIA	SEE	Total
		0	0	2	1	40	60	100
Contact Classes: Nil	**Tutorial Classes: NIL**	**Practical Classes: 30**				**Total Classes: 30**	
Prerequisite: There are no prerequisites to take this course.							

I. COURSE OVERVIEW:

This course provides a solid foundation in object-oriented programming concepts and hands-on experience in using them. It introduces the concepts of abstraction and reusable code design via the object-oriented paradigm. Through a series of examples and exercises students gain coding skills and develop an understanding of professional programming practices. Mastering Java facilitate the learning of other technologies.

II. COURSES OBJECTIVES:

The students will try to learn

I.	The strong foundation with the Java Virtual Machine, its concepts and features.
II.	The systematic understanding of key aspects of the Java Class Library
III.	The usage of a modern IDE with an object oriented programming language to develop programs.

III. COURSE OUTCOMES:

At the end of the course students should be able to:

CO 1   Develop non-trivial programs in a modern programming language.

CO 2   Apply the principles of selection and iteration.

CO 3   Appreciate uses of modular programming concepts for handling complex problems.

CO 4   Recognize and apply principle features of object-oriented design such as abstraction and encapsulation.

CO 5   Design classes with a view of flexibility and reusability.

CO 6   Code, test and evaluate small use cases to conform to a specification.

EXERCISES FOR OBJECT ORIENTED PROGRAMMING LABORATORY

Note: Students are encouraged to bring their own laptops for laboratory practice sessions.

1. Getting Started Exercises

1.1 `HelloWorld`

1. Install JDK on your machine.

2. Write a Hello-world program using JDK and a source-code editor, such as:

   o For All Platforms: Sublime Text, Atom

   o For Windows: TextPad, NotePad++

   o For macOS: jEdit, gedit

   o For Ubuntu: gedit

3. Do ALL the exercises.

1.2 *Writing Good Programs*

The only way to learn programming is program, program and program. Learning programming is like learning cycling, swimming or any other sports. You can't learn by watching or reading books. Start to program immediately. On the other hands, to improve your programming, you need to read many books and study how the masters program.

It is easy to write programs that work. It is much harder to write programs that not only work but also easy to maintain and understood by others – I call these *good programs*. In the real world, writing program is not meaningful. You have to write good programs, so that others can understand and maintain your programs.

Pay particular attention to:

1. Coding Style:

   o Read "Java Code Convention"
   (@ https://www.oracle.com/technetwork/java/codeconventions-150003.pdf or google "Java Code Convention").

   o Follow the *Java Naming Conventions* for variables, methods, and classes STRICTLY. Use *CamelCase* for names. Variable and method names begin with lowercase, while class names begin with uppercase. Use nouns for variables (e.g., `radius`) and class names (e.g., `Circle`). Use verbs for methods (e.g., `getArea()`, `isEmpty()`).

   o **Use Meaningful Names**: Do not use names like a, b, c, d, x, x1, x2, and x1688 - they are meaningless. Avoid single-alphabet names like `i`, `j`, `k`. They are easy to type, but usually meaningless. Use single-alphabet names only when their meaning is clear, e.g., `x`, `y`, `z` for co-ordinates and `i` for array index. Use meaningful names like `row` and `col` (instead
   of `x` and `y`, `i` and `j`, `x1` and `x2`), `numStudents` (not n), `maxGrade`, `size` (not n),
   and `upperbound` (not n again). Differentiate between singular and plural nouns (e.g., use `books` for an array of books, and `book` for each item).

o   Use consistent indentation and coding style. Many IDEs (such as Eclipse/NetBeans) can re-format your source codes with a single click.

2.   Program Documentation: Comment! Comment! and more Comment to explain your code to other people and to yourself three days later.

1.3 CheckPassFail (if-else)

Write a program called **CheckPassFail** which prints "PASS" if the int variable "mark" is more than or equal to 50; or prints "FAIL" otherwise. The program shall always print "DONE" before exiting.

Hints

Use >= for *greater than or equal to* comparison.

```java
/* Trying if-else statement.
 */
public class CheckPassFail {  // Save as "CheckPassFail.java"
   public static void main(String[] args) {  // Program entry point
      int mark = 49;   // Set the value of "mark" here!
      System.out.println("The mark is " + mark);

      // if-else statement
      if ( ...... ) {
         System.out.println( ...... );
      } else {
         System.out.println( ...... );
      }
      System.out.println( ...... );
   }
}
```

Try

mark = 0, 49, 50, 51, 100 and verify your results.

Take note of the source-code **indentation**!!! Whenever you open a block with '{', indent all the statements inside the block by 3 (or 4 spaces). When the block ends, un-indent the closing '}' to align with the opening statement.

1.4 CheckOddEven (if-else)

Write a program called **CheckOddEven** which prints "Odd Number" if the int variable "number" is odd, or "Even Number" otherwise. The program shall always print "bye!" before exiting.

Hints

n is an even number if (*n* % 2) is 0; otherwise, it is an odd number. Use == for comparison, e.g., (n % 2) == 0.

```java
/**
 * Trying if-else statement and modulus (%) operator.
 */
public class CheckOddEven {    // Save as "CheckOddEven.java"
   public static void main(String[] args) {  // Program entry point
      int number = 49;        // Set the value of "number" here!
      System.out.println("The number is " + number);
      if ( ...... ) {
         System.out.println( ...... );   // even number
      } else {
```

```
            System.out.println( ...... );   // odd number
        }
        System.out.println( ...... );
    }
}
```

Try

`number = 0, 1, 88, 99, -1, -2` and verify your results.

Again, take note of the source-code indentation! Make it a good habit to ident your code properly, for ease of reading your program.

1.5 *PrintNumberInWord (nested-if, switch-case)*

Write a program called **PrintNumberInWord** which prints "ONE", "TWO",... , "NINE", "OTHER" if the int variable "number" is 1, 2,... , 9, or other, respectively. Use (a) a "nested-`if`" statement; (b) a "`switch-case-default`" statement.

Hints

```
/**
 * Trying nested-if and switch-case statements.
 */
public class PrintNumberInWord {    // Save as "PrintNumberInWord.java"
   public static void main(String[] args) {
      int number = 5;   // Set the value of "number" here!

      // Using nested-if
      if (number == 1) {    // Use == for comparison
         System.out.println( ...... );
      } else if ( ...... ) {
         ......
      } else if ( ...... ) {
         ......
      ......
      ......
      } else {
         ......
      }

      // Using switch-case-default
      switch(number) {
         case 1:
            System.out.println( ...... ); break;   // Don't forget the "break"
after each case!
         case 2:
            System.out.println( ...... ); break;
         ......
         ......
         default: System.out.println( ...... );
      }
   }
}
```

Try
`number = 0, 1, 2, 3, ..., 9, 10` and verify your results.

1.6 PrintDayInWord (nested-if, switch-case)

Write a program called **PrintDayInWord** which prints "Sunday", "Monday", ... "Saturday" if the int variable "dayNumber" is 0, 1, ..., 6, respectively. Otherwise, it shall print "Not a valid day". Use (a) a "nested-if" statement; (b) a "switch-case-default" statement.

Try

dayNumber = 0, 1, 2, 3, 4, 5, 6, 7 and verify your results.

2. Exercises on Number Systems (for Science/Engineering Students)

To be proficient in programming, you need to be able to operate on these number systems:

1. Decimal (used by human beings for input and output)

2. Binary (used by computer for storage and processing)

3. Hexadecimal (shorthand or compact form for binary)

2.1   Exercises (Number Systems Conversion)

1. Convert the following *decimal* numbers into *binary* and *hexadecimal* numbers:
    a. 108
    b. 4848
    c. 9000

    Convert the following binary numbers into hexadecimal and decimal numbers:

    a. 10000000
    b. 101010101010
    c. 1000011000

    Convert the following hexadecimal numbers into binary and decimal numbers:

    a. 1234
    b. 80F
    c. ABCDE

    Convert the following decimal numbers into binary equivalent:

    a. 123.456D
    b. 19.25D

2.2 Exercise (Integer Representation)

1. What are the ranges of 8-bit, 16-bit, 32-bit and 64-bit integer, in "unsigned" and "signed" representation?
2. Give the value of 88, 0, 1, 127, and 255 in 8-bit unsigned representation.
3. Give the value of +88, -88 , -1, 0, +1, -128, and +127 in 8-bit 2's complement signed representation.
4. Give the value of +88, -88 , -1, 0, +1, -127, and +127 in 8-bit sign-magnitude representation.
5. Give the value of +88, -88 , -1, 0, +1, -127 and +127 in 8-bit 1's complement representation.

2.3 Exercises (Floating-point Numbers)

1. Compute the largest and smallest positive numbers that can be represented in the 32-bit normalized form.

2. Compute the largest and smallest negative numbers can be represented in the 32-bit normalized form.

3. Repeat (1) for the 32-bit denormalized form.

4. Repeat (2) for the 32-bit denormalized form.

Hints:

1. Largest positive number: S=0, E=1111 1110 (254), F=111 1111 1111 1111 1111 1111.
    Smallest positive number: S=0, E=0000 00001 (1), F=000 0000 0000 0000 0000 0000.
2. Same as above, but S=1.
3. Largest positive number: S=0, E=0, F=111 1111 1111 1111 1111 1111.
    Smallest positive number: S=0, E=0, F=000 0000 0000 0000 0000 0001.
4. Same as above, but S=1.

2.4 Exercises (Data Representation)

For the following 16-bit codes:

```
0000 0000 0010 1010;
1000 0000 0010 1010;
```

Give their values, if they are representing:

1. a 16-bit unsigned integer;

2. a 16-bit signed integer;

3. two 8-bit unsigned integers;

4. two 8-bit signed integers;

5. a 16-bit Unicode characters;

6. two 8-bit ISO-8859-1 characters.

3. Exercises on Decision and Loop

3.1 SumAverageRunningInt (Decision & Loop)

Write a program called **SumAverageRunningInt** to produce the sum of 1, 2, 3, ..., to 100. Store 1 and 100 in variables lowerbound and upperbound, so that we can change their values easily. Also compute and display the average.

The output shall look like:

```
The sum of 1 to 100 is 5050
The average is 50.5
```

Hints

```java
/**
 * Compute the sum and average of running integers from a lowerbound to an
 upperbound using loop.
 */
public class SumAverageRunningInt {   // Save as "SumAverageRunningInt.java"
   public static void main (String[] args) {
      // Define variables
      int sum = 0;            // The accumulated sum, init to 0
      double average;        // average in double
      final int LOWERBOUND = 1;
      final int UPPERBOUND = 100;
```

```
        // Use a for-loop to sum from lowerbound to upperbound
        for (int number = LOWERBOUND; number <= UPPERBOUND; ++number) {
             // The loop index variable number = 1, 2, 3, ..., 99, 100
          sum += number;      // same as "sum = sum + number"
        }
        // Compute average in double. Beware that int / int produces int!
        ......
        // Print sum and average
        ......
     }
}
```

Try

1. Modify the program to use a "while-do" loop instead of "for" loop.

```
int sum = 0;
        int number = LOWERBOUND;         // declare and init loop index variable
        while (number <= UPPERBOUND) {   // test
           sum += number;
           ++number;                     // update
        }
```

2. Modify the program using do-while loop

```
int sum = 0;
        int number = LOWERBOUND;            // declare and init loop index variable
        do {
           sum += number;
           ++number;                        // update
        } while (number <= UPPERBOUND);   // test
```

3. What is the difference between "for" and "while-do" loops? What is the difference between "while-do" and "do-while" loops?
4. Modify the program to sum from 111 to 8899, and compute the average. Introduce an int variable called count to count the numbers in the specified range (to be used in computing the average).
5. Modify the program to find the "sum of the squares" of all the numbers from 1 to 100, i.e. 1*1 + 2*2 + 3*3 + ... + 100*100.
6. Modify the program to produce two sums: sum of odd numbers and sum of even numbers from 1 to 100. Also computer their absolute difference.

3.2 Product1ToN (or Factorial) (Decision & Loop)

Write a program called Product1ToN to compute the product of integers from 1 to 10 (i.e., 1×2×3×…×10), as an int. Take note that It is the same as factorial of N.

Hints

Declare an int variable called product, initialize to 1, to accumulate the product.

```
        // Define variables
        int product = 1;      // The accumulated product, init to 1
        final int LOWERBOUND = 1;
        final int UPPERBOUND = 10;
```

Try

1. Compute the product from 1 to 11, 1 to 12, 1 to 13 and 1 to 14. Write down the product obtained and decide if the results are correct.

    HINTS: Factorial of 13 (=6227020800) is outside the range of `int [-2147483648, 2147483647]`. Take note that computer programs may not produce the correct result even though the code seems correct!

2. Repeat the above, but use `long` to store the `product`. Compare the products obtained with `int` for N=13 and N=14.

    HINTS: With `long`, you can store factorial of up to 20.

3.3 HarmonicSum (Decision & Loop)

Write a program called **HarmonicSum** to compute the sum of a harmonic series, as shown below, where *n=50000*. The program shall compute the sum from *left-to-right* as well as from the *right-to-left*. Are the two sums the same? Obtain the absolute difference between these two sums and explain the difference. Which sum is more accurate?

$$Harmonic(n) = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$$

Hints

```
/**
 * Compute the sum of harmonics series from left-to-right and right-to-left.
 */
public class HarmonicSum {    // Save as "HarmonicSum.java"
   public static void main (String[] args) {
      // Define variables
      final int MAX_DENOMINATOR = 50000;   // Use a more meaningful name instead of
n
      double sumL2R = 0.0;            // Sum from left-to-right
      double sumR2L = 0.0;            // Sum from right-to-left
      double absDiff;                // Absolute difference between the two sums

      // for-loop for summing from left-to-right
      for (int denominator = 1; denominator <= MAX_DENOMINATOR; ++denominator) {
         // denominator = 1, 2, 3, 4, 5, ..., MAX_DENOMINATOR
         ......
         // Beware that int/int gives int, e.g., 1/2 gives 0.
      }
      System.out.println("The sum from left-to-right is: " + sumL2R);

      // for-loop for summing from right-to-left
      ......

      // Find the absolute difference and display
      if (sumL2R > sumR2L) ......
      else ......
   }
}
```

3.4 ComputePI (Decision & Loop)

Write a program called **ComputePI** to compute the value of π, using the following series expansion. Use the maximum denominator (`MAX_DENOMINATOR`) as the terminating condition.

Try `MAX_DENOMINATOR` of `1000`, `10000`, `100000`, `1000000` and compare the PI obtained. Is this series suitable for computing PI? Why?

$$\pi = 4 \times \left(1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} - \frac{1}{11} + \frac{1}{13} - \frac{1}{15} + \cdots\right)$$

Hints

Add to `sum` if the `denominator % 4` is `1`, and subtract from `sum` if it is `3`.

```
double sum = 0.0;
int MAX_DENOMINATOR = 1000;    // Try 10000, 100000, 1000000
for (int denominator = 1; denominator <= MAX_DENOMINATOR; denominator += 2)
{
        // denominator = 1, 3, 5, 7, ..., MAX_DENOMINATOR
    if (denominator % 4 == 1) {
        sum += ......;
    } else if (denominator % 4 == 3) {
        sum -= ......;
    } else {    // remainder of 0 or 2
        System.out.println("Impossible!!!");
    }
}
......
```

Try

1. Instead of using maximum denominator as the terminating condition, rewrite your program to use the maximum number of terms (`MAX_TERM`) as the terminating condition.

```
int MAX_TERM = 10000;   // number of terms used in computation
    int sum = 0.0;
    for (int term = 1; term <= MAX_TERM; term++) {
        // term = 1, 2, 3, 4, ..., MAX_TERM
    if (term % 2 == 1) {  // odd term number: add
        sum += 1.0 / (term * 2 - 1);
    } else {                // even term number: subtract
        ......
    }
}
```

2. JDK maintains the value of π in a built-in `double` constant called `Math.PI` (=3.141592653589793). Add a statement to compare the values obtained and the `Math.PI`, in percents of `Math.PI`, i.e., (piComputed / Math.PI) * 100.

3.5 CozaLozaWoza (Decision & Loop)

Write a program called **CozaLozaWoza** which prints the numbers 1 to 110, 11 numbers per line. The program shall print "Coza" in place of the numbers which are multiples of 3, "Loza" for multiples of 5, "Woza" for multiples of 7, "CozaLoza" for multiples of 3 and 5, and so on. The output shall look like:

```
1 2 Coza 4 Loza Coza Woza 8 Coza Loza 11
Coza 13 Woza CozaLoza 16 17 Coza 19 Loza CozaWoza 22
23 Coza Loza 26 Coza Woza 29 CozaLoza 31 32 Coza
......
```

Hints

```java
public class CozaLozaWoza {    // Save as "CozaLozaWoza.java"
   public static void main(String[] args) {
      final int LOWERBOUND = 1, UPPERBOUND = 110;
      for (int number = LOWERBOUND; number <= UPPERBOUND; ++number) {
            // number = LOWERBOUND+1, LOWERBOUND+2, ..., UPPERBOUND
         // Print "Coza" if number is divisible by 3
         if ( ...... ) {
            System.out.print("Coza");
         }
         // Print "Loza" if number is divisible by 5
         if ( ...... ) {
            System.out.print(.....);
         }
         // Print "Woza" if number is divisible by 7
         ......
         // Print the number if it is not divisible by 3, 5 and 7 (i.e., it has
not been processed above)
         if ( ...... ) {
            ......
         }
         // After processing the number, print a newline if number is divisible by
11;
         // else print a space
         if ( ...... ) {
            System.out.println();  // print newline
         } else {
            System.out.print( ...... );  // print a space
         }
      }
   }
}
```

Notes

1. You cannot use nested-if (if … else if … else if … else) for this problem. It is because the tests are not mutually exclusive. For example, 15 is divisible by both 3 and 5. Nested-if is only applicable if the tests are mutually exclusive.

2. The tests above look messy. A better solution is to use a boolean flag to keep track of whether the number has been processed, as follows:

```java
   final int LOWERBOUND = 1, UPPERBOUND = 110;
   boolean printed;
   for (int number = LOWERBOUND; number <= UPPERBOUND; ++number) {
      printed = false;  // init before processing each number
      // Print "Coza" if number is divisible by 3
      if ( ...... ) {
         System.out.print( ...... );
         printed = true;   // processed!
      }
      // Print "Loza" if number is divisible by 5
      if ( ...... ) {
         System.out.print( ..... );
         printed = true;   // processed!
      }
      // Print "Woza" if number is divisible by 7
      ......
```

```
        // Print the number if it has not been processed
        if (!printed) {
            ......
        }
        // After processing the number, print a newline if it is divisible by 11;
        // else, print a space
        ......
    }
```

3.6 Fibonacci (Decision & Loop)

Write a program called **Fibonacci** to print the first 20 Fibonacci numbers F(n), where F(n)=F(n−1)+F(n−2) and F(1)=F(2)=1. Also compute their average. The output shall look like:

```
The first 20 Fibonacci numbers are:
1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597 2584 4181 6765
The average is 885.5
```

Hints

```
/**
 * Print first 20 Fibonacci numbers and their average
 */
public class Fibonacci {
   public static void main (String[] args) {
      int n = 3;              // The index n for F(n), starting from n=3, as n=1 and
n=2 are pre-defined
      int fn;                 // F(n) to be computed
      int fnMinus1 = 1;    // F(n-1), init to F(2)
      int fnMinus2 = 1;    // F(n-2), init to F(1)
      int nMax = 20;       // maximum n, inclusive
      int sum = fnMinus1 + fnMinus2;   // Need sum to compute average
      double average;

      System.out.println("The first " + nMax + " Fibonacci numbers are:");
      ......

      while (n <= nMax) {   // n starts from 3
            // n = 3, 4, 5, ..., nMax
         // Compute F(n), print it and add to sum
         ......
         // Increment the index n and shift the numbers for the next iteration
         ++n;
         fnMinus2 = fnMinus1;
         fnMinus1 = fn;
      }

      // Compute and display the average (=sum/nMax).
      // Beware that int/int gives int.
      ......
   }
}
```

Try

1. *Tribonacci numbers* are a sequence of numbers `T(n)` similar to *Fibonacci numbers*, except that a number is formed by adding the three previous numbers, i.e., `T(n)=T(n-1)+T(n-2)+T(n-3)`, `T(1)` `=T(2)=1`, and `T(3)=2`. Write a program called **Tribonacci** to produce the first twenty Tribonacci numbers.

3.7 ExtractDigits (Decision & Loop)

Write a program called **ExtractDigits** to extract each digit from an `int`, in the reverse order. For example, if the `int` is 15423, the output shall be "3 2 4 5 1", with a space separating the digits.

Hints

The *coding pattern* for extracting individual digits from an integer *n* is:
1. Use (`n % 10`) to extract the last (least-significant) digit.
2. Use `n = n / 10` to drop the last (least-significant) digit.
3. Repeat if (`n > 0`), i.e., more digits to extract.

Take note that *n* is destroyed in the process. You may need to clone a copy.

```
int n = ...;
  while (n > 0) {
      int digit = n % 10;  // Extract the least-significant digit
      // Print this digit
      ......
      n = n / 10;  // Drop the least-significant digit and repeat the loop
  }
```

4. Exercises on Input, Decision and Loop

4.1 Add2Integer (Input)

Write a program called `Add2Integers` that prompts user to enter two integers. The program shall read the two integers as `int`; compute their sum; and print the result. For example,

```
Enter first integer: 8
Enter second integer: 9
The sum is: 17
```

Hints

```
import java.util.Scanner;   // For keyboard input
/**
 * 1. Prompt user for 2 integers
 * 2. Read inputs as "int"
 * 3. Compute their sum in "int"
 * 4. Print the result
 */
public class Add2Integers {  // Save as "Add2Integers.java"
   public static void main (String[] args) {
      // Declare variables
      int number1, number2, sum;

      // Put up prompting messages and read inputs as "int"
      Scanner in = new Scanner(System.in);  // Scan the keyboard for input
      System.out.print("Enter  first  integer: ");   // No  newline  for  prompting
message
```

```
        number1 = in.nextInt();                    // Read next input as "int"
        ......
        in.close();  // Close Scanner

        // Compute sum
        sum = ......

        // Display result
        System.out.println("The sum is: " + sum);    // Print with newline
    }
}
```

4.2 SumProductMinMax3 (Arithmetic & Min/Max)

Write a program called SumProductMinMax3 that prompts user for three integers. The program shall read the inputs as int; compute the sum, product, minimum and maximum of the three integers; and print the results. For example,

```
Enter 1st integer: 8
Enter 2nd integer: 2
Enter 3rd integer: 9
The sum is: 19
The product is: 144
The min is: 2
The max is: 9
```

Hints

```
    // Declare variables
    int number1, number2, number3;  // The 3 input integers
    int sum, product, min, max;      // To compute these

    // Prompt and read inputs as "int"
    Scanner in = new Scanner(System.in);  // Scan the keyboard
    ......
    ......
    in.close();

    // Compute sum and product
    sum = ......
    product = ......

    // Compute min
    // The "coding pattern" for computing min is:
    // 1. Set min to the first item
    // 2. Compare current min with the second item and update min if second item
is smaller
    // 3. Repeat for the next item
    min = number1;        // Assume min is the 1st item
    if (number2 < min) {  // Check if the 2nd item is smaller than current min
        min = number2;    // Update min if so
    }
    if (number3 < min) {  // Continue for the next item
        min = number3;
    }

    // Compute max - similar to min
    ......

    // Print results
```

```
        ......
```

Try

1. Write a program called `SumProductMinMax5` that prompts user for five integers. The program shall read the inputs as `int`; compute the sum, product, minimum and maximum of the five integers; and print the results. Use five `int` variables: `number1`, `number2`, ..., `number5` to store the inputs.

4.3 CircleComputation (double & printf())

Write a program called **CircleComputation** that prompts user for the radius of a circle in floating point number. The program shall read the input as `double`; compute the diameter, circumference, and area of the circle in `double`; and print the values rounded to 2 decimal places. Use System-provided constant `Math.PI` for pi. The formulas are:

```
diameter = 2.0 * radius;
area = Math.PI * radius * radius;
circumference = 2.0 * Math.PI * radius;
```

Hints

```
    // Declare variables
      double radius, diameter, circumference, area;   // inputs and results - all
in double
      ......

      // Prompt and read inputs as "double"
      System.out.print("Enter the radius: ");
      radius = in.nextDouble();  // read input as double

      // Compute in "double"
      ......

      // Print results using printf() with the following format specifiers:
      //   %.2f for a double with 2 decimal digits
      //   %n for a newline
      System.out.printf("Diameter is: %.2f%n", diameter);
      ......
```

Try

1. Write a program called **SphereComputation** that prompts user for the `radius` of a sphere in floating point number. The program shall read the input as `double`; compute the volume and surface area of the sphere in `double`; and print the values rounded to 2 decimal places. The formulas are:

```
surfaceArea = 4 * Math.PI * radius * radius;
volume = 4 /3 * Math.PI * radius * radius * radius;   // But this does not work in
programming?! Why?
```

Take note that you cannot name the variable `surface  area` with a space or `surface-area` with a dash. Java's naming convention is `surfaceArea`. Other languages recommend `surface_area` with an underscore.

2. Write a program called **CylinderComputation** that prompts user for the base `radius` and `height` of a cylinder in floating point number. The program shall read the inputs as `double`; compute the base area, surface area, and volume of the cylinder; and print the values rounded to 2 decimal places. The

formulas are:

```
baseArea = Math.PI * radius * radius;
surfaceArea = 2.0 * Math.PI * radius + 2.0 * baseArea;
volume = baseArea * height;
```

4.4 Swap2Integers

Write a program called Swap2Integers that prompts user for two integers. The program shall read the inputs as int, save in two variables called number1 and number2; swap the contents of the two variables; and print the results. For examples,

```
Enter first integer: 9
Enter second integer: -9
After the swap, first integer is: -9, second integer is: 9
```

Hints

To swap the contents of two variables x and y, you need to introduce a temporary storage, say temp, and do: temp ⇐ x; x ⇐ y; y ⇐ temp.

4.5 IncomeTaxCalculator (Decision)

The progressive income tax rate is mandated as follows:

Taxable Income	Rate (%)
First $20,000	0
Next $20,000	10
Next $20,000	20
The remaining	30

For example, suppose that the taxable income is $85000, the income tax payable is $20000*0% + $20000*10% + $20000*20% + $25000*30%.

Write a program called **IncomeTaxCalculator** that reads the taxable income (in int). The program shall calculate the income tax payable (in double); and print the result rounded to 2 decimal places. For examples,

```
Enter the taxable income: $41234
The income tax payable is: $2246.80

Enter the taxable income: $67891
The income tax payable is: $8367.30

Enter the taxable income: $85432
The income tax payable is: $13629.60

Enter the taxable income: $12345
The income tax payable is: $0.00
```

Hints

```
    // Declare constants first (variables may use these constants)
    // The keyword "final" marked these as constant (i.e., cannot be changed).
    // Use uppercase words joined with underscore to name constants
    final double TAX_RATE_ABOVE_20K = 0.1;
```

```java
        final double TAX_RATE_ABOVE_40K = 0.2;
        final double TAX_RATE_ABOVE_60K = 0.3;

        // Declare variables
        int taxableIncome;
        double taxPayable;
        ......

        // Compute tax payable in "double" using a nested-if to handle 4 cases
        if (taxableIncome <= 20000) {          // [0, 20000]
           taxPayable = ......;
        } else if (taxableIncome <= 40000) {  // [20001, 40000]
           taxPayable = ......;
        } else if (taxableIncome <= 60000) {  // [40001, 60000]
           taxPayable = ......;
        } else {                               // [60001, ]
           taxPayable = ......;
        }
        // Alternatively, you could use the following nested-if conditions
        // but the above follows the table data
        //if (taxableIncome > 60000) {          // [60001, ]
        //   ......
        //} else if (taxableIncome > 40000) {    // [40001, 60000]
        //   ......
        //} else if (taxableIncome > 20000) {    // [20001, 40000]
        //   ......
        //} else {                               // [0, 20000]
        //   ......
        //}

        // Print results rounded to 2 decimal places
        System.out.printf("The income tax payable is: $%.2f%n", ...);
```

Try

Suppose that a 10% tax rebate is announced for the income tax payable, capped at $1,000, modify your program to handle the tax rebate. For example, suppose that the tax payable is $12,000, the rebate is $1,000, as 10% of $12,000 exceed the cap.

4.6 IncomeTaxCalculatorWithSentinel (Decision & Loop)

Based on the previous exercise, write a program called IncomeTaxCalculatorWithSentinel which shall repeat the calculation until user enter -1. For example,

```
Enter the taxable income (or -1 to end): $41000
The income tax payable is: $2200.00

Enter the taxable income (or -1 to end): $62000
The income tax payable is: $6600.00

Enter the taxable income (or -1 to end): $73123
The income tax payable is: $9936.90

Enter the taxable income (or -1 to end): $84328
The income tax payable is: $13298.40

Enter the taxable income: $-1
bye!
```

The -1 is known as the *sentinel value*. (Wiki: In programming, a *sentinel value*, also referred to as a flag value, trip value, rogue value, signal value, or dummy data, is a special value which uses its presence as a condition of termination.)

Hints

The *coding pattern* for handling input with sentinel value is as follows:

```java
// Declare constants first
final int SENTINEL = -1;    // Terminating value for input
......
// Declare variables
int taxableIncome;
double taxPayable;
......

// Read the first input to "seed" the while loop
System.out.print("Enter the taxable income (or -1 to end): $");
taxableIncome = in.nextInt();

while (taxableIncome != SENTINEL) {
   // Compute tax payable
   ......
   // Print result
   ......

   // Read the next input
   System.out.print("Enter the taxable income (or -1 to end): $");
   taxableIncome = in.nextInt();
      // Repeat the loop body, only if the input is not the SENTINEL value.
      //  Take  note  that  you  need  to  repeat  these  two  statements
inside/outside the loop!
   }
   System.out.println("bye!");
```

Take note that we repeat the input statements inside and outside the loop. Repeating statements is NOT a good programming practice. This is because it is easy to repeat (Cntl-C/Cntl-V), but hard to maintain and synchronize the repeated statements. In this case, we have no better choices!

4.7 PensionContributionCalculatorWithSentinel (Decision & Loop)

Based on the previous `PensionContributionCalculator`,
write a program called **PensionContributionCalculatorWithSentinel** which shall repeat the calculations until user enter -1 for the salary. For examples,

```
Enter the monthly salary (or -1 to end): $5123
Enter the age: 21
The employee's contribution is: $1024.60
The employer's contribution is: $870.91
The total contribution is: $1895.51

Enter the monthly salary (or -1 to end): $5123
Enter the age: 64
The employee's contribution is: $384.22
The employer's contribution is: $461.07
The total contribution is: $845.30

Enter the monthly salary (or -1 to end): $-1
bye!
```

Hints

```
    // Read the first input to "seed" the while loop
    System.out.print("Enter the monthly salary (or -1 to end): $");
    salary = in.nextInt();

    while (salary != SENTINEL) {
       // Read the remaining
       System.out.print("Enter the age: ");
       age = in.nextInt();

       ......
       ......

       // Read the next input and repeat
       System.out.print("Enter the monthly salary (or -1 to end): $");
       salary = in.nextInt();
    }
```

4.8 SalesTaxCalculator (Decision & Loop)

A sales tax of 7% is levied on all goods and services consumed. It is also mandatory that all the price tags should include the sales tax. For example, if an item has a price tag of $107, the actual price is $100 and $7 goes to the sales tax.

Write a program using a loop to continuously input the tax-inclusive price (in double); compute the actual price and the sales tax (in double); and print the results rounded to 2 decimal places. The program shall terminate in response to input of -1; and print the total price, total actual price, and total sales tax. For examples,

```
Enter the tax-inclusive price in dollars (or -1 to end): 107
Actual Price is: $100.00, Sales Tax is: $7.00

Enter the tax-inclusive price in dollars (or -1 to end): 214
Actual Price is: $200.00, Sales Tax is: $14.00

Enter the tax-inclusive price in dollars (or -1 to end): 321
Actual Price is: $300.00, Sales Tax is: $21.00

Enter the tax-inclusive price in dollars (or -1 to end): -1
Total Price is: $642.00
Total Actual Price is: $600.00
Total Sales Tax is: $42.00
```

Hints

```
    // Declare constants
    final double SALES_TAX_RATE = 0.07;
    final int SENTINEL = -1;          // Terminating value for input

    // Declare variables
    double price, actualPrice, salesTax;  // inputs and results
    double totalPrice = 0.0, totalActualPrice = 0.0, totalSalesTax = 0.0;  // to
accumulate
    ......

    // Read the first input to "seed" the while loop
    System.out.print("Enter the tax-inclusive price in dollars (or -1 to end):
");
```

```
    price =  in.nextDouble();

    while (price != SENTINEL) {
       // Compute the tax
       ......
       // Accumulate into the totals
       ......
       // Print results
       ......

       // Read the next input and repeat
       System.out.print("Enter  the  tax-inclusive  price  in  dollars  (or  -1  to
end): ");
       price =  in.nextDouble();
    }
    // print totals
    ......
```

4.9 ReverseInt (Loop with Modulus/Divide)

Write a program that prompts user for a positive integer. The program shall read the input as int; and print the "reverse" of the input integer. For examples,

```
Enter a positive integer: 12345
The reverse is: 54321
```

Hints

Use the following *coding pattern* which uses a while-loop with repeated modulus/divide operations to extract and drop the last digit of a positive integer.

```
    // Declare variables
    int inNumber;   // to be input
    int inDigit;    // each digit
    ......

    // Extract  and  drop  the  "last"  digit  repeatably  using  a  while-loop  with
modulus/divide operations
    while (inNumber > 0) {
       inDigit = inNumber % 10; // extract the "last" digit
       // Print this digit (which is extracted in reverse order)
       ......
       inNumber /= 10;           // drop "last" digit and repeat
    }
    ......
```

4.10 SumOfDigitsInt (Loop with Modulus/Divide)

Write a program that prompts user for a positive integer. The program shall read the input as int; compute and print the sum of all its digits. For examples,

```
Enter a positive integer: 12345
The sum of all digits is: 15
```

Hints

See "ReverseInt".

4.11 InputValidation (Loop with boolean flag)

Your program often needs to validate the user's inputs, e.g., marks shall be between 0 and 100.

Write a program that prompts user for an integer between 0-10 or 90-100. The program shall read the input as int; and repeat until the user enters a valid input. For examples,

```
Enter a number between 0-10 or 90-100: -1
Invalid input, try again...
Enter a number between 0-10 or 90-100: 50
Invalid input, try again...
Enter a number between 0-10 or 90-100: 101
Invalid input, try again...
Enter a number between 0-10 or 90-100: 95
You have entered: 95
```

Hints

Use the following *coding pattern* which uses a do-while loop controlled by a boolean flag to do input validation. We use a do-while instead of while-do loop as we need to execute the body to prompt and process the input at least once.

```java
    // Declare variables
    int numberIn;      // to be input
    boolean isValid;   // boolean flag to control the loop
    ......

    // Use a do-while loop controlled by a boolean flag
    // to repeatably read the input until a valid input is entered
    isValid = false;   // default assuming input is not valid
    do {
       // Prompt and read input
       ......

       // Validate input by setting the boolean flag accordingly
       if (numberIn ......) {
          isValid = true;   // exit the loop
       } else {
          System.out.println(......);  // Print error message and repeat
       }
    } while (!isValid);
    ......
```

4.12 AverageWithInputValidation (Loop with boolean flag)

Write a program that prompts user for the mark (between 0-100 in int) of 3 students; computes the average (in double); and prints the result rounded to 2 decimal places. Your program needs to perform input validation. For examples,

```
Enter the mark (0-100) for student 1: 56
Enter the mark (0-100) for student 2: 101
Invalid input, try again...
Enter the mark (0-100) for student 2: -1
Invalid input, try again...
Enter the mark (0-100) for student 2: 99
Enter the mark (0-100) for student 3: 45
The average is: 66.67
```

```
    // Declare constant
    final int NUM_STUDENTS = 3;

    // Declare variables
    int numberIn;
    boolean isValid;    // boolean flag to control the input validation loop
    int sum = 0;
    double average;
    ......

    for (int studentNo = 1; studentNo <= NUM_STUDENTS; ++studentNo) {
        // Prompt user for mark with input validation
        ......
        isValid = false;   // reset assuming input is not valid
        do {
           ......
        } while (!isValid);

        sum += ......;
    }
    ......
```

5. Exercises on Nested-Loops

5.1 SquarePattern (nested-loop)

Write a program called **SquarePattern** that prompts user for the size (a non-negative integer in `int`); and prints the following square pattern using two nested for-loops.

```
Enter the size: 5
# # # # #
# # # # #
# # # # #
# # # # #
# # # # #
```

Hints

The *code pattern* for printing 2D patterns using nested loops is:

```
    // Outer loop to print each of the rows
    for (int row = 1; row <= size; row++) {  // row = 1, 2, 3, ..., size
       // Inner loop to print each of the columns of a particular row
       for (int col = 1; col <= size; col++) {  // col = 1, 2, 3, ..., size
          System.out.print( ...... );   // Use print() without newline inside
the inner loop
          ......
       }
       // Print a newline after printing all the columns
       System.out.println();
    }
```

Notes

1. You should name the loop indexes `row` and `col`, NOT `i` and `j`, or `x` and `y`, or `a` and `b`, which are meaningless.

2.   The `row` and `col` could start at 1 (and upto `size`), or start at 0 (and upto `size-1`). As computer counts from 0, it is probably more efficient to start from 0. However, since humans counts from 1, it is easier to read if you start from 1.

Try

Rewrite the above program using nested while-do loops.

5.2 CheckerPattern (nested-loop)

Write a program called **CheckerPattern** that prompts user for the size (a non-negative integer in `int`); and prints the following checkerboard pattern.

```
Enter the size: 7
# # # # # # #
 # # # # # # #
# # # # # # #
 # # # # # # #
# # # # # # #
 # # # # # # #
# # # # # # #
```

Hints

```
 // Outer loop to print each of the rows
      for (int row = 1; row <= size; row++) {  // row = 1, 2, 3, ..., size
         // Inner loop to print each of the columns of a particular row
         for (int col = 1; col <= size; col++) {  // col = 1, 2, 3, ..., size
            if ((row % 2) == 0) {   // row 2, 4, 6, ...
               ......
            }
            System.out.print( ...... );    // Use print() without newline inside
the inner loop
            ......
         }
         // Print a newline after printing all the columns
         System.out.println();
      }
```

5.3 TimeTable (nested-loop)

Write a program called **TimeTable** that prompts user for the size (a positive integer in `int`); and prints the multiplication table as shown:

```
Enter the size: 10
  * |   1   2   3   4   5   6   7   8   9  10
-------------------------------------------
  1 |   1   2   3   4   5   6   7   8   9  10
  2 |   2   4   6   8  10  12  14  16  18  20
  3 |   3   6   9  12  15  18  21  24  27  30
  4 |   4   8  12  16  20  24  28  32  36  40
  5 |   5  10  15  20  25  30  35  40  45  50
  6 |   6  12  18  24  30  36  42  48  54  60
  7 |   7  14  21  28  35  42  49  56  63  70
  8 |   8  16  24  32  40  48  56  64  72  80
  9 |   9  18  27  36  45  54  63  72  81  90
 10 |  10  20  30  40  50  60  70  80  90 100
```

Hints

1. Use `printf()` to format the output, e.g., each cell is `%4d`.
2. See "Java Basics" article.

5.4 TriangularPattern (nested-loop)

Write 4 programs called **TriangularPatternX** (X = A, B, C, D) that prompts user for the size (a non-negative integer in `int`); and prints each of the patterns as shown:

```
Enter the size: 8

#                 # # # # # # # #       # # # # # # # #                       #
# #               # # # # # # #           # # # # # # #                     # #
# # #             # # # # # #               # # # # # #                   # # #
# # # #           # # # # #                   # # # # #                 # # # #
# # # # #         # # # #                       # # # #               # # # # #
# # # # # #       # # #                           # # #             # # # # # #
# # # # # # #     # #                                # #         # # # # # # #
# # # # # # # #   #                                    #       # # # # # # # #
      (a)                  (b)                    (c)                   (d)
```

Hints

1. On the main diagonal, `row = col`. On the opposite diagonal, `row + col = size + 1`, where `row` and `col` begin from 1.
2. You need to print the *leading* blanks, in order to push the # to the right. The *trailing* blanks are optional, which does not affect the pattern.
3. For pattern (a), if `(row >= col)` print #. Trailing blanks are optional.
4. For pattern (b), if `(row + col <= size + 1)` print #. Trailing blanks are optional.
5. For pattern (c), if `(row >= col)` print #; else print blank. Need to print the *leading* blanks.
6. For pattern (d), if `(row + col >= size + 1)` print #; else print blank. Need to print the *leading* blanks.
7. The *coding pattern* is:

```
// Outer loop to print each of the rows
    for (int row = 1; row <= size; row++) {   // row = 1, 2, 3, ..., size
        // Inner loop to print each of the columns of a particular row
        for (int col = 1; col <= size; col++) {   // col = 1, 2, 3, ..., size
            if (......) {
                System.out.print("# ");
            } else {
                System.out.print("  ");  // Need to print the "leading" blanks
            }
        }
        // Print a newline after printing all the columns
        System.out.println();
    }
```

5.5 BoxPattern (nested-loop)

Write 4 programs called **BoxPatternX** (X = A, B, C, D) that prompts user for the size (a non-negative integer in `int`); and prints the pattern as shown:

```
Enter the size: 8
```

```
# # # # # # #     # # # # # # #     # # # # # # #     # # # # # # #     # # # # # # #
#           #     #                             #     #           #     # #       # #
#           #       #                         #       #   #   #         #   #   #   #
#           #         #                     #             #             #     #     #
#           #           #                 #           #   #   #         #   #   #   #
#           #             #             #             #           #     # #       # #
# # # # # # #     # # # # # # #     # # # # # # #     # # # # # # #     # # # # # # #
    (a)               (b)               (c)               (d)               (e)
```

Hints

1. On the main diagonal, row = col. On the opposite diagonal, row + col = size + 1, where row and col begin from 1.
2. For pattern (a), if (row == 1 || row == size || col == 1 || col == size) print #; else print blank. Need to print the intermediate blanks.
3. For pattern (b), if (row == 1 || row == size || row == col) print #; else print blank.

5.6 HillPattern (nested-loop)

Write 3 programs called **HillPatternX** (X = A, B, C, D) that prompts user for the size (a non-negative integer in int); and prints the pattern as shown:

```
Enter the rows: 6

        #               # # # # # # # # # # #                   #               # # # # # # # # # # #
      # # #               # # # # # # # # #                    # # #              # # # # #     # # # # #
    # # # # #               # # # # # # #                     # # # # #            # # # #       # # # #
  # # # # # # #               # # # # #                      # # # # # # #          # # #         # # #
 # # # # # # # #                # # #                       # # # # # # # # #        # #           # #
# # # # # # # # # #               #                        # # # # # # # # # # #      #             #
      (a)                        (b)                        # # # # # # # # #        # #           # #
                                                             # # # # # # #           # # #         # # #
                                                              # # # # #              # # # #       # # # #
                                                               # # #                # # # # #     # # # # #
                                                                #                  # # # # # # # # # # #
                                                               (c)                        (d)
```

Hints

For pattern (a):

```
for (int row = 1; ......) {
       // numCol = 2*numRows - 1
       for (int col = 1; ......) {
          if ((row + col >= numRows + 1) && (row >= col - numRows + 1)) {
             ......;
          } else {
             ......;
          }
       }
       ......;
}
```

or, use 2 sequential inner loops to print the columns:

```
    for (int row = 1; row <= rows; row++) {
       for (int col = 1; col <= rows; col++) {
          if ((row + col >= rows + 1)) {
             ......
```

```
            } else {
                ......
            }
        }
        for (int col = 2; col <= rows; col++) {  // skip col = 1
            if (row >= col) {
                ......
            } else {
                ......
            }
        }
        ......
    }
```

5.7 NumberPattern (nested-loop)

Write 4 programs called **NumberPatternX** (X = A, B, C, D) that prompts user for the size (a non-negative integer in int); and prints the pattern as shown:

```
Enter the size: 8

1                    1 2 3 4 5 6 7 8                      1    8 7 6 5 4 3 2 1
1 2                    1 2 3 4 5 6 7                    2 1    7 6 5 4 3 2 1
1 2 3                    1 2 3 4 5 6                  3 2 1    6 5 4 3 2 1
1 2 3 4                    1 2 3 4 5                4 3 2 1    5 4 3 2 1
1 2 3 4 5                    1 2 3 4              5 4 3 2 1    4 3 2 1
1 2 3 4 5 6                    1 2 3            6 5 4 3 2 1    3 2 1
1 2 3 4 5 6 7                    1 2          7 6 5 4 3 2 1    2 1
1 2 3 4 5 6 7 8                    1        8 7 6 5 4 3 2 1    1
    (a)                  (b)                   (c)                (d)
```

6. Magic(Special) Numbers

6.1. Amicable umbers

Two different numbers are said to be so Amicable numbers if each sum of divisors is equal to the other number. Amicalble Numbers are: (220, 284), (1184, 1210), (2620, 2924), (5020, 5564), (6232, 6368). For example,

Enter 1st number: 228
Enter 2nd number: 220
The numbers are Amicable Numbers.

Hints

220 and 284 are Amicable Numbers.

Divisors of 220 = 1, 2, 4, 5, 10, 11, 20, 22, 44, 55, 110

1+2+4+5+10+11+20+22+44+55+110 = 284

Divisors of 284 = 1, 2, 4, 71, 142

1+2+4+71+142 = 220

6.2. Armstrong Number

Armstrong number is a positive number if it is equal to the sum of cubes of its digits is called Armstrong number and if its sum is not equal to the number then it's not a Armstrong number. For example,

```
Enter number=145
145 is not an Armstrong Number

Enter number = 153
153 is an Armstrong Number
```

Hints

```
Examples: 153 is Armstrong

(1*1*1)+(5*5*5)+(3*3*3) = 153
```

6.3. Capricorn Number

A number is called Capricorn or Kaprekar number whose square is divided into two parts in any conditions and parts are added, the additions of parts is equal to the number, is called Capricorn or Kaprekar number. For example,

```
Enter a number : 45
45 is a Capricorn/Kaprekar number
Enter a number : 297
297 is a Capricorn/Kaprekar number
Enter a number : 44
44 is not a Capricorn/Kaprekar number
```

Hints

```
Number = 45
(45)2  = 2025

All parts for 2025:
202   + 5   =    207 (not 45)
20    + 25  =    45
2+ 025   =    27 (not 45)
```

From the above we can see one combination is equal to number so that 45 is Capricorn or Kaprekar number.

Try

Write a Java program to generate and show all Kaprekar numbers less than 1000.

6.4. Circular Prime

A circular prime is a prime number with the property that the number generated at each intermediate step when cyclically permuting its digits will be prime. For example, 1193 is a circular prime, since 1931,

9311 and 3119 all are also prime. For example,

6.5. Happy Number

A happy number is a natural number in a given number base that eventually reaches 1 when iterated over the perfect digital invariant function for. Those numbers that do not end in 1 are -unhappy numbers. For example,

Enter a number : 31
31 is a Happy number

Enter a number : 32
32 is not a Happy number

6.6. Automorphic Number

An Automorphic number is a number whose square "ends" in the same digits as the number itself. For example,

Enter a number : 5
5 is a Automorphic Number

Enter a number : 25
25 is a Automorphic Number

Enter a number : 2
2 is not a Automorphic Number

Hints

5*5 = 25, 6*6 = 36, 25*25 = 625

5,6,25 are automorphic numbers

6.7. Disarium Number

A number is called Disarium number if the sum of its power of the positions from left to right is equal to the number. For example,

Enter a number : 135
135 is a Disarium Number

Enter a number : 32
32 is not a Disarium Number

Hints

$1^1 + 3^2 + 5^3 = 1 + 9 + 125 = 135$

6.8. Magic Number

Magic number is the if the sum of its digits recursively are calculated till a single digit If the single digit is 1 then the number is a magic number. Magic number is very similar with Happy Number. For example,

Enter a number : 226
226 is a Magic Number

Enter a number : 32
32 is not a Magic Number
Enter number = 541
153 is a Magic Number

Hints

226 is said to be a magic number

2+2+6=10 sum of digits is 10 then again 1+0=1 now we get a single digit number is 1.if we single digit number will now 1 them it would not a magic number.

6.9. Neon Number

A neon number is a number where the sum of digits of square of the number is equal to the number. For example if the input number is 9, its square is 9*9 = 81 and sum of the digits is 9. i.e. 9 is a neon number. For example,

Enter a number: 9
9 is a Neon Number

Enter a number: 8
8 is not a Neon Number

6.10. Palindromic Number

A palindromic number is a number that remains the same when its digits are reversed. For example,

Enter a number : 16461
16461 is a Palendromic Number

Enter a number : 1234
1234 is not a Plaindromic Number

6.11. Perfect Number

A perfect number is a positive integer that is equal to the sum of its positive divisors, excluding the number itself. For instance, 6 has divisors 1, 2 and 3, and 1 + 2 + 3 = 6, so 6 is a perfect number. For example,

Enter a number : 6
6 is a Perfect Number

Enter a number : 3
3 is not a Perfect Number

6.12. Special Number

A number is said to be special number when the sum of factorial of its digits is equal to the number itself. Example- 145 is a Special Number as 1!+4!+5!=145. For example,

Enter a number : 145
145 is a Special Number

Enter a number : 23
23 is not a Special Number

6.13. Spy Number

A spy number is a number where the sum of its digits equals the product of its digits. For example, 1124 is a spy number, the sum of its digits is 1+1+2+4=8 and the product of its digits is 1*1*2*4=8. For example,

Enter a number : 1124
1124 is a Spy Number

Enter a number : 12
12 is not a Spy Number

6.14. Ugly Number

A number is said to be an Ugly number if positive numbers whose prime factors only include 2, 3, 5. For example, 6(2×3), 8(2x2x2), 15(3×5) are ugly numbers while 14(2×7) is not ugly since it includes another prime factor 7. Note that 1 is typically treated as an ugly number. For example,

Enter a number : 6
6 is an Ugly Number

Enter a number : 14
14 is not an Ugly Number

7. Exercises on `String` and `char` Operations

7.1 ReverseString (String & char)

Write a program called **ReverseString**, which prompts user for a `String`, and prints the *reverse* of the `String` by extracting and processing each character. The output shall look like:

```
Enter a String: abcdef
The reverse of the String "abcdef" is "fedcba".
```

Hints

For a `String` called `inStr`, you can use `inStr.length()` to get the *length* of the `String`; and `inStr.charAt(idx)` to retrieve the `char` at the `idx` position, where `idx` begins at 0, up to `instr.length() - 1`.

```
    // Define variables
    String inStr;          // input String
    int inStrLen;          // length of the input String
    ......
```

```
    // Prompt and read input as "String"
    System.out.print("Enter a String: ");
    inStr = in.next();    // use next() to read a String
    inStrLen = inStr.length();

    // Use inStr.charAt(index) in a loop to extract each character
    // The String's index begins at 0 from the left.
    // Process the String from the right
    for (int charIdx = inStrLen - 1; charIdx >= 0; --charIdx) {
        // charIdx = inStrLen-1, inStrLen-2, ... ,0
      ......
    }
```

7.2 CountVowelsDigits (String & char)

Write a program called **CountVowelsDigits**, which prompts the user for a String, counts the number of vowels (a, e, i, o, u, A, E, I, O, U) and digits (0-9) contained in the string, and prints the counts and the percentages (rounded to 2 decimal places). For example,

```
Enter a String: testing12345
Number of vowels: 2 (16.67%)
Number of digits: 5 (41.67%)
```

Hints
1. To check if a char c is a digit, you can use boolean expression (c >= '0' && c <= '9'); or use built-in boolean function Character.isDigit(c).
2. You could use in.next().toLowerCase() to convert the input String to lowercase to reduce the number of cases.
3. To print a % using printf(), you need to use %%. This is because % is a prefix for format specifier in printf(), e.g., %d and %f.

7.3 PhoneKeyPad (String & char)

On you phone keypad, the alphabets are mapped to digits as follows:

ABC(2), DEF(3), GHI(4), JKL(5), MNO(6), PQRS(7), TUV(8), WXYZ(9).

Write a program called **PhoneKeyPad**, which prompts user for a String (case insensitive), and converts to a sequence of keypad digits. Use (a) a nested-if, (b) a switch-case-default.

Hints
1. You can use in.next().toLowerCase() to read a String and convert it to lowercase to reduce your cases.
2. In switch-case, you can handle multiple cases by omitting the break statement, e.g.,

```
switch (inChar) {
   case 'a': case 'b': case 'c':  // No break for 'a' and 'b', fall thru 'c'
      System.out.print(2); break;
   case 'd': case 'e': case 'f':
      ......
   default:
      ......
}
```

7.4 Caesar's Code *(String & char)*

Caesar's Code is one of the simplest encryption techniques. Each letter in the plaintext is replaced by a letter some fixed number of position (n) down the alphabet cyclically. In this exercise, we shall pick n=3. That is, 'A' is replaced by 'D', 'B' by 'E', 'C' by 'F', ..., 'X' by 'A', ..., 'Z' by 'C'.

Write a program called **CaesarCode** to cipher the Caesar's code. The program shall prompt user for a plaintext string consisting of mix-case letters only; compute the ciphertext; and print the ciphertext in uppercase. For example,

```
Enter a plaintext string: Testing
The ciphertext string is: WHVWLQJ
```

Hints

1. Use `in.next().toUpperCase()` to read an input string and convert it into uppercase to reduce the number of cases.
2. You can use a big nested-if with 26 cases ('A'-'Z'). But it is much better to consider 'A' to 'W' as one case; 'X', 'Y' and 'Z' as 3 separate cases.
3. Take note that char 'A' is represented as Unicode number 65 and char 'D' as 68. However, 'A' + 3 gives 68. This is because `char + int` is implicitly casted to `int + int` which returns an `int` value. To obtain a `char` value, you need to perform explicit type casting using `(char)('A' + 3)`. Try printing `('A' + 3)` with and without type casting.

7.5 Decipher Caesar's Code *(String & char)*

Write a program called **DecipherCaesarCode** to decipher the Caesar's code described in the previous exercise. The program shall prompts user for a ciphertext string consisting of mix-case letters only; compute the plaintext; and print the plaintext in uppercase. For example,

```
Enter a ciphertext string: wHVwLQJ
The plaintext string is: TESTING
```

7.6 Exchange Cipher *(String & char)*

This simple cipher exchanges 'A' and 'Z', 'B' and 'Y', 'C' and 'X', and so on.
Write a program called **ExchangeCipher** that prompts user for a plaintext string consisting of mix-case letters only. You program shall compute the ciphertext; and print the ciphertext in uppercase. For examples,

```
Enter a plaintext string: abcXYZ
The ciphertext string is: ZYXCBA
```

Hints

1. Use `in.next().toUpperCase()` to read an input string and convert it into uppercase to reduce the number of cases.
2. You can use a big nested-if with 26 cases ('A'-'Z'), or use the following relationship:

```
'A' + 'Z' == 'B' + 'Y' == 'C' + 'X' == ... == plainTextChar + cipherTextChar

Hence, cipherTextChar = 'A' + 'Z' - plainTextChar
```

7.7 TestPalindromicWord and TestPalindromicPhrase (String & char)

A word that reads the same backward as forward is called a *palindrome*, e.g., "mom", "dad", "racecar", "madam", and "Radar" (case-insensitive).

Write a program called **TestPalindromicWord**, that prompts user for a word and prints ""xxx" is|is not a palindrome".

A phrase that reads the same backward as forward is also called a palindrome, e.g., "Madam, I'm Adam", "A man, a plan, a canal - Panama!" (ignoring punctuation and capitalization).

Modify your program (called **TestPalindromicPhrase**) to check for palindromic phrase. Use in.nextLine() to read a line of input.

Hints

1. Maintain two indexes, forwardIndex (fIdx) and backwardIndex (bIdx), to scan the phrase forward and backward.

```
int fIdx = 0, bIdx = strLen - 1;
while (fIdx < bIdx) {
   ......
   ++fIdx;
   --bIdx;
}
// or
for (int fIdx = 0, bIdx = strLen - 1; fIdx < bIdx; ++fIdx, --bIdx) {
   ......
}
```

2. You can check if a char c is a letter either using built-in boolean function Character.isLetter(c); or boolean expression (c >= 'a' && c <= 'z'). Skip the index if it does not contain a letter.

7.8 CheckBinStr (String & char)

The binary number system uses 2 symbols, 0 and 1. Write a program called **CheckBinStr** to verify a binary string. The program shall prompt user for a binary string; and decide if the input string is a valid binary string. For example,

```
Enter a binary string: 10101100
"10101100" is a binary string

Enter a binary string: 10120000
"10120000" is NOT a binary string
```

Hints

Use the following coding pattern which involves a boolean flag to check the input string.

```
// Declare variables
    String inStr;     // The input string
    int inStrLen;     // The length of the input string
    char inChar;      // Each char of the input string
    boolean isValid;  // "is" or "is not" a valid binary string?
    ......

    isValid = true;   // Assume that the input is valid, unless our check fails
    for (......) {
       inChar = ......;
       if (!(inChar == '0' || inChar == '1')) {
          isValid = false;
```

```
            break;   // break the loop upon first error, no need to continue for
more errors
                     // If this is not encountered, isValid remains true after the
loop.
        }
    }
    if (isValid) {
        System.out.println(......);
    } else {
        System.out.println(......);
    }
    // or using one liner
    //System.out.println(isValid ? ... : ...);
```

7.9 CheckHexStr (String & char)

The hexadecimal (hex) number system uses 16 symbols, 0-9 and A-F (or a-f). Write a program to verify a hex string. The program shall prompt user for a hex string; and decide if the input string is a valid hex string. For examples,

```
Enter a hex string: 123aBc
"123aBc" is a hex string

Enter a hex string: 123aBcx
"123aBcx" is NOT a hex string
```

Hints

```
if (!((inChar >= '0' && inChar <= '9')
      || (inChar >= 'A' && inChar <= 'F')
      || (inChar >= 'a' && inChar <= 'f'))) {   // Use positive logic and then
reverse
   ......
}
```

7.10 Bin2Dec (String & char)

Write a program called **Bin2Dec** to convert an input binary string into its equivalent decimal number. Your output shall look like:

```
Enter a Binary string: 1011
The equivalent decimal number for binary "1011" is: 11

Enter a Binary string: 1234
error: invalid binary string "1234"
```

Hints

See "Code Example".

7.11 Hex2Dec (String & char)

Write a program called **Hex2Dec** to convert an input hexadecimal string into its equivalent decimal number. Your output shall look like:

```
Enter a Hexadecimal string: 1a
The equivalent decimal number for hexadecimal "1a" is: 26

Enter a Hexadecimal string: 1y3
```

```
error: invalid hexadecimal string "1y3"
```

Hints

See "Code Example".

7.12 Oct2Dec (String & char)

Write a program called **Oct2Dec** to convert an input Octal string into its equivalent decimal number. For example,

```
Enter an Octal string: 147
The equivalent decimal number "147" is: 103
```


8. Exercises on Arrays

8.1 PrintArray (Array)

Write a program called PrintArray which prompts user for the number of items in an array (a non-negative integer), and saves it in an int variable called NUM_ITEMS. It then prompts user for the values of all the items and saves them in an int array called items. The program shall then print the contents of the array in the form of [x1, x2, ..., xn]. For example,

```
Enter the number of items: 5
Enter the value of all items (separated by space): 3 2 5 6 9
The values are: [3, 2, 5, 6, 9]
```

Hints

```
    // Declare variables
    tinal int NUM_ITEMS;
    int[] items;    // Declare array name, to be allocated after  NUM_ITEMS  is
known
    ......

    // Prompt for for the number of items and read the input as "int"
    ......
    NUM_ITEMS = ......

    // Allocate the array
    items = new int[NUM_ITEMS];

    // Prompt and read the items into the "int" array, if array length > 0
    if (items.length > 0) {
       ......
       for (int i = 0; i < items.length; ++i) {   // Read all items
          ......
       }
    }

    // Print array contents, need to handle first item and subsequent items
differently
    ......
    for (int i = 0; i < items.length; ++i) {
       if (i == 0) {
          // Print the first item without a leading commas
          ......
       } else {
```

```
            // Print the subsequent items with a leading commas
            ......
         }
         // or, using a one liner
         //System.out.print((i == 0) ? ...... : ......);
      }
```

8.2 PrintArrayInStars (Array)

Write a program called **printArrayInStars** which prompts user for the number of items in an array (a non-negative integer), and saves it in an `int` variable called `NUM_ITEMS`. It then prompts user for the values of all the items (non-negative integers) and saves them in an `int` array called `items`. The program shall then print the contents of the array in a graphical form, with the array index and values represented by number of stars. For examples,

```
Enter the number of items: 5
Enter the value of all items (separated by space): 7 4 3 0 7
0: *******(7)
1: ****(4)
2: ***(3)
3: (0)
4: *******(7)
```

Hints

```
      // Declare variables
      final int NUM_ITEMS;
      int[] items;    // Declare array name, to be allocated after NUM_ITEMS is
known
      ......
      ......
      // Print array in "index: number of stars" using a nested-loop
      // Take note that rows are the array indexes and columns are the value in
that index
      for (int idx = 0; idx < items.length; ++idx) {   // row
         System.out.print(idx + ": ");
         // Print value as the number of stars
         for (int starNo = 1; starNo <= items[idx]; ++starNo) {   // column
            System.out.print("*");
         }
         ......
      }
      ......
```

8.3 GradesStatistics (Array)

Write a program which prompts user for the number of students in a class (a non-negative integer), and saves it in an `int` variable called `numStudents`. It then prompts user for the grade of each of the students (integer between 0 to 100) and saves them in an `int` array called `grades`. The program shall then compute and print the average (in `double` rounded to 2 decimal places) and minimum/maximum (in `int`).

```
Enter the number of students: 5
Enter the grade for student 1: 98
Enter the grade for student 2: 78
Enter the grade for student 3: 78
Enter the grade for student 4: 87
Enter the grade for student 5: 76
The average is: 83.40
The minimum is: 76
```

```
The maximum is: 98
```

8.4 Hex2Bin (Array for Table Lookup)

Write a program called **Hex2Bin** that prompts user for a hexadecimal string and print its equivalent binary string. The output shall look like:

```
Enter a Hexadecimal string: 1abc
The equivalent binary for hexadecimal "1abc" is: 0001 1010 1011 1100
```

Hints

1. Use an array of 16 `Strings` containing binary strings corresponding to hexadecimal number 0-9A-F (or a-f), as follows

```
final String[] HEX_BITS = {"0000", "0001", "0010", "0011",
                   "0100", "0101", "0110", "0111",
                   "1000", "1001", "1010", "1011",
                   "1100", "1101", "1110", "1111"};
```

8.5 Dec2Hex (Array for Table Lookup)

Write a program called **Dec2Hex** that prompts user for a positive decimal number, read as `int`, and print its equivalent hexadecimal string. The output shall look like:

```
Enter a decimal number: 1234
The equivalent hexadecimal number is 4D2
```

9. Exercises on Methods

9.1 exponent() (method)

Write a method called exponent(int base, int exp) that returns an `int` value of `base` raises to the power of `exp`. The signature of the method is:

```
  public static int exponent(int base, int exp);
```

Assume that `exp` is a non-negative integer and `base` is an integer. Do not use any Math library functions.
Also write the `main()` method that prompts user for the `base` and `exp`; and prints the result. For example,

```
Enter the base: 3
Enter the exponent: 4
3 raises to the power of 4 is: 81
```

Hints

```
......
public class Exponent {
   public static void main(String[] args) {
      // Declare variables
      int exp;    // exponent (non-negative integer)
      int base;   // base (integer)
      ......
      // Prompt and read exponent and base
      ......
      // Print result
```

```
      System.out.println(base + " raises to the power of " + exp + " is: "
+ exponent(base, exp));
   }

   // Returns "base" raised to the power "exp"
   public static int exponent(int base, int exp) {
      int product = 1;    // resulting product

      // Multiply product and base for exp number of times
      for (......) {
         product *= base;
      }

      return product;
   }
}
```

9.2 isOdd() (method)

Write a boolean method called isOdd() in a class called **OddEvenTest**, which takes an int as input and returns true if the it is odd. The signature of the method is as follows:

```
public static boolean isOdd(int number);
```

Also write the main() method that prompts user for a number, and prints "ODD" or "EVEN". You should test for negative input. For examples,

```
Enter a number: 9
9 is an odd number

Enter a number: 8
8 is an even number

Enter a number: -5
-5 is an odd number
```

Hints

See Notes.

9.3 hasEight() (method)

Write a boolean method called hasEight(), which takes an int as input and returns true if the number contains the digit 8 (e.g., 18, 168, 1288). The signature of the method is as follows:

```
public static boolean hasEight(int number);
```

Write a program called **MagicSum**, which prompts user for integers (or -1 to end), and produce the sum of numbers containing the digit 8. Your program should use the above methods. A sample output of the program is as follows:

```
Enter a positive integer (or -1 to end): 1
Enter a positive integer (or -1 to end): 2
Enter a positive integer (or -1 to end): 3
Enter a positive integer (or -1 to end): 8
Enter a positive integer (or -1 to end): 88
Enter a positive integer (or -1 to end): -1
The magic sum is: 96
```

Hints

The *coding pattern* to repeat until input is `-1` (called *sentinel* value) is:

```java
final int SENTINEL = -1;  // Terminating input
int number;

// Read first input to "seed" the while loop
System.out.print("Enter a positive integer (or -1 to end): ");
number = in.nextInt();

while (number != SENTINEL) {  // Repeat until input is -1
   ......
   ......

   // Read next input. Repeat if the input is not the SENTINEL
   // Take note that you need to repeat these codes!
   System.out.print("Enter a positive integer (or -1 to end): ");
   number = in.nextInt();
}
```

You can either repeatably use modulus/divide (`n%10` and `n=n/10`) to extract and drop each digit in `int`; or convert the `int` to `String` and use the `String`'s `charAt()` to inspect each `char`.

9.4 print() (Array & Method)

Write a method called **print()**, which takes an `int` array and print its contents in the form of `[a1, a2, ..., an]`. Take note that there is no comma after the last element. The method's signature is as follows:

```java
public static void print(int[] array);
```

Also write a test driver to test this method (you should test on empty array, one-element array, and n-element array).

How to handle `double[]` or `float[]`? You need to write a overloaded version for `double[]` and a overloaded version for `float[]`, with the following signatures:

```java
public static void print(double[] array)
public static void print(float[] array)
```

The above is known as *method overloading*, where the same method name can have many versions, differentiated by its parameter list.

Hints

For the first element, print its value; for subsequent elements, print commas followed by the value.

9.5 arrayToString() (Array & Method)

Write a method called **arrayToString()**, which takes an `int` array and return a `String` in the form of `[a1, a2, ..., an]`. Take note that this method returns a `String`, the previous exercise returns `void` but prints the output. The method's signature is as follows:

```java
public static String arrayToString(int[] array);
```

Also write a test driver to test this method (you should test on empty array, one-element array, and n-element array).

Notes: This is similar to the built-in function `Arrays.toString()`. You could study its source code.

9.6 contains() (Array & Method)

Write a boolean method called **contains()**, which takes an array of int and an int; and returns true if the array contains the given int. The method's signature is as follows:

```
public static boolean contains(int[] array, int key);
```

Also write a test driver to test this method.

9.7 search() (Array & Method)

Write a method called **search()**, which takes an array of int and an int; and returns the array *index* if the array contains the given int; or -1 otherwise. The method's signature is as follows:

```
public static int search(int[] array, int key);
```

Also write a test driver to test this method.

9.8 equals() (Array & Method)

Write a boolean method called **equals()**, which takes two arrays of int and returns true if the two arrays are exactly the same (i.e., same length and same contents). The method's signature is as follows:

```
public static boolean equals(int[] array1, int[] array2)
```

Also write a test driver to test this method.

9.9 copyOf() (Array & Method)

Write a boolean method called **copyOf()**, which takes an int Array and returns a copy of the given array. The method's signature is as follows:

```
public static int[] copyOf(int[] array)
```

Also write a test driver to test this method.

Write another version for **copyOf()** which takes a second parameter to specify the length of the new array. You should truncate or pad with zero so that the new array has the required length.

```
public static int[] copyOf(int[] array, int newLength)
```

NOTES: This is similar to the built-in function Arrays.copyOf().

9.10 swap() (Array & Method)

Write a method called **swap()**, which takes two arrays of int and swap their contents if they have the same length. It shall return true if the contents are successfully swapped. The method's signature is as follows:

```
public static boolean swap(int[] array1, int[] array2)
```

Also write a test driver to test this method.

Hints

You need to use a temporary location to swap two storage locations.

```
// Swap item1 and item2
int item1, item2, temp;
temp = item1;
item1 = item2;
item2 = item1;
// You CANNOT simply do: item1 = item2; item2 = item2;
```

9.11 reverse() (Array & Method)

Write a method called **reverse()**, which takes an array of `int` and reverse its contents. For example, the reverse of [1,2,3,4] is [4,3,2,1]. The method's signature is as follows:

```
public static void reverse(int[] array)
```

Take note that the array passed into the method can be modified by the method (this is called "*pass by reference*"). On the other hand, primitives passed into a method cannot be modified. This is because a clone is created and passed into the method instead of the original copy (this is called "*pass by value*").

Also write a test driver to test this method.

Hints

You might use two indexes in the loop, one moving forward and one moving backward to point to the two elements to be swapped.

```
for (int fIdx = 0, bIdx = array.length - 1; fIdx < bIdx; ++fIdx, --bIdx) {
    // Swap array[fIdx] and array[bIdx]
    // Only need to transverse half of the array elements
}
```

You need to use a temporary location to swap two storage locations.

```
// Swap item1 and item2
int item1, item2, temp;
temp = item1;
item1 = item2;
item2 = item1;
// You CANNOT simply do: item1 = item2; item2 = item2;
```

9.12 GradesStatistics (Array & Method)

Write a program called **GradesStatistics**, which reads in *n* grades (of `int` between 0 and 100, inclusive) and displays the *average*, *minimum*, *maximum*, *median* and *standard deviation*. Display the floating-point values upto 2 decimal places. Your output shall look like:

```
Enter the number of students: 4
Enter the grade for student 1: 50
Enter the grade for student 2: 51
Enter the grade for student 3: 56
Enter the grade for student 4: 53
The grades are: [50, 51, 56, 53]
The average is: 52.50
The median is: 52.00
The minimum is: 50
The maximum is: 56
The standard deviation is: 2.29
```

The formula for calculating standard deviation is:

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=0}^{n-1} x_i^2 - \mu^2}, \text{ where } \mu \text{ is the mean}$$

Hints:

```java
public class GradesStatistics {
   public static int[] grades;  // Declare an int[], to be allocated later.
                                // This array is accessible by all the methods.

   public static void main(String[] args) {
      readGrades();  // Read and save the inputs in global int[] grades
      System.out.println("The grades are: ");
      print(grades);
      System.out.println("The average is " + average(grades));
      System.out.println("The median is " + median(grades));
      System.out.println("The minimum is " + min(grades));
      System.out.println("The maximum is " + max(grades));
      System.out.println("The standard deviation is " + stdDev(grades));
   }

   // Prompt user for the number of students and allocate the global "grades"
array.
   // Then, prompt user for grade, check for valid grade, and store in "grades".
   public static void readGrades() { ....... }

   // Print the given int array in the form of [x1, x2, x3,..., xn].
   public static void print(int[] array) { ....... }

   // Return the average value of the given int[]
   public static double average(int[] array) { ...... }

   // Return the median value of the given int[]
   // Median is the center element for odd-number array,
   // or average of the two center elements for even-number array.
   // Use Arrays.sort(anArray) to sort anArray in place.
   public static double median(int[] array) { ...... }

   // Return the maximum value of the given int[]
   public static int max(int[] array) {
      int max = array[0];   // Assume that max is the first element
      // From second element, if the element is more than max, set the max to this
element.
      ......
   }

   // Return the minimum value of the given int[]
   public static int min(int[] array) { ....... }

   // Return the standard deviation of the given int[]
   public static double stdDev(int[] array) { ....... }
}
```

Take note that besides readGrade() that relies on global variable grades, all the methods are *self-contained general utilities* that operate on any given array.

9.13 GradesHistogram (Array & Method)

Write a program called **GradesHistogram**, which reads in *n* grades (as in the previous exercise), and displays the horizontal and vertical histograms. For example:

```
  0 -  9: ***
 10 - 19: ***
 20 - 29:
 30 - 39:
 40 - 49: *
 50 - 59: *****
 60 - 69:
 70 - 79:
 80 - 89: *
 90 -100: **


                                *
                                *
    *       *                   *
    *       *                   *                   *
    *       *           *        *                   *       *
  0-9   10-19 20-29 30-39 40-49 50-59 60-69 70-79 80-89 90-100
```

10. Exercises on Command-line Arguments, Recursion

10.1 Arithmetic (Command-Line Arguments)

Write a program called **Arithmetic** that takes three command-line arguments: two integers followed by an arithmetic operator (+, -, * or /). The program shall perform the corresponding operation on the two integers and print the result. For example:

```
java Arithmetic 3 2 +
3+2=5

java Arithmetic 3 2 -
3-2=1

java Arithmetic 3 2 /
3/2=1
```

Hints

The method `main(String[] args)` takes an argument: "an array of `String`", which is often (but not necessary) named `args`. This parameter captures the command-line arguments supplied by the user when the program is invoked. For example, if a user invokes:

```
java Arithmetic 12345 4567 +
```

The three command-line arguments "12345", "4567" and "+" will be captured in a `String` array {"12345", "4567", "+"} and passed into the `main()` method as the argument `args`. That is,

```
args is: {"12345", "4567", "+"}  // args is a String array
args.length is: 3                // length of the array
args[0] is: "12345"              // 1st element of the String array
args[1] is: "4567"               // 2nd element of the String array
args[2] is: "+"                  // 3rd element of the String array
args[0].length() is: 5           // length of 1st String element
args[1].length() is: 4           // length of the 2nd String element
```

```
args[2].length() is: 1          // length of the 3rd String element
public class Arithmetic {
  public static void main (String[] args) {
    int operand1, operand2;
    char theOperator;

    // Check if there are 3 command-line arguments in the
    //  String[] args by using length variable of array.
    if (args.length != 3) {
      System.err.println("Usage: java Arithmetic int1 int2 op");
      return;
    }

    // Convert the 3 Strings args[0], args[1], args[2] to int and char.
    // Use the Integer.parseInt(aStr) to convert a String to an int.
    operand1 = Integer.parseInt(args[0]);
    operand2 = ......

    // Get the operator, assumed to be the first character of
    //  the 3rd string. Use method charAt() of String.
    theOperator = args[2].charAt(0);
    System.out.print(args[0] + args[2] + args[1] + "=");

    switch(theOperator) {
      case ('-'): System.out.println(operand1 - operand2); break;
      case ('+'): ......
      case ('*'): ......
      case ('/'): ......
      default:
        System.err.println("Error: invalid operator!");
    }
  }
}
```

Notes:

- To provide command-line arguments, use the "cmd" or "terminal" to run your program in the form "java *ClassName arg1 arg2 ....*".

- To provide command-line arguments in Eclipse, right click the source code ⇒ "Run As" ⇒ "Run Configurations..." ⇒ Select "Main" and choose the proper main class ⇒ Select "Arguments" ⇒ Enter the command-line arguments, e.g., "3 2 +" in "Program Arguments".

- To provide command-line arguments in NetBeans, right click the "Project" name ⇒ "Set Configuration" ⇒ "Customize..." ⇒ Select categories "Run" ⇒ Enter the command-line arguments, e.g., "3 2 +" in the "Arguments" box (but make sure you select the proper Main class).

Question: Try "java Arithmetic 2 4 *" (in CMD shell and Eclipse/NetBeans) and explain the result obtained. How to resolve this problem?

In Windows' CMD shell, * is known as a wildcard character, that expands to give the list of file in the directory (called Shell Expansion). For example, "dir *.java" lists all the file with extension of ".java". You could double-quote the * to prevent shell expansion. Eclipse has a bug in handling this, even * is double-quoted. NetBeans??

SumDigits (Command-line Arguments)
Write a program called **SumDigits** to sum up the individual digits of a positive integer, given in the command line. The output shall look like:

java SumDigits 12345

```
The sum of digits = 1 + 2 + 3 + 4 + 5 = 15
```

Exercises on Recursion

In programming, a recursive function (or method) calls itself. The classical example is `factorial(n)`, which can be defined recursively as `f(n)=n*f(n-1)`. Nonetheless, it is important to take note that a recursive function should have a terminating condition (or base case), in the case of factorial, `f(0)=1`. Hence, the full definition is:

```
factorial(n) = 1, for n = 0
factorial(n) = n * factorial(n-1), for all n > 1
```

For example, suppose n = 5:

```
// Recursive call
factorial(5) = 5 * factorial(4)
factorial(4) = 4 * factorial(3)
factorial(3) = 3 * factorial(2)
factorial(2) = 2 * factorial(1)
factorial(1) = 1 * factorial(0)
factorial(0) = 1   // Base case
// Unwinding
factorial(1) = 1 * 1 = 1
factorial(2) = 2 * 1 = 2
factorial(3) = 3 * 2 = 6
factorial(4) = 4 * 6 = 24
factorial(5) = 5 * 24 = 120 (DONE)
```

10.2 Factorial Recursive

Write a *recursive* method called `factorial()` to compute the factorial of the given integer.

```
public static int factorial(int n)
```

The recursive algorithm is:

```
factorial(n) = 1, if n = 0
factorial(n) = n * factorial(n-1), if n > 0
```

Compare your code with the *iterative* version of the `factorial()`:

```
factorial(n) = 1*2*3*...*n
```

Hints

Writing recursive function is straight forward. You simply translate the recursive definition into code with `return`.

```
// Return the factorial of the given integer, recursively
public static int factorial(int n) {
   if (n == 0) {
      return 1;    // base case
   } else {
      return n * factorial(n-1);   // call itself
   }
   // or one liner
   // return (n == 0) ? 1 : n*factorial(n-1);
}
```

Notes

1. Recursive version is often much shorter.

2. The recursive version uses much more computational and storage resources, and it need to save its current states before each successive recursive call, so as to unwind later.

10.3 Fibonacci (Recursive)

Write a *recursive* method to compute the Fibonacci number of n, defined as follows:

```
F(0) = 0
F(1) = 1
F(n) = F(n-1) + F(n-2)  for n >= 2
```

Compare the recursive version with the *iterative* version written earlier.

Hints

```
// Translate the recursive definition into code with return statements
public static int fibonacci(int n) {
   if (n == 0) {
      return 0;
   } else if (n == 1) {
      return 1;
   } else {
      return fibonacci(n-1) + fibonacci(n-2);
   }
}
```

10.4 Length of a Running Number Sequence (Recursive)

A special number sequence is defined as follows:

```
S(1) = 1
S(2) = 12
S(3) = 123
S(4) = 1234
......
S(9) = 123456789         // length is 9
S(10) = 12345678910      // length is 11
S(11) = 1234567891011    // length is 13
S(12) = 123456789101112  // length is 15
......
```

Write a *recursive* method to compute the length of S(n), defined as follows:

```
len(1) = 1
len(n) = len(n-1) + numOfDigits(n)
```

Also write an *iterative* version.

10.5 GCD (Recursive)

Write a recursive method called `gcd()` to compute the greatest common divisor of two given integers.

```
public static void int gcd(int a, int b)
```

```
gcd(a,b) = a, if b = 0
gcd(a,b) = gcd(b, remainder(a,b)), if b > 0
```

11. More (Difficult) Exercises

11.1 JDK Source Code

Extract the source code of the class `Math` from the JDK source code (JDK Installed Directory ⇒ "lib" ⇒ "src.zip" ⇒ "java.base" ⇒ "java" ⇒ "lang" ⇒ "Math.java"). Study how constants such as `E` and `PI` are defined. Also study how methods such as `abs()`, `max()`, `min()`, `toDegree()`, etc, are written.

Also study the "Integer.java", "String.java".

11.2 Matrices (2D Arrays)

Similar to `Math` class, write a `Matrix` library that supports matrix operations (such as addition, subtraction, multiplication) via 2D arrays. The operations shall support both `double` and `int`. Also write a test class to exercise all the operations programmed.

Hints

```java
public class Matrix {
   // Method signatures
   public static void print(int[][] m);
   public static void print(double[][] m);
   public static boolean haveSameDimension(int[][] m1, int[][] m2);   // Used in
add(), subtract()
   public static boolean haveSameDimension(double[][] m1, double[][] m2);
   public static int[][] add(int[][] m1, int[][] m2);
   public static double[][] add(double[][] m1, double[][] m2);
   public static int[][] subtract(int[][] m1, int[][] m2);
   public static double[][] subtract(double[][] m1, double[][] m2);
   public static int[][] multiply(int[][] m1, int[][] m2);
   public static double[][] multiply(double[][] m1, double[][] m2);
   ......
}
```

11.3 PrintAnimalPattern (Special Characters and Escape Sequences)

Write a program called **PrintAnimalPattern**, which uses `println()` to produce this pattern:

```
         '__'
         (◎◎)
  /=======\/
 / || %% ||
*  ||----||
    ¥¥     ¥¥
    ""     ""
```

Hints

Use escape sequence \uhhhh where hhhh are four hex digits to display Unicode characters such as ¥ and ©. ¥ is 165 (00A5H) and © is 169 (00A9H) in both ISO-8859-1 (Latin-1) and Unicode character sets.

Double-quote (") and black-slash (\) require escape sequence inside a String. Single quote (') does not require escape sign.

Try

Print the same pattern using `printf()`. (Hints: Need to use %% to print a % in `printf()` because % is the suffix for format specifier.)

11.4 Print Patterns (nested-loop)

Write a method to print each of the followings patterns using nested loops in a class called **PrintPatterns**. The program shall prompt user for the sizde of the pattern. The signatures of the methods are:

```
public static void printPatternX(int size);  // X: A, B, C,...; size is a positive
integer.
```

```
# # # # # # # # # #              #                        #
  # # # # # # # # #            # # #                    # # #
    # # # # # # #            # # # # #                # # # # #
      # # # # #            # # # # # # #            # # # # # # #
        # # #            # # # # # # # # #        # # # # # # # # #
          #            # # # # # # # # # # #    # # # # # # # # # # #
        (a)                    (b)              # # # # # # # # #
                                                  # # # # # # #
                                                    # # # # #
                                                      # # #
                                                        #
                                                       (c)
```

```
1                     1 2 3 4 5 6 7 8            1        8 7 6 5 4 3 2 1
1 2                     1 2 3 4 5 6 7          2 1        7 6 5 4 3 2 1
1 2 3                     1 2 3 4 5 6        3 2 1        6 5 4 3 2 1
1 2 3 4                     1 2 3 4 5      4 3 2 1        5 4 3 2 1
1 2 3 4 5                     1 2 3 4    5 4 3 2 1        4 3 2 1
1 2 3 4 5 6                     1 2 3  6 5 4 3 2 1        3 2 1
1 2 3 4 5 6 7                     1 2 7 6 5 4 3 2 1       2 1
1 2 3 4 5 6 7 8                     1 8 7 6 5 4 3 2 1     1
    (d)                    (e)              (f)             (g)
```

```
          1                        1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
        1 2 1                      1 2 3 4 5 6 7 6 5 4 3 2 1
      1 2 3 2 1                      1 2 3 4 5 6 5 4 3 2 1
    1 2 3 4 3 2 1                    1 2 3 4 5 4 3 2 1
  1 2 3 4 5 4 3 2 1                    1 2 3 4 3 2 1
  1 2 3 4 5 6 5 4 3 2 1                  1 2 3 2 1
 1 2 3 4 5 6 7 6 5 4 3 2 1                 1 2 1
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1                1
        (h)                                (i)
```

```
1                          1     1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
1 2                        2 1    1 2 3 4 5 6 7   7 6 5 4 3 2 1
1 2 3                    3 2 1    1 2 3 4 5 6       6 5 4 3 2 1
1 2 3 4                4 3 2 1    1 2 3 4 5           5 4 3 2 1
```

```
1 2 3 4 5                5 4 3 2 1        1 2 3 4                    4 3 2 1
1 2 3 4 5 6          6 5 4 3 2 1          1 2 3                        3 2 1
1 2 3 4 5 6 7    7 6 5 4 3 2 1            1 2                            2 1
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1            1                                1
          (j)                                        (k)
```

```
          1
        2 3 2
      3 4 5 4 3
    4 5 6 7 6 5 4
  5 6 7 8 9 8 7 6 5
 6 7 8 9 0 1 0 9 8 7 6
7 8 9 0 1 2 3 2 1 0 9 8 7
8 9 0 1 2 3 4 5 4 3 2 1 0 9 8
          (l)
```

11.5 Print Triangles (nested-loop)

Write a method to print each of the following patterns using nested-loops in a class called **PrintTriangles**. The program shall prompt user for the number of rows. The signatures of the methods are:

```
public static void printXxx(int numRows);   // Xxx is the pattern's name
```

```
                            1
                        1    2    1
                    1    2    4    2    1
                1    2    4    8    4    2    1
            1    2    4    8   16    8    4    2    1
        1    2    4    8   16   32   16    8    4    2    1
    1    2    4    8   16   32   64   32   16    8    4    2    1
1    2    4    8   16   32   64  128   64   32   16    8    4    2    1
                    (a) PowerOf2Triangle
```

```
1                                            1
1  1                                      1    1
1  2  1                                 1    2    1
1  3  3  1                            1    3    3    1
1  4  6  4  1                       1    4    6    4    1
1  5 10 10  5  1                  1    5   10   10    5    1
1  6 15 20 15  6  1             1    6   15   20   15    6    1
(b) PascalTriangle1              (c) PascalTriangle2
```

11.6 Trigonometric Series

Write a method to compute $\sin(x)$ and $\cos(x)$ using the following series expansion, in a class called **TrigonometricSeries**. The signatures of the methods are:

```
public static double sin(double x, int numTerms);   // x in radians, NOT degrees
```

```
public static double cos(double x, int numTerms);
```

$$\sin(x) = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \frac{x^9}{9!} - \cdots$$

$$\cos(x) = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \frac{x^8}{8!} - \cdots$$

Compare the values computed using the series with the JDK methods `Math.sin()`, `Math.cos()` at x=0, π/6, π/4, π/3, π/2 using various numbers of terms.

Hints

Do not use `int` to compute the factorial; as factorial of 13 is outside the `int` range. Avoid generating large numerator and denominator. Use `double` to compute the terms as:

$$\frac{x^n}{n!} = \left(\frac{x}{n}\right)\left(\frac{x}{n-1}\right)\cdots\left(\frac{x}{1}\right)$$

11.7 Exponential Series

Write a method to compute e and `exp(x)` using the following series expansion, in a class called **ExponentialSeries**. The signatures of the methods are:

```
public static double exp(int numTerms);    // x in radians
public static double exp(double x, int numTerms);
```

$$e = 1 + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \cdots$$

$$e^x = 1 + \frac{x}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \cdots$$

11.8 Special Series

Write a method to compute the sum of the series in a class called `SpecialSeries`. The signature of the method is:

```
public static double specialSeries(double x, int numTerms);
```

$$x + \frac{1}{2} \times \frac{x^3}{3} + \frac{1 \times 3}{2 \times 4} \times \frac{x^5}{5} + \frac{1 \times 3 \times 5}{2 \times 4 \times 6} \times \frac{x^7}{7} + \frac{1 \times 3 \times 5 \times 7}{2 \times 4 \times 6 \times 8} \times \frac{x^9}{9} + \cdots; \quad -1 \le x \le 1$$

11.9 FactorialInt (Handling Overflow)

Write a program called **FactorialInt** to list all the factorials that can be expressed as an `int` (i.e., 32-bit signed integer in the range of [-2147483648, 2147483647]). Your output shall look like:

```
The factorial of 1 is 1
The factorial of 2 is 2
...
The factorial of 12 is 479001600
The factorial of 13 is out of range
```

Hints

The maximum and minimum values of a 32-bit `int` are kept in constants `Integer.MAX_VALUE` and `Integer.MIN_VALUE`, respectively. Try these statements:

```
System.out.println(Integer.MAX_VALUE);
System.out.println(Integer.MIN_VALUE);
```

```
System.out.println(Integer.MAX_VALUE + 1);
```

Take note that in the third statement, Java Runtime does not flag out an overflow error, but silently wraps the number around. Hence, you cannot use F(n) * (n+1) > Integer.MAX_VALUE to check for overflow. Instead, overflow occurs for F(n+1) if (Integer.MAX_VALUE / Factorial(n)) < (n+1), i.e., no more room for the next number.

Try

Modify your program called **FactorialLong** to list all the factorial that can be expressed as a long (64-bit signed integer). The maximum value for long is kept in a constant called Long.MAX_VALUE.

11.10 FibonacciInt (Handling Overflow)

Write a program called **FibonacciInt** to list all the Fibonacci numbers, which can be expressed as an int (i.e., 32-bit signed integer in the range of [-2147483648, 2147483647]). The output shall look like:

```
F(0) = 1
F(1) = 1
F(2) = 2
...
F(45) = 1836311903
F(46) is out of the range of int
```

Hints

The maximum and minimum values of a 32-bit int are kept in constants Integer.MAX_VALUE and Integer.MIN_VALUE, respectively. Try these statements:

```
System.out.println(Integer.MAX_VALUE);
System.out.println(Integer.MIN_VALUE);
System.out.println(Integer.MAX_VALUE + 1);
```

Take note that in the third statement, Java Runtime does not flag out an overflow error, but silently wraps the number around. Hence, you cannot use F(n) = F(n-1) + F(n-2) > Integer.MAX_VALUE to check for overflow. Instead, overflow occurs for F(n) if Integer.MAX_VALUE – F(n-1) < F(n-2) (i.e., no more room for the next Fibonacci number).

Try

Write a similar program called **TribonacciInt** for Tribonacci numbers.

11.11 Number System Conversion

Write a method call **toRadix()** which converts a positive integer from one radix into another. The method has the following header:

```
public static String toRadix(String in, int inRadix, int outRadix)  // The input
and output are treated as String.
```

Write a program called **NumberConversion**, which prompts the user for an input string, an input radix, and an output radix, and display the converted number. The output shall look like:

```
Enter a number and radix: A1B2
Enter the input radix: 16
Enter the output radix: 2
"A1B2" in radix 16 is "1010000110110010" in radix 2.
```

11.12 NumberGuess

Write a program called **NumberGuess** to play the number guessing game. The program shall generate a random number between 0 and 99. The player inputs his/her guess, and the program shall response with "Try higher", "Try lower" or "You got it in n trials" accordingly. For example:

```
java NumberGuess
Key in your guess:
50
Try higher
70
Try lower
65
Try lower
61
You got it in 4 trials!
```

Hints

Use `Math.random()` to produce a random number in double between 0.0 (inclusive) and 1.0 (exclusive). To produce an int between 0 and 99, use:

```
final int SECRET_NUMBER = (int)(Math.random()*100);   // truncate to int
```

11.13 WordGuess

Write a program called **WordGuess** to guess a word by trying to guess the individual characters. The word to be guessed shall be provided using the command-line argument. Your program shall look like:

```
java WordGuess testing
Key in one character or your guess word: t
Trial 1: t__t___
Key in one character or your guess word: g
Trial 2: t__t__g
Key in one character or your guess word: e
Trial 3: te_t__g
Key in one character or your guess word: testing
Congratulation!
You got in 4 trials
```

Hints

Set up a `boolean` array (of the length of the word to be guessed) to indicate the positions of the word that have been guessed correctly.

Check the length of the input `String` to determine whether the player enters a single character or a guessed word. If the player enters a single character, check it against the word to be guessed, and update the `boolean` array that keeping the result so far.

Try

Try retrieving the word to be guessed from a text file (or a dictionary) randomly.

11.14 DateUtil

Complete the following methods in a class called **DateUtil**:

- **boolean isLeapYear(int year)**: returns true if the given year is a leap year. A year is a leap year if it is divisible by 4 but not by 100, or it is divisible by 400.
- **boolean isValidDate(int year, int month, int day)**: returns true if the given year, month and day constitute a given date. Assume that year is between 1 and 9999, month is between 1 (Jan) to 12 (Dec) and day shall be between 1 and 28|29|30|31 depending on the month and whether it is a leap year.
- **int getDayOfWeek(int year, int month, int day)**: returns the day of the week, where 0 for SUN, 1 for MON, ..., 6 for SAT, for the given date. Assume that the date is valid.
- **String toString(int year, int month, int day)**: prints the given date in the format "xxxday d mmm yyyy", e.g., "Tuesday 14 Feb 2012". Assume that the given date is valid.

Hints

To find the day of the week (Reference: Wiki "Determination of the day of the week"):

1700-	1800-	1900-	2000-	2100-	2200-	2300-	2400-
4	2	0	6	4	2	0	6

1. Based on the first two digit of the year, get the number from the following "century" table.
2. Take note that the entries 4, 2, 0, 6 repeat.
3. Add to the last two digit of the year.
4. Add to "the last two digit of the year divide by 4, truncate the fractional part".
5. Add to the number obtained from the following month table:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Non-Leap Year	0	3	3	6	1	4	6	2	5	0	3	5
Leap Year	6	2					same as above					

6. Add to the day.
7. The sum modulus 7 gives the day of the week, where 0 for SUN, 1 for MON, ..., 6 for SAT.

For example: 2012, Feb, 17

```
(6 + 12 + 12/4 + 2 + 17) % 7 = 5 (Fri)
```

The skeleton of the program is as follows:

```java
/* Utilities for Date Manipulation */
public class DateUtil {

   // Month's name - for printing
   public static String[] strMonths
      = {"Jan", "Feb", "Mar", "Apr", "May", "Jun",
         "Jul", "Aug", "Sep", "Oct", "Nov", "Dec"};

   // Number of days in each month (for non-leap years)
   public static int[] daysInMonths
      = {31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31};

   // Returns true if the given year is a leap year
   public static boolean isLeapYear(int year) { ...... }
```

```java
      // Return true if the given year, month, day is a valid date
      // year: 1-9999
      // month: 1(Jan)-12(Dec)
      // day: 1-28|29|30|31. The last day depends on year and month
      public static boolean isValidDate(int year, int month, int day) { ...... }

      // Return the day of the week, 0:Sun, 1:Mon, ..., 6:Sat
      public static int getDayOfWeek(int year, int month, int day) { ...... }

      // Return String "xxxday d mmm yyyy" (e.g., Wednesday 29 Feb 2012)
      public static String printDate(int year, int month, int day) { ...... }

      // Test Driver
      public static void main(String[] args) {
         System.out.println(isLeapYear(1900));  // false
         System.out.println(isLeapYear(2000));  // true
         System.out.println(isLeapYear(2011));  // false
         System.out.println(isLeapYear(2012));  // true

         System.out.println(isValidDate(2012, 2, 29));  // true
         System.out.println(isValidDate(2011, 2, 29));  // false
         System.out.println(isValidDate(2099, 12, 31)); // true
         System.out.println(isValidDate(2099, 12, 32)); // false

         System.out.println(getDayOfWeek(1982, 4, 24));  // 6:Sat
         System.out.println(getDayOfWeek(2000, 1, 1));    // 6:Sat
         System.out.println(getDayOfWeek(2054, 6, 19));  // 5:Fri
         System.out.println(getDayOfWeek(2012, 2, 17));  // 5:Fri

         System.out.println(toString(2012, 2, 14)); // Tuesday 14 Feb 2012
      }
}
```

Notes

You can compare the day obtained with the Java's `Calendar` class as follows:

```java
// Construct a Calendar instance with the given year, month and day
Calendar cal = new GregorianCalendar(year, month - 1, day);  // month is 0-based
// Get the day of the week number: 1 (Sunday) to 7 (Saturday)
int dayNumber = cal.get(Calendar.DAY_OF_WEEK);
String[] calendarDays = { "Sunday", "Monday", "Tuesday", "Wednesday",
                          "Thursday", "Friday", "Saturday" };
// Print result
System.out.println("It is " + calendarDays[dayNumber - 1]);
```

The calendar we used today is known as *Gregorian calendar*, which came into effect in October 15, 1582 in some countries and later in other countries. It replaces the *Julian calendar*. 10 days were removed from the calendar, i.e., October 4, 1582 (Julian) was followed by October 15, 1582 (Gregorian). The only difference between the Gregorian and the Julian calendar is the "leap-year rule". In Julian calendar, every four years is a leap year. In Gregorian calendar, a leap year is a year that is divisible by 4 but not divisible by 100, or it is divisible by 400, i.e., the Gregorian calendar omits century years which are not divisible by 400. Furthermore, Julian calendar considers the first day of the year as march 25th, instead of January 1st.

This above algorithm work for Gregorian dates only. It is difficult to modify the above algorithm to handle pre-Gregorian dates. A better algorithm is to find the number of days from a known date.

12. Exercises on Classes and Objects

12.1 The Rectangle Class

A class called `Rectangle`, which models a rectangle with a length and a width (in `float`), is designed as shown in the following class diagram. Write the `Rectangle` class.

Hints:

Rectangle
-length:float = 1.0f -width:float = 1.0f
+Rectangle() +Rectangle(length:float,width:float) +getLength():float +setLength(length:float):void +getWidth():float +setWidth(width:float):void +getArea():double +getPerimeter():double +toString():String •------------------ "Rectangle[length=?,width=?]"
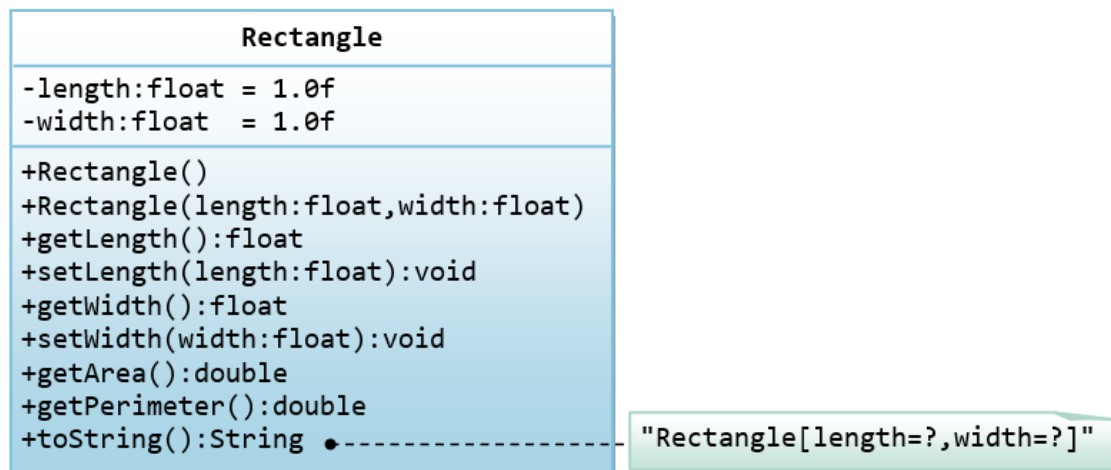
The expected output is:

```
Rectangle[length=1.2,width=3.4]
Rectangle[length=1.0,width=1.0]
Rectangle[length=5.6,width=7.8]
length is: 5.6
width is: 7.8
area is: 43.68
perimeter is: 26.80
```

12.2 The Employee Class

A class called `Employee`, which models an employee with an ID, name and salary, is designed as shown in the following class diagram. The method `raiseSalary(percent)` increases the salary by the given percentage. Write the `Employee` class.

Hints:

Employee
-id:int -firstName:String -lastName:String -salary:int
+Employee(id:int,firstName:String,   lastName:String,salary:int) +getId():int +getFirstName():String +getLastName():String +getName():String •------------- "firstName Lastname" +getSalary():int +setSalary(salary:int):void +getAnnualSalary():int •--------- salary * 12 +raiseSalary(int percent):int •------ Increase the salary by the percent and +toString():String•   return the new salary

"Employee[id=?,name=*firstName Lastname*,salary=?]"

The expected out is:

```
Employee[id=8,name=Peter Tan,salary=2500]
Employee[id=8,name=Peter Tan,salary=999]
id is: 8
firstname is: Peter
lastname is: Tan
salary is: 999
name is: Peter Tan
annual salary is: 11988
1098
Employee[id=8,name=Peter Tan,salary=1098]
```

12.3 The InvoiceItem Class

A class called `InvoiceItem`, which models an item of an invoice, with ID, description, quantity and unit price, is designed as shown in the following class diagram. Write the `InvoiceItem` class.

Hints:
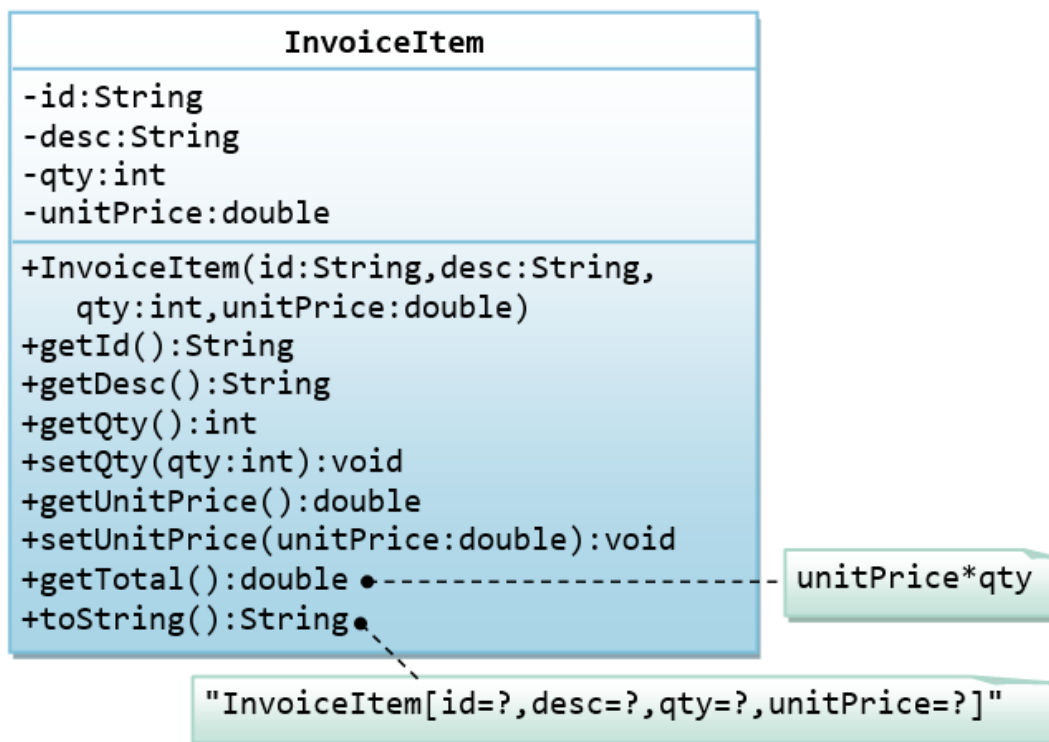
The expected output is:

```
InvoiceItem[id=A101,desc=Pen Red,qty=888,unitPrice=0.08]
InvoiceItem[id=A101,desc=Pen Red,qty=999,unitPrice=0.99]
id is: A101
desc is: Pen Red
qty is: 999
unitPrice is: 0.99
The total is: 989.01
```

12.4 The Account Class

A class called `Account`, which models a bank account of a customer, is designed as shown in the following class diagram. The methods `credit(amount)` and `debit(amount)` add or subtract the given amount to the balance. The method `transferTo(anotherAccount, amount)` transfers the given amount from this `Account` to the given `anotherAccount`. Write the `Account` class.

Hints:

Account
-id:String -name:String -balance:int = 0

+Account(id:String,name:String)
+Account(id:String,name:String,
   balance:int)
+getId():String
+getName():String
+getBalance():int
+credit(amount:int):int●---
+debit(amount:int):int ●-----
+transferTo(another:Account,
   amount:int):int ●-----------
+toString():String ●-------------

Add amount to balance, return balance

If amount <= balance
  subtract amount from balance
else print "Amount exceeded balance"
return balance

If amount <= balance
  transfer amount to the given Account
else print "Amount exceeded balance"
return balance

"Account[id=?,name=?,balance=?]"

The expected output is:

```
Account[id=A101,name=Tan Ah Teck,balance=88]
Account[id=A102,name=Kumar,balance=0]
ID: A101
Name: Tan Ah Teck
Balance: 88
Account[id=A101,name=Tan Ah Teck,balance=188]
Account[id=A101,name=Tan Ah Teck,balance=138]
Amount exceeded balance
Account[id=A101,name=Tan Ah Teck,balance=138]
Account[id=A101,name=Tan Ah Teck,balance=38]
Account[id=A102,name=Kumar,balance=100]
```

12.5 The Date Class

A class called `Date`, which models a calendar date, is designed as shown in the following class diagram. Write the `Date` class.

Hints:

```
                  Date
-day:int
-month:int                        •-------------
-year:int
+Date(day:int,month:int,year:int)
+getDay():int
+getMonth():int
+getYear():int
+setDay(day:int):void
+setMonth(month:int):void
+setYear(year:int):void
+setDate(day:int,month:int,year:int):void
+toString():String •-------------------
```

```
day = [1, 31]
month = [1, 12]
year = [1900, 9999]
No input validation needed.
```

"dd/mm/yyyy" with leading zero
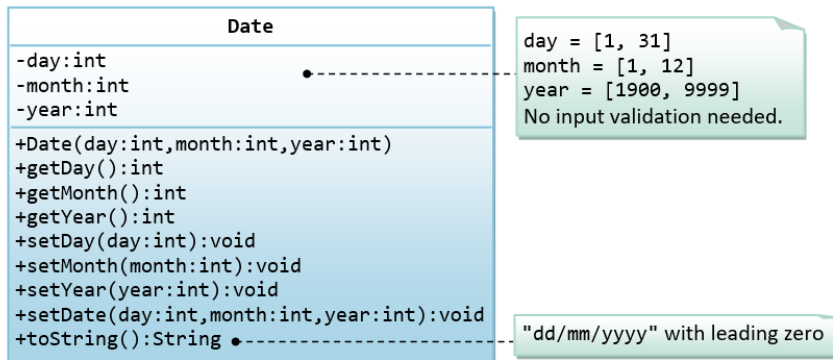
The expected output is:

```
01/02/2014
09/12/2099
Month: 12
Day: 9
Year: 2099
03/04/2016
```

13. Exercises on Inheritance

13.1 An Introduction to OOP Inheritance - The Circle and Cylinder Classes

This exercise shall guide you through the important concepts in inheritance.

```
                  Circle
-radius:double = 1.0
-color:String = "red"
+Circle()
+Circle(radius:double)
+Circle(radius:double,color:String)
+getRadius():double
+setRadius(radius:double):void
+getColor():String
+setColor(color:String):void
+getArea():double
+toString():String •-------------------
```

"Circle[radius=r,color=c]"

```
                superclass
extends    △
                subclass
                  Cylinder
-height:double = 1.0
+Cylinder()
+Cylinder(radius:double)
+Cylinder(radius:double,height:double)
+Cylinder(radius:double,height:double,
     color:String)
+getHeight():double
+setHeight(height:double):void
+getVolume():double
```

In this exercise, a subclass called `Cylinder` is derived from the superclass `Circle` as shown in the class diagram (where an an arrow pointing up from the subclass to its superclass). Study how the

subclass `Cylinder` invokes the superclass' constructors (via `super()` and `super(radius)`) and inherits the variables and methods from the superclass `Circle`.

You can reuse the `Circle` class that you have created in the previous exercise. Make sure that you keep "`Circle.class`" in the same directory.

```java
public class Cylinder extends Circle {  // Save as "Cylinder.java"
   private double height;  // private variable

   // Constructor with default color, radius and height
   public Cylinder() {
      super();          // call superclass no-arg constructor Circle()
      height = 1.0;
   }
   // Constructor with default radius, color but given height
   public Cylinder(double height) {
      super();          // call superclass no-arg constructor Circle()
      this.height = height;
   }
   // Constructor with default color, but given radius, height
   public Cylinder(double radius, double height) {
      super(radius);  // call superclass constructor Circle(r)
      this.height = height;
   }

   // A public method for retrieving the height
   public double getHeight() {
      return height;
   }

   // A public method for computing the volume of cylinder
   //  use superclass method getArea() to get the base area
   public double getVolume() {
      return getArea()*height;
   }
}
```

Method Overriding and "Super": The subclass `Cylinder` inherits `getArea()` method from its superclass Circle. Try *overriding* the `getArea()` method in the subclass `Cylinder` to compute the surface area (=2π×radius×height + 2×base-area) of the cylinder instead of base area. That is, if `getArea()` is called by a `Circle` instance, it returns the area. If `getArea()` is called by a `Cylinder` instance, it returns the surface area of the cylinder.

If you override the `getArea()` in the subclass `Cylinder`, the `getVolume()` no longer works. This is because the `getVolume()` uses the *overridden* `getArea()` method found in the same class. (Java runtime will search the superclass only if it cannot locate the method in this class). Fix the `getVolume()`.

Hints: After overridding the `getArea()` in subclass `Cylinder`, you can choose to invoke the `getArea()` of the superclass `Circle` by calling `super.getArea()`.

Try:

Provide a `toString()` method to the `Cylinder` class, which overrides the `toString()` inherited from the superclass `Circle`, e.g.,

```java
@Override
```

```
public String toString() {       // in Cylinder class
   return "Cylinder: subclass of " + super.toString()  // use Circle's toString()
          + " height=" + height;
}
```

Try out the `toString()` method in `TestCylinder`.

13.2 Superclass Person and its subclasses

Write the classes as shown in the following class diagram. Mark all the overridden methods with annotation @Override.
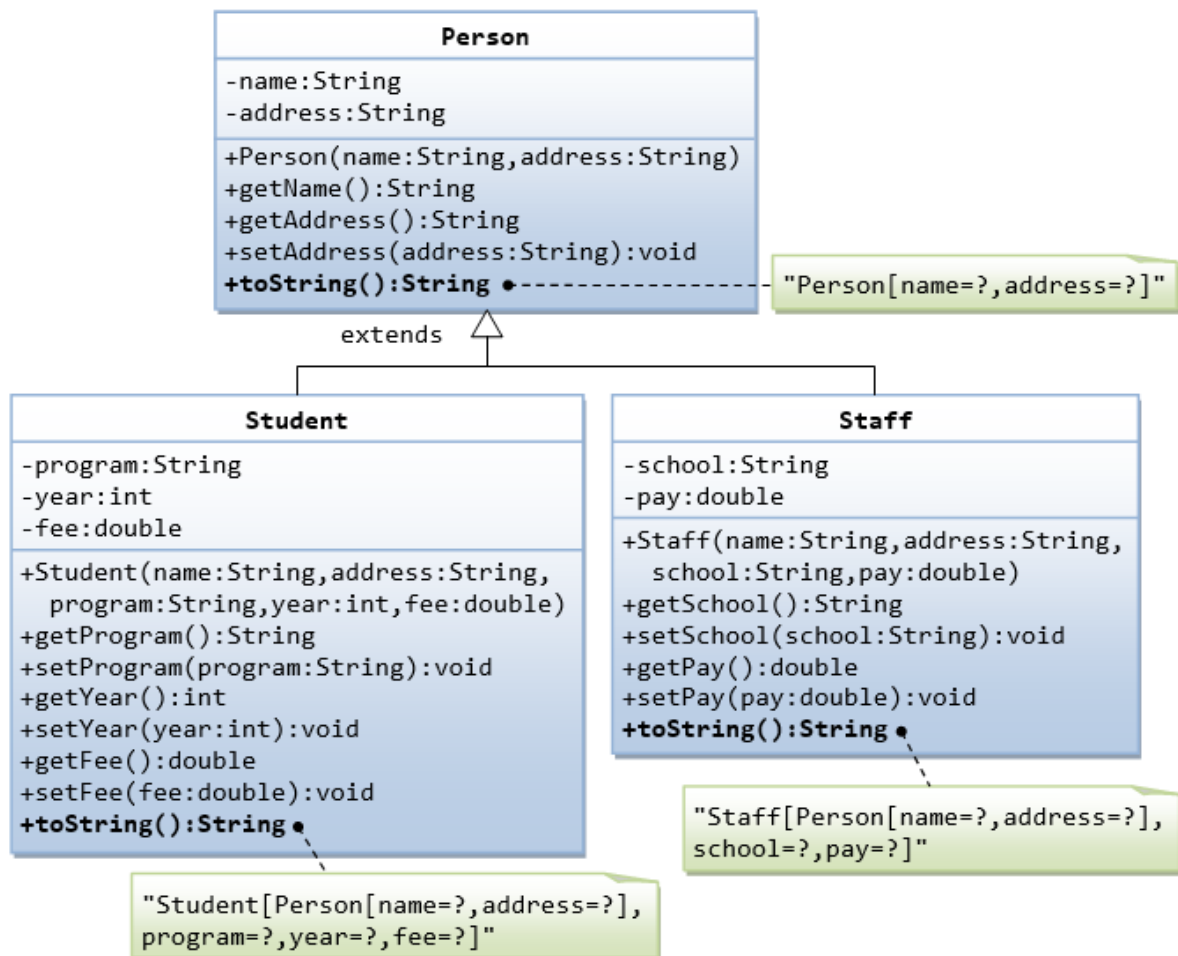
13.3 Point2D and Point3D

Write the classes as shown in the following class diagram. Mark all the overridden methods with annotation @Override.
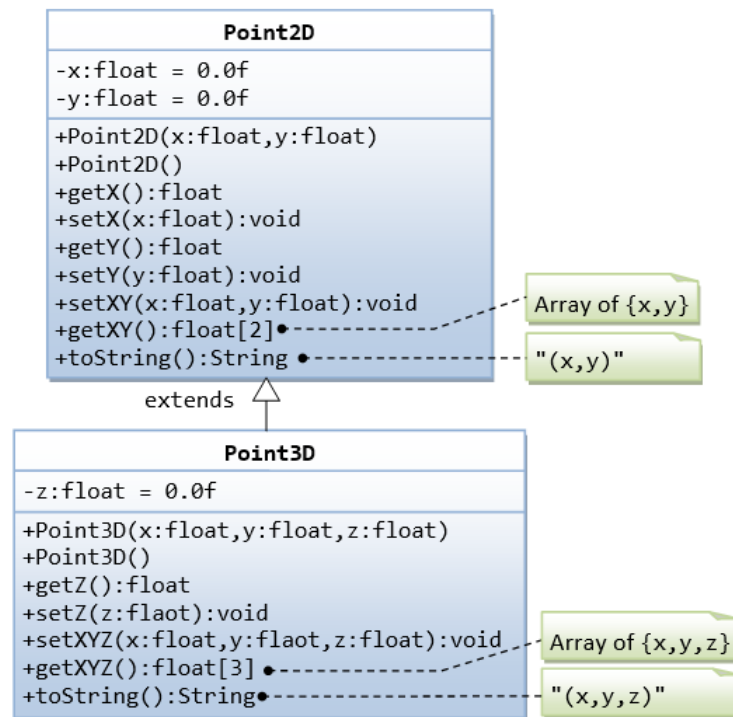
Hints:

1. You cannot assign floating-point literal say `1.1` (which is a `double`) to a `float` variable, you need to add a suffix f, e.g. `0.0f`, `1.1f`.

2. The instance variables x and y are `private` in `Point2D` and cannot be accessed directly in the subclass `Point3D`. You need to access via the `public` getters and setters. For example,

```
public void setXYZ(float x, float y, float z) {
      setX(x);     // or super.setX(x), use setter in superclass
      setY(y);
      this.z = z;
  }
```

3. The method `getXY()` shall return a `float` array:

```
public float[] getXY() {
      float[] result = new float[2];  // construct an array of 2 elements
      result[0] = ...
      result[1] = ...
      return result;  // return the array
  }
```

Write the classes as shown in the following class diagram. Mark all the overridden methods with annotation @Override.

```
┌─────────────────────────────────────┐
│               Point                  │
├─────────────────────────────────────┤
│ -x:float = 0.0f                      │
│ -y:float = 0.0f                      │
├─────────────────────────────────────┤
│ +Point(x:float,y:float)              │
│ +Point()                             │
│ +getX():float                        │
│ +setX(x:float):void                  │
│ +getY():float                        │
│ +setY(y:float):void                  │
│ +setXY(x:float,y:float):void         │
│ +getXY():float[2]                    │
│ +toString():String ●───────────── "(x,y)"
└─────────────────────────────────────┘
                 extends △
┌─────────────────────────────────────┐
│            MovablePoint              │
├─────────────────────────────────────┤
│ -xSpeed:float = 0.0f                 │
│ -ySpeed:float = 0.0f                 │
├─────────────────────────────────────┤
│ +MovablePoint(x:float,y:float,       │
│    xSpeed:float,ySpeed:float)        │
│ +MovablePoint(xSpeed:float,ySpeed:float)
│ +MovablePoint()                      │
│ +getXSpeed():float                   │
│ +setXSpeed(xSpeed:float):void        │
│ +getYSpeed():float        "(x,y),speed=(xs,ys)"
│ +setYSpeed(ySpeed:float):void        │
│ +setSpeed(xSpeed:float,ySpeed:float):void    x += xSpeed;
│ +getSpeed():float[2]                         y += ySpeed;
│ +toString():String ●──────────────          return this;
│ +move():MovablePoint ●───────────────────────
└─────────────────────────────────────┘
```
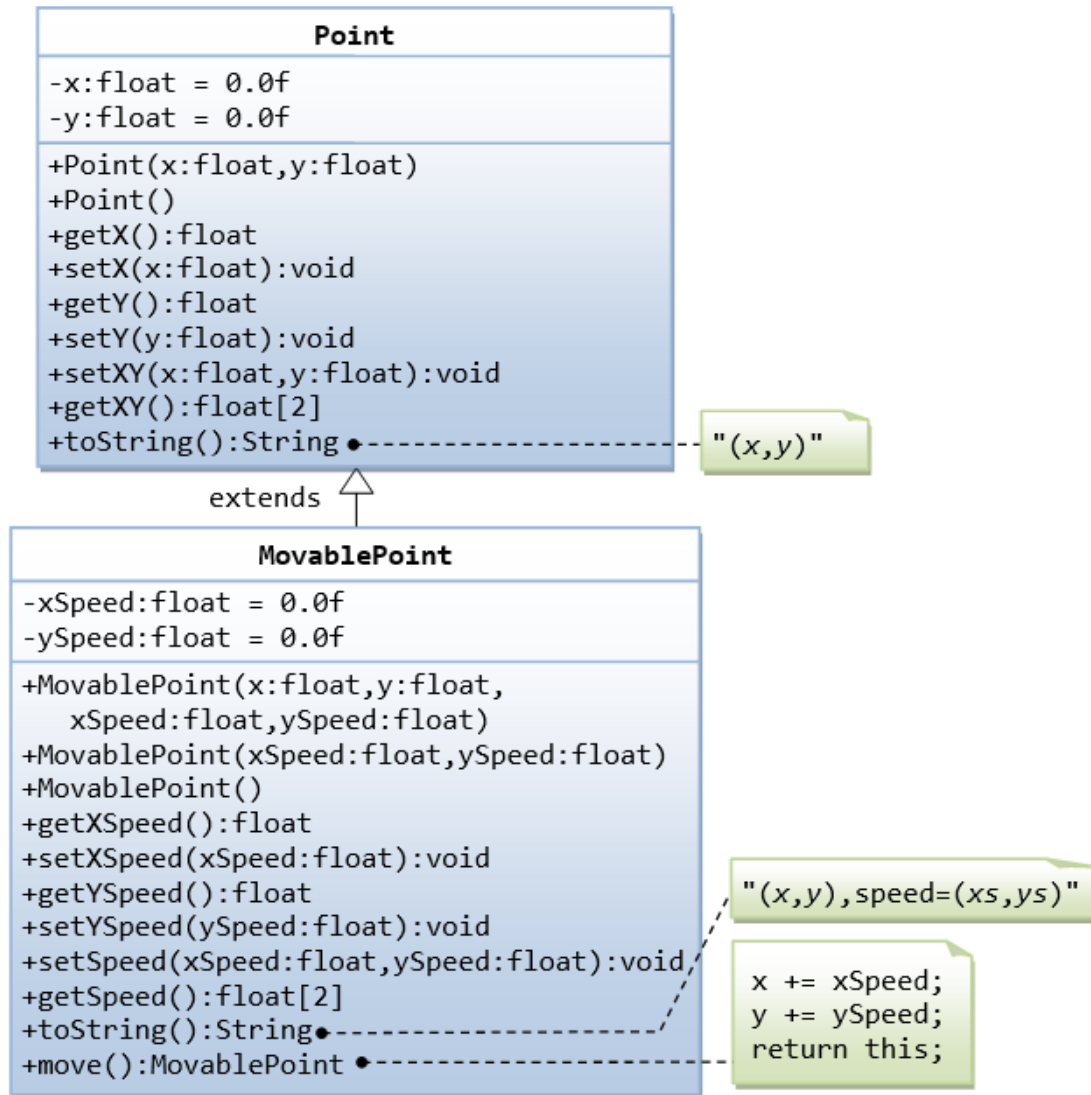
Hints

1. You cannot assign floating-point literal say 1.1 (which is a double) to a float variable, you need to add a suffix f, e.g. 0.0f, 1.1f.

2. The instance variables x and y are private in Point and cannot be accessed directly in the subclass MovablePoint. You need to access via the public getters and setters. For example, you cannot write x += xSpeed, you need to write setX(getX() + xSpeed).

13.5 Superclass Shape and its subclasses Circle, Rectangle and Square

```
                    Shape
-----------------------------------------
-color:String = "red"
-filled:boolean = true
-----------------------------------------
+Shape()
+Shape(color:String,filled:boolean)
+getColor():String
+setColor(color:String):void
+isFilled():boolean
+setFilled(filled:boolean):void
+toString():String •------------------ "Shape[color=?,filled=?]"
```

extends △

```
              Circle
---------------------------------
-radius:double = 1.0
---------------------------------
+Circle()
+Circle(radius:double)
+Circle(radius:double,
    color:String,filled:boolean)
+getRadius():double
+setRadius(radius:double):void
+getArea():double
+getPerimeter():double
+toString():String •
```

"Circle[Shape[color=?,
filled=?],radius=?]"

```
              Rectangle
---------------------------------------
-width:double = 1.0
-length:double = 1.0
---------------------------------------
+Rectangle()
+Rectangle(width:double,
    length:double)
+Rectangle(width:double,
    length:double, color:String,
    filled:boolean)
+getWidth():double
+setWidth(width:double):void
+getLength():double
+setLength(legnth:double):void
+getArea():double
+getPerimeter():double
•+toString():String
```

△

"Rectangle[Shape[color=?,
filled=?],width=?,length=?]"

```
              Square
---------------------------------------
+Square()
+Square(side:double)
+Square(side:double,
    color:String,filled:boolean)
+getSide():double
+setSide(side:double):void
•+setWidth(side:double):void
•+setLength(side:double):void
•+toString():String
```

The length and width shall be
set to the same value.

"Square[Rectangle[Shape[color=?,
filled=?],width=?,length=?]]"

Write a superclass called Shape (as shown in the class diagram)
Write a test program to test all the methods defined in Shape.
Write two subclasses of Shape called Circle and Rectangle, as shown in the class diagram.
Write a class called Square, as a subclass of Rectangle. Convince yourself that Square can be modeled as a subclass of Rectangle. Square has no instance variable, but inherits the instance variables width and length from its superclass Rectangle.

- Provide the appropriate constructors (as shown in the class diagram).

Hints:

```
public Square(double side) {
   super(side, side);   // Call superclass Rectangle(double, double)
}
```

- Override the `toString()` method to return "A Square with side=xxx, which is a subclass of yyy", where yyy is the output of the `toString()` method from the superclass.
- Do you need to override the `getArea()` and `getPerimeter()`? Try them out.
- Override the `setLength()` and `setWidth()` to change both the `width` and `length`, so as to maintain the square geometry.

14. Exercises on Polymorphism, Abstract Classes and Interfaces

14.1 Ex: Abstract Superclass Shape and Its Concrete Subclasses

Rewrite the superclass `Shape` and its subclasses `Circle`, `Rectangle` and `Square`, as shown in the class diagram.

`Shape` is an `abstract` class containing 2 abstract methods: `getArea()` and `getPerimeter()`, where its concrete subclasses must provide its implementation. All instance variables shall have `protected` access, i.e., accessible by its subclasses and classes in the same package. Mark all the overridden methods with annotation `@Override`.

```
                  <<abstract>> Shape
        #color:String = "red"              •-------- # denotes protected access
        #filled:Boolean = true
        +Shape()
        +Shape(color:String,filled:boolean)
        +getColor():String
        +setColor(color:String):void
        +isFilled():boolean
        +setFilled(filled:boolean):void
        +abstract getArea():double
        +abstract getPerimeter():double
        +toString():String •--------------- "Shape[color=?,filled=?]"
                        △ extends
```

```
            Circle                              Rectangle
  #radius:double = 1.0                   #width:double = 1.0
                                         #length:double = 1.0
  +Circle()
  +Circle(radius:double)                 +Rectangle()
  +Circle(radius:double,                 +Rectangle(width:double,length:double)
     color:String,filled:boolean)        +Rectangle(width:double,length:double,
  +getRadius():double                        color:String,filled:boolean)
  +setRadius(radius:double):void         +getWidth():double
  +getArea():double                      +setWidth(width:double):void
  +getPerimeter():double                 +getLength():double
  +toString():String •                   +setLength(legnth:double):void
                                         +getArea():double
          "Circle[Shape[color=?,         +getPerimeter():double
           filled=?],radius=?]"          +toString():String
                                                     △
     "Rectangle[Shape[color=?,
      filled=?],width=?,length=?]"                Square
                                         +Square()
                                         +Square(side:double)
                                         +Square(side:double,color:String,
                                             filled:boolean)
                                         +getSide():double
                                         +setSide(side:double):void
                                         +setWidth(side:double):void
     "Square[Rectangle[Shape[color=?,    +setLength(side:double):void
      filled=?],width=?,length=?]]"      +toString():String
```

In this exercise, Shape shall be defined as an `abstract` class, which contains:

- Two protected instance variables **color(String)** and **filled(boolean).** The protected variables can be accessed by its subclasses and classes in the same package. They are denoted with a '#' sign in the class diagram.
- Getter and setter for all the instance variables, and toString().
- Two abstract methods getArea() and getPerimeter() (shown in italics in the class diagram).
- Subclasses Circle and Rectangle shall *override* the abstract methods getArea() and getP erimeter() and provide the proper implementation. They also *override* the toString().

Write a test class to test these statements involving polymorphism and explain the outputs. Some statements may trigger compilation errors. Explain the errors, if any.

```
Shape s1 = new Circle(5.5, "red", false);  // Upcast Circle to Shape
System.out.println(s1);                     // which version?
System.out.println(s1.getArea());           // which version?
System.out.println(s1.getPerimeter());      // which version?
System.out.println(s1.getColor());
System.out.println(s1.isFilled());
System.out.println(s1.getRadius());

Circle c1 = (Circle)s1;                      // Downcast back to Circle
System.out.println(c1);
System.out.println(c1.getArea());
System.out.println(c1.getPerimeter());
System.out.println(c1.getColor());
System.out.println(c1.isFilled());
System.out.println(c1.getRadius());

Shape s2 = new Shape();

Shape s3 = new Rectangle(1.0, 2.0, "red", false);   // Upcast
System.out.println(s3);
System.out.println(s3.getArea());
System.out.println(s3.getPerimeter());
System.out.println(s3.getColor());
System.out.println(s3.getLength());

Rectangle r1 = (Rectangle)s3;    // downcast
System.out.println(r1);
System.out.println(r1.getArea());
System.out.println(r1.getColor());
System.out.println(r1.getLength());

Shape s4 = new Square(6.6);       // Upcast
System.out.println(s4);
System.out.println(s4.getArea());
System.out.println(s4.getColor());
System.out.println(s4.getSide());

// Take note that we downcast Shape s4 to Rectangle,
//  which is a superclass of Square, instead of Square
Rectangle r2 = (Rectangle)s4;
System.out.println(r2);
System.out.println(r2.getArea());
System.out.println(r2.getColor());
System.out.println(r2.getSide());
System.out.println(r2.getLength());

// Downcast Rectangle r2 to Square
```

```
Square sq1 = (Square)r2;
System.out.println(sq1);
System.out.println(sq1.getArea());
System.out.println(sq1.getColor());
System.out.println(sq1.getSide());
System.out.println(sq1.getLength());
```

Try:

Explain the usage of the `abstract` method and `abstract` class?

14.2 GeometricObject Interface and its Implementation Classes Circle and Rectangle

Write an interface called `GeometricObject`, which contains 2 abstract methods: getArea() and getPerimeter(), as shown in the class diagram. Also write an implementation class called `Circle`. Mark all the overridden methods with annotation `@Override`.
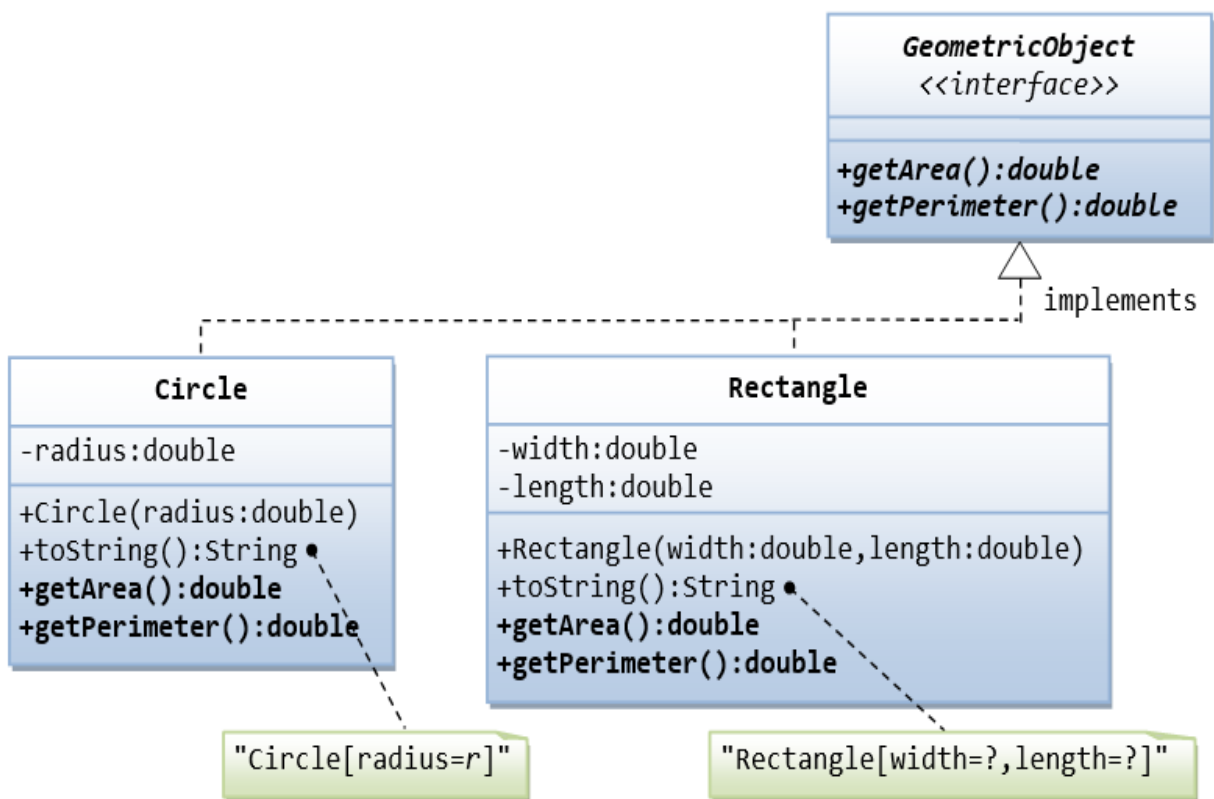
14.3 Ex: Movable Interface and its Implementation MovablePoint Class

Write an interface called Movaable, which contains 4 abstract methods moveUp(), moveDown(), moveLeft() and moveRight(), as shown in the class diagram. Also write an implementation class called MovablePoint. Mark all the overridden methods with annotation @Override.
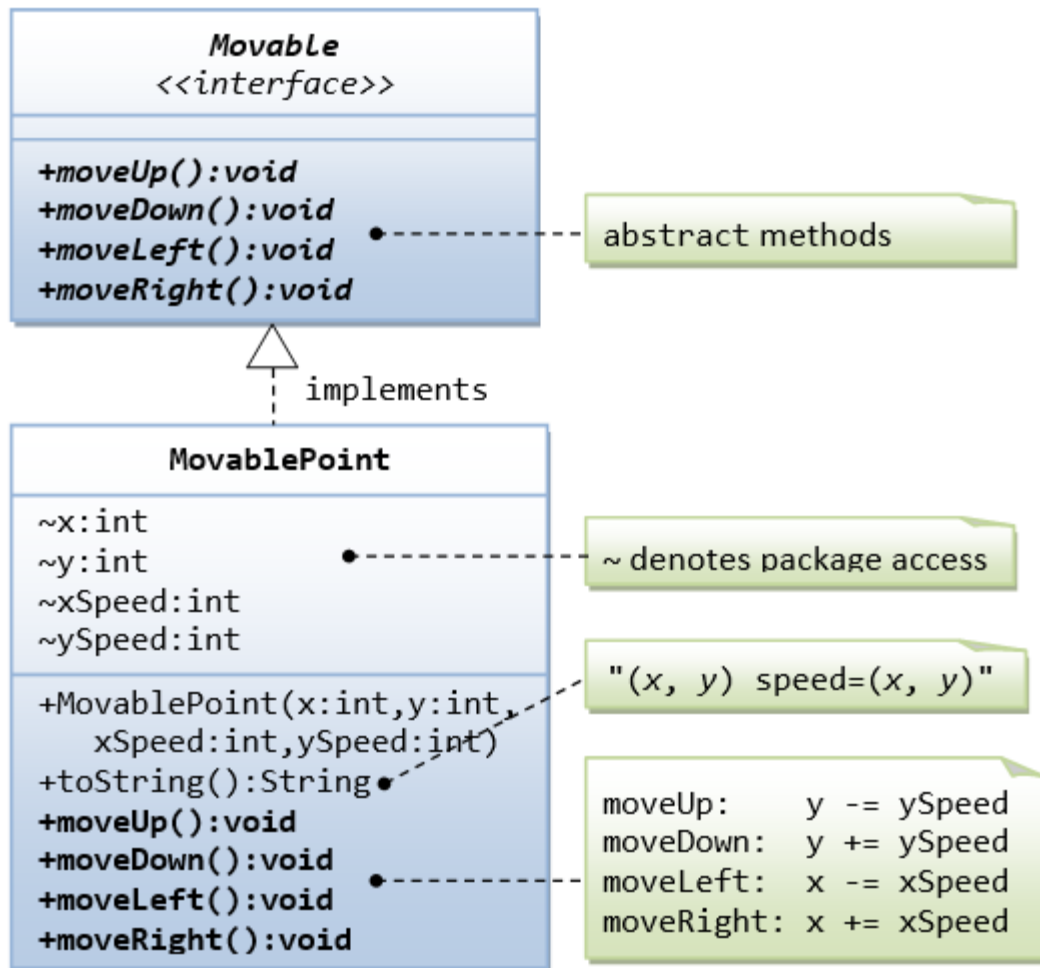
14.4 Movable Interface and Classes MovablePoint and MovableCircle

Write an interface called Movaable, which contains 4 abstract methods moveUp(), moveDown(), moveLeft() and moveRight(), as shown in the class diagram.

Write the implementation classes called MovablePoint and MovableCircle. Mark all the overridden methods with annotation @Override.

```
          <<interface>> Movable

          +moveUp():void
          +moveDown():void
          +moveLeft():void
          +moveRight():void
```

implements

```
          MovablePoint                          MovableCircle
~x:int                                   -radius:int
~y:int                         1         -center:MovablePoint
~xSpeed:int
~ySpeed:int                    composes  +MovableCircle(x:int,y:int
                                             xSpeed:int,ySpeed:int,
+MovablePoint(x:int,y:int,                   radius:int)
   xSpeed:int,ySpeed:int)               +toString():String
+toString():String                      +moveUp():void
+moveUp():void                          +moveDown():void
+moveDown():void                        +moveLeft():void
+moveLeft():void                        +moveRight():void
+moveRight():void
```

"(x,y),speed=(x,y)"   "(x,y),speed=(x,y),radius=?"

14.5 Interfaces Resizable and GeometricObject

```
                    GeometricObject
                      <<interface>>

                    +getPerimeter():double
                    +getArea():double
```

```
          Circle
#radius:double                # for protected

+Circle(radius:double)
+toString():String                       Resizable
+getPerimeter():double                  <<interface>>
+getArea():double
                                 +resize(percent:int):void
```

```
          ResizableCircle

+ResizableCircle(radius:double)
+toString():String                 radius *= percent/100.0
+resize(percent:int):void
```

ResizableCircle[Circle[radius=?]]

Circle[radius=?]
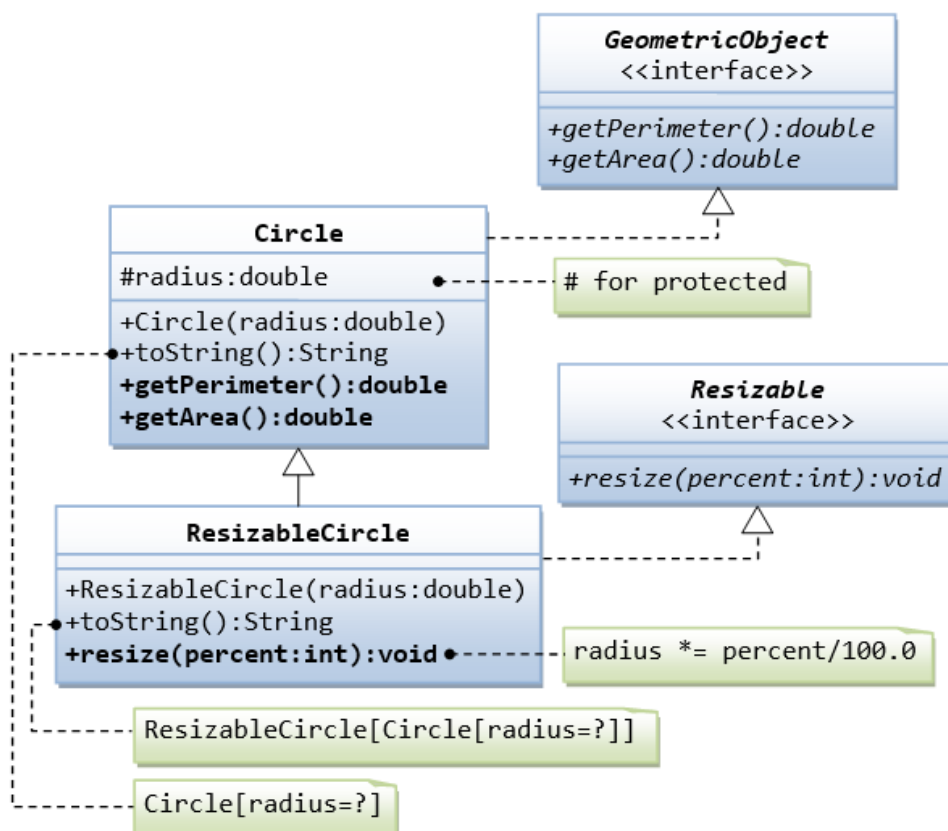
Write the interface called GeometricObject, which declares two abstract methods: getParameter() and getArea(), as specified in the class diagram.

Hints:

```
public interface GeometricObject {
   public double getPerimeter();
   ......
}
```

Write the implementation class `Circle`, with a protected variable `radius`, which implements the interface `GeometricObject`.

Hints:

```
public class Circle implements GeometricObject {
   // Private variable
   ......

   // Constructor
   ......

   // Implement methods defined in the interface GeometricObject
   @Override
   public double getPerimeter() { ...... }

   ......
}
```

Write a test program called `TestCircle` to test the methods defined in `Circle`.

The class `ResizableCircle` is defined as a subclass of the class `Circle`, which also implements an interface called `Resizable`, as shown in class diagram. The interface `Resizable` declares an `abstract` method `resize()`, which modifies the dimension (such as `radius`) by the given percentage. Write the interface `Resizable` and the class `ResizableCircle`.

Hints:

```
public interface Resizable {
   public double resize(...);
}
```

```
public class ResizableCircle extends Circle implements Resizeable {

   // Constructor
   public ResizableCircle(double radius) {
      super(...);
   }

   // Implement methods defined in the interface Resizable
   @Override
   public double resize(int percent) { ...... }
}
```

Try:

Write a test program called `TestResizableCircle` to test the methods defined in `ResizableCircle`.

14.6 Abstract Superclass Animal and its Implementation Subclasses

Write the codes for all the classes shown in the class diagram. Mark all the overridden methods with annotation @Override.
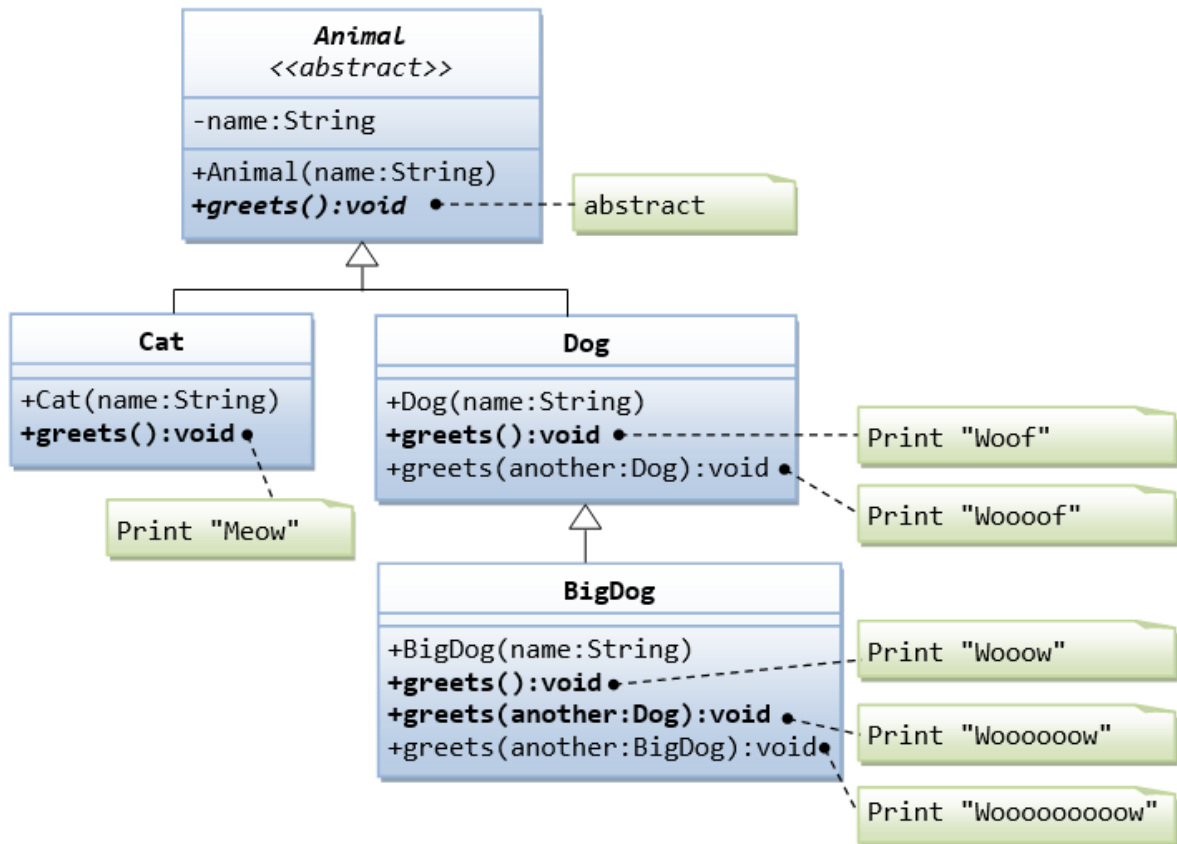
14.7 Another View of Abstract Superclass Animal and its Implementation Subclasses

Examine the following codes and draw the class diagram.

```java
abstract public class Animal {
    abstract public void greeting();
}
```

```java
public class Cat extends Animal {
    @Override
    public void greeting() {
        System.out.println("Meow!");
    }
}
public class Dog extends Animal {
    @Override
    public void greeting() {
        System.out.println("Woof!");
    }

    public void greeting(Dog another) {
        System.out.println("Wooooooooof!");
    }
}
```

```java
public class BigDog extends Dog {
    @Override
```

```java
    public void greeting() {
        System.out.println("Woow!");
    }

    @Override
    public void greeting(Dog another) {
        System.out.println("Woooooowwwww!");
    }
}
```

Try:
Explain the outputs (or error) for the following test program.

```java
public class TestAnimal {
    public static void main(String[] args) {
        // Using the subclasses
        Cat cat1 = new Cat();
        cat1.greeting();
        Dog dog1 = new Dog();
        dog1.greeting();
        BigDog bigDog1 = new BigDog();
        bigDog1.greeting();

        // Using Polymorphism
        Animal animal1 = new Cat();
        animal1.greeting();
        Animal animal2 = new Dog();
        animal2.greeting();
        Animal animal3 = new BigDog();
        animal3.greeting();
        Animal animal4 = new Animal();

        // Downcast
        Dog dog2 = (Dog)animal2;
        BigDog bigDog2 = (BigDog)animal3;
        Dog dog3 = (Dog)animal3;
        Cat cat2 = (Cat)animal2;
        dog2.greeting(dog3);
        dog3.greeting(dog2);
        dog2.greeting(bigDog2);
        bigDog2.greeting(dog2);
        bigDog2.greeting(bigDog1);
    }
}
```

15. Final Notes

The only way to learn programming is program, program and program on challenging problems. The problems in this tutorial are certainly NOT challenging. There are tens of thousands of challenging problems available – used in training for various programming contests (such as International Collegiate Programming Contest (ICPC), International Olympiad in Informatics (IOI)). Check out these sites:

- The ACM - ICPC International collegiate programming contest (https://icpc.global/)
- The Topcoder Open (TCO) annual programming and design contest (https://www.topcoder.com/)
- Universidad de Valladolid's online judge (https://uva.onlinejudge.org/).
- Peking University's online judge (http://poj.org/).

- USA Computing Olympiad (USACO) Training Program @ http://train.usaco.org/usacogate.
- Google's coding competitions (https://codingcompetitions.withgoogle.com/codejam, https://codingcompetitions.withgoogle.com/hashcode)
- The ICFP programming contest (https://www.icfpconference.org/)
- BME International 24-hours programming contest (https://www.challenge24.org/)
- The International Obfuscated C Code Contest (https://www0.us.ioccc.org/main.html)
- Internet Problem Solving Contest (https://ipsc.ksp.sk/)
- Microsoft Imagine Cup (https://imaginecup.microsoft.com/en-us)
- Hewlett Packard Enterprise (HPE) Codewars (https://hpecodewars.org/)
- OpenChallenge (https://www.openchallenge.org/)

Coding Contests Scores

Students must solve problems and attain scores in the following coding contests:

Name of the contest	Minimum number of problems to solve	Required score
CodeChef	20	200
Leetcode	20	200
GeeksforGeeks	20	200
SPOJ	5	50
InterviewBit	10	1000
Hackerrank	25	250
Codeforces	10	100
BuildIT	50	500
Total score need to obtain		2500

Student must have any one of the following certifications:

- HackerRank – Java Basic Skills Certification
- Oracle Certified Associate Java Programmer OCAJP
- CodeChef - Learn Java Certification
- NPTEL – Programming in Java
- NPTEL – Data Structures and Algorithms in Java

V. TEXT BOOKS:

1. Farrell, Joyce.*Java Programming*, Cengage Learning B S Publishers, 8th Edition, 2020
2. Schildt, Herbert. *Java: The Complete Reference* 11th Edition, McGraw-Hill Education, 2018.

VI. REFERENCE BOOKS:

1. Deitel, Paul and Deitel, Harvey. *Java: How to Program*, Pearson, 11th Edition, 2018.
2. Evans, Benjamin J. and Flanagan, David. *Java in a Nutshell*, O'Reilly Media, 7th Edition, 2018.
3. Bloch, Joshua. *Effective Java*, Addison-Wesley Professional, 3rd Edition, 2017.
4. Sierra, Kathy and Bates, Bert. *Head First Java*, O'Reilly Media, 2nd Edition, 2005

VII. ELECTRONICS RESOURCES:

1. https://docs.oracle.com/en/java/
2. https://www.geeksforgeeks.org/java
3. https://www.tutorialspoint.com/java/index.htm
4. https://www.coursera.org/courses?query=java

VIII. MATERIALS ONLINE;

1. Syllabus
2. Lab manual

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

ENGINEERING PHYSICS LABORATORY							
I Semester: AE | ME | CE | ECE | EEE | CSE (AI&ML) | CSE (DS) **II Semester:** CSE | IT							
Course Code	**Category**	**Hours / Week**		**Credits**	**Maximum Marks**		
AHSE05	**Foundation**	**L**	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
		-	-	2	1	40	60	100
Contact Classes: Nil	**Tutorial Classes: Nil**	**Practical Classes: 45**			**Total Classes: 45**		
Prerequisite: Basic Principles of Physics							

I. COURSE OVERVIEW:

The aim of the course is to provide hands on experience for experiments in different areas of physics. Students will be able to perform the experiments with interest and an attitude of learning. This laboratory includes experiments involving electromagnetism and optoelectronics. These also develop student's expertise in applying physical concepts to practical problem and apply it for different applications.

II. COURSES OBJECTIVES:
The students will try to learn:

I   Familiarize with the lab facilities, equipment, standard operating procedures.

II   The different kinds of functional magnetic materials which paves a way for them to use   in various technical and engineering applications.

III The analytical techniques and graphical analysis to study the experimental data for optoelectronicdevices.

IV   The application of characteristics of lasers and its propagation in optical fiber communication.

III. COURSE OUTCOMES:
After successful completion of the course, students should be able to:

CO1   Identify the type of semiconductor using the principle of Hall effect and also determine the energy gap and resistivity of a semiconductor diode using four probe method.

CO2   Illustrate principle, working and application of wave propagation and compare the results of frequency   with theoretical harmonics and overtones.

CO3   Investigate the energy losses, curie temperature and properties associated with a given Ferro magnetic material.

CO4   Examine launching of light through optical fiber from the concept of light gathering capacity of numerical aperture and determine the divergence of Laser beam

CO5   Graph V-I /L-I characteristics of various optoelectronic devices like Light Emitting diode, Solar cell at different intensities to understand their basic principle of functioning as well as to infer the value of Planck's constant.

CO6   Analyze the variation of magnetic field induction produced at various points along the axis of current carrying coil.

IV.COURSE SYLLABUS:

1. GETTING STARTED EXCERCISES

1.1 On Errors and Uncertainty in a measurement:

When a number represents a physical measurement, it is never exact because of the limitations of the instrument used or the way it was employed etc. It is essential, therefore, that each experimental result be presented in a way that indicates its reliability. The accuracy of result is important, for example, the calibration of the measuring instruments or systematic errors on the part of whoever is taking the data.

The following table is useful in thinking about these concepts:

Problem	Remedy
Mistakes and blunders	Repeat measurements several times to check yourself
Systematic errors	Use calibrated instruments properly and carefully
Random errors	Treat data statistically and report on the average magnitude of errors

1.2 Making a good graph:

- Keep your axes straight: If you need to plot "A vs B", or "A as a function of B", then A is on the vertical axis and B is on the horizontal axis.
- The crucial part is choosing the range and scale for each axis. The range must be just large enough to accommodate all data and small enough that the scale is readable.
- The scale should be spread out enough so that data take up most of the graph area and labeled so that plotting (and reading) is easy. Where appropriate, error bars should be included to indicate the uncertainty in measurements.
- When a line is drawn, it should be a smooth one that best fits data. In general, there should be as many points on one side of the line as on the other. If data is taken properly, the line should pass inside of the error bars for each point.
- If graph shows that one quantity is proportional to another, it should be a straight line that starts at the origin and passes through the plotted data with as many points on one side as the other.
- If the slope of the line is to be found, choose two points on the line that are as far apart as possible. This will minimize the error that is introduced in reading the value of those points.
- The slope is the difference between the vertical values of those points divided by the difference in the horizontal values of those points.

1.3 Data recording and worksheets

- Write the work sheets for the allotted experiment and keep them ready before the beginning of each lab.
- Perform the experiment and record the observations in the worksheets.
- Analyze the results and get the work sheets evaluated by the faculty.
- Upload the evaluated reports online from CMS LOGIN within the stipulated time.

GETTING STARTED WITH EXPERIMENTATION

2. HALL EFFECT (LORENTZ FORCE)

2.1 Study the phenomenon of Hall effect and determine the charge carrier density and Hall coefficient of a given sample.

2.2 Hint whether the given semiconductor is p - type or n - type using the principle of hall effect.

3. ENERGY GAP OF A SEMICONDUCTOR DIODE

3.1 Determination of energy gap of a given semiconductor diode by measuring the variation of current as a function of temperature.

3.2 Try to find the Fermi level of the given semiconductor

4. RESISTIVITY – FOUR PROBE METHOD

4.1 Determination of the resistivity by forcing current through two outer probes

4.2 Formulate the reading of voltage across the two inner probes of semiconductor by four probe method.

5. MAGNETIC MOMENT

5.1 Determination of magnetic moment of a bar magnet.

5.2 Try to find horizontal component of earth's magnetic field.

6. B-H CURVE WITH CRO

6.1   Evaluate the energy loss per unit volume of a given magnetic material per cycle by tracing the hysteresis loop (B-H curve).

6.2   Observe the hysteresis loss of ferro magnetic materials.

7. FERROMAGNETIC MATERIAL

7.1 Determine the curie temperature (Tc) of a ferromagnetic material.

7.2 Evaluate the relative permeability (μ_r) of a ferromagnetic material.

8. OPTICAL FIBER

8.1 Determine the numerical aperture of a given optical fiber.

8.2 Calculate the acceptance angle of a given optical fiber.

9. LASER DIVERGENCE

9.1 Determination of the beam divergence of the given laser beam.

9.2 Try to estimate the laser output

10. SOLAR CELL

10.1 Studying the characteristics of solar cell at different intensities

10.2 Try to get the maximum workable power.

11. LIGHT EMITTING DIODE

11.1   Studying V-I characteristics of LED in forward bias for different LEDs.

11.2   Measure the threshold voltage and forward resistance, and try for the dynamic Resistance

12. PLANCK'S CONSTANT

12.1   Determination of Planck's constant by measuring threshold voltage of given LED.

12.2   Draw the L -I characteristics of the given LED.

13. STEWART GEE'S APPARATUS

13.1   Study the magnetic field along the axis of current carrying coil – Stewart and Gee's method.

13.2   Estimate the magnetic lines of force.

14. MELDE'S EXPERIMENT

14.1   Determination of frequency of a given tuning fork in longitudinal wave propagation.

14.2   Try to establish the transverse mode of wave propagation by understanding the theoretical harmonics and overtones

V. TEXTBOOKS:
1. Laboratory Experiments in College Physics", C.H. Bernard and C.D. Epp, John Wiely and Sons, Inc., New York, 1995.

VI.   REFERENCE BOOKS:
1. C. L. Arora, "Practical Physics", S. Chand & Co., New Delhi, 3rd Edition, 2012.
2. Vijay Kumar, Dr. T Radhakrishna, "Practical Physics for Engineering Students", SM Enterprises, 2nd Edition, 2014.
3. Dr. Rizwana, "Engineering Physics Manual", Spectrum Techno Press, 2018.

VII.   ELECTRONICS RESOURCES:
1. https://nptel.ac.in/translation
2. https://nptel.ac.in/courses/115105120
3. NPTEL:: courses-Sem 1 and 2 - Engineering Physics and Applied Physics I
4. Experimental Physics I - Course (nptel.ac.in)
5. NPTEL:: Physics - Waves and Oscillations

VIII.   MATERIALS ONLINE:
1. Course template
2. Lab manual

COURSE CONTENT

ENGINEERING WORKSHOP

I Semester: AE / CE / ME / ECE / EEE / CSE (AI&ML) / CSE (DS)
II Semester: CSE / IT

Course Code	Category	Hours / Week			Credits	Maximum Marks		
		L	T	P	C	CIA	SEE	Total
AMEE02	Foundation	0	0	2	1	40	60	100
Contact Classes: Nil	**Tutorial Classes: Nil**	**Practical Classes: 45**				**Total Classes:45**		
Prerequisite: There is no prerequisite for this course.								

I. COURSE OVERVIEW:

This course provides the opportunity to become confident with new tools, equipment, and techniques for creating physical objects and mechanisms with a variety of materials. The students will learn principles of contemporary trends in manufacturing processes, such as CNC machining and 3D printing, as well as gain practical experience in carpentry, fitting, and welding. Skills learned in the course enable the students to learn about the design process in digital manufacturing used in various industrial applications.

II. COURSES OBJECTIVES:

The students will try to learn

I. The basics and hands-on practice of carpentry, fitting, and welding
II. The impart knowledge and skill to use tools, equipment, measuring instruments, and modern techniques.
III. The concepts apply to the manufacturing processes of casting, moulding and forging.
IV. The basic machining operations by CNC lathe, CNC milling, and 3D printing machine.

III. COURSE OUTCOMES:

At the end of the course students should be able to:

CO 1   Select appropriate tools, work material and measuring instruments useful for carpentry, fitting, and welding.
CO 2   Use flat sheets for sheet metal and intricate shapes made from mild steel for Black smithy.
CO 3   Choose appropriate components and tools to prepare pipe fitting and joints of specific shapes and sizes.
CO 4   Experiment with the moulding techniques for producing cast components in complex shapes using different patterns.
CO 5   Execute hard soldering techniques to join similar and dissimilar materials used in industries.
CO 6   Demonstrate appropriate equipment and methods for various machining processes used in CNC machines and 3D printing for manufacturing industries.

EXERCISES IN ENGINEERING WORKSHOP

Note: All dimensions are in mm in experiments.

Getting started experiments

Introduction

Engineering workshop provides both tools and equipments (or machinery) that are required for the manufacture of the goods. Students are familiarized with basic workshop practice like Wood working, Sheet metal, metal joining processes, manufacturing processes etc. and required to identify, operate and control various machines, tools and equipments.

Safety

Safety is a vital issue in all workplaces. Before using any equipment and machines or attempt practical work in a workshop everyone must understand basic safety rules. These rules will help keep all safe in the workshop.

Safety Rules:

- Always listen carefully to the teacher and follow instructions.
- When learning how to use a machine, listen very carefully to all the instructions given by the faculty / instructor. Ask questions, especially if you do not fully understand.
- Always wear an apron as it will protect your clothes and holds lose clothing such as ties in place.
- Bags should not be brought into a workshop as people can trip over them.
- Do not use a machine if you have not been shown how to operate it safely by the faculty / instructors
- Know where the emergency stop buttons are positioned in the workshop. If you see an accident at the other side of the workshop you can use the emergency stop button to turn off all electrical power to machines.
- Wherever required, wear protective equipment, such as goggles, safety glasses, masks, gloves, hair nets, etc.
- Always be patient, never rush in the workshop.
- Always use a guard when working on a machine.
- Keep hands away from moving/rotating machinery.
- Use hand tools carefully, keeping both hands behind the cutting edge.
- Report any UNSAFE condition or acts to instructor.
- Report any damage to machines/equipment as this could cause an accident.
- Keep your work area clean.

DO's

- Students must always wear uniform and shoes before entering the lab.
- Proper code of conduct and ethics must be followed in the lab.
- Note down the specifications/drawings before working on the preparation of models.

- Receive the tools and materials required for preparation of models with signing in register.
- Properly fix hacksaw blade in frame with help of instructor.
- Use of safety goggles / face shield during welding.
- Do the models under the supervision/guidance of a faculty/ lab instructor only.
- Keep the sufficient distance from other students while preparing models.
- In case of fire use fire extinguisher/throw the sand provided in the lab.
- In case of any physical injuries or emergencies use first aid box provided.

DONT's

- Do not touch electrical circuits of welding machine.
- Be cautious while fixing hacksaw blade in frame, that may cause injuries to hand.
- Don't touch /operate power tools without aid from instructors.
- Don't gather while preparing models, that may hurt other with tools.
- Don't unlock snip/sheet metal cutter lock, without use.

1. Introduction to carpentry

Carpentry is the process of shaping wood, using hand tools. The products produced are used in building construction, such as doors and windows, furniture manufacturing, patterns for moulding infoundries, etc. Carpentry work mainly involves the joining together of wooden pieces and finishing the surfaces after shaping them. Hence, the term joining is also used commonly for carpentry. A student studying the fundamentals of wood working has to know about timber and other carpentry materials, wood working tools, carpentry operations and the method of making common types of joints.

1.1. Experiments on carpentry

1. Preparation of the cross-half lap joint as shown in Fig. 1.1

Fig.1.1 Dimensions of pieces
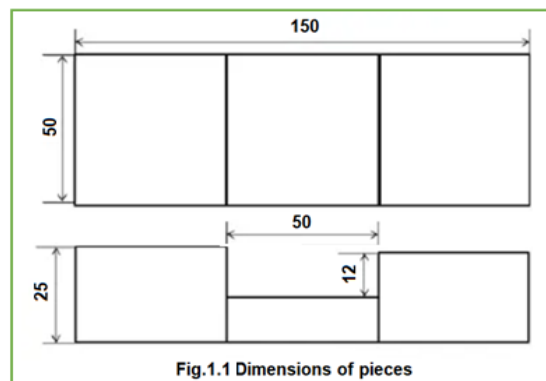
2. Preparation of the dove tail joint as depicted in Fig.1.2

Try

1. Mortise and tenon joint preparation as illustrated in Fig.1.3 with dimensions of width = 50 mm and tenon thickness = 10 mm.
2. End lap joint preparation as illustrated in Fig. 1.4. The end lap projection dimensions to be taken into consideration are width = 50 mm and thickness = 15 mm.

Fig.1.2 Dimensions of pieces

Fig.1.3 Mortise and tenon joint

Fig.1.4 End lap joint
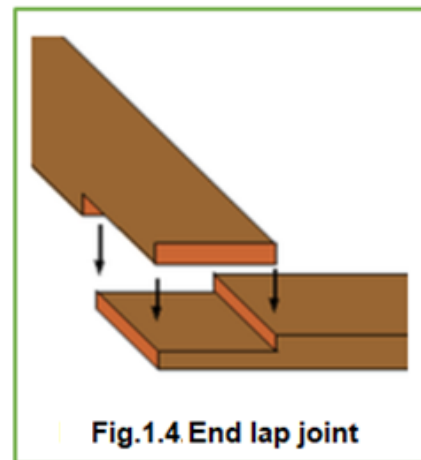
2. Introduction to fitting

The term fitting, is related to assembly of parts, after bringing the dimension or shape to the required size or form, in order to secure the necessary fit. The operations required for the same are usually carried out on a work bench, hence the term bench work is also added with the name fitting. The bench work and fitting play an important role in engineering. Although in today's industries most of the work is done by automatic machines which produces the jobs with good accuracy but still it(job) requires some hand operations called fitting operations.

2.1. Experiments on fitting

1. Making of a square fitting using mild steel plates of the specified size, as shown in Fig. 2.1
2. Making of a V-fit according to the size of the provided mild steel plates, as shown in Fig. 2.2

Fig.2.1 Dimensions of mild steel plates

Fig.2.2 Dimensions of mild steel plates
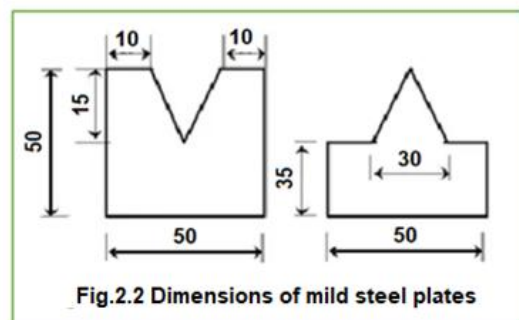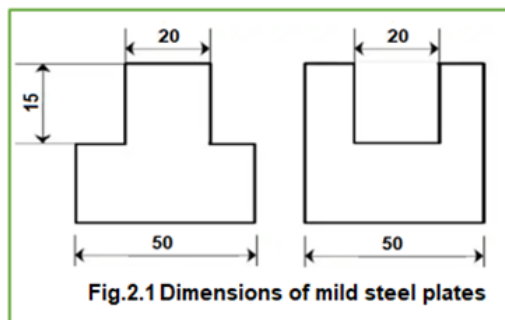
Try

1. Straight fitting of mild steel plates to the specified sizes, as shown in Fig. 2.3
2. Making of semicircular fit with mild steel plates of the specified size, as depicted in Fig. 2.4
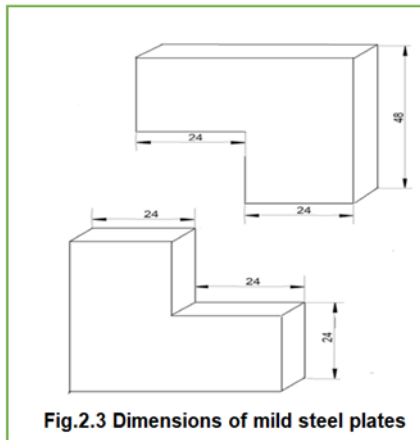
Fig.2.3 Dimensions of mild steel plates
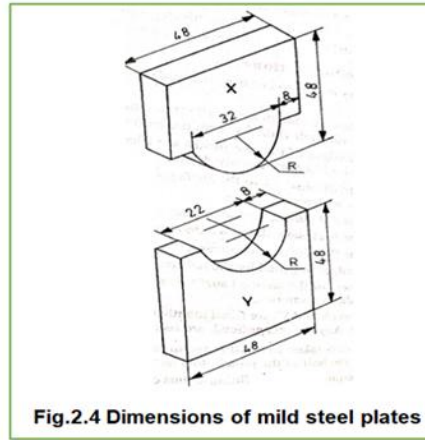
Fig.2.4 Dimensions of mild steel plates

3. Introduction to welding

Welding is a process for joining two similar or dissimilar metals by fusion. It joins different metals/alloys, with or without the application of pressure and with or without the use of filler metal. The fusion of metal takes place by means of heat. The heat may be generated either from combustion of gases, electric arc, electric resistance or by chemical reaction. Welding provides a permanent joint but it normally affects the metallurgy of the components. It is therefore usually accompanied by post weld heat treatment for most of the critical components. The welding is widely used as a fabrication and repairing process in industries. Some of the typical applications of welding include the fabrication of ships, pressure vessels, automobile bodies, off-shore platform, bridges, welded pipes, sealing of nuclear fuel and explosives, etc.

3.1. Experiments and demonstration on different welding techniques

1. Creating the lap joint in accordance with the mild steel plates given, as shown in Fig .3.1
2. Making the butt joint as depicted in Fig. 3.2 using the mild steel plates as are offered.
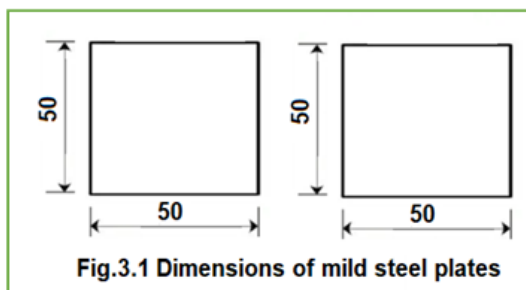
Fig.3.1 Dimensions of mild steel plates
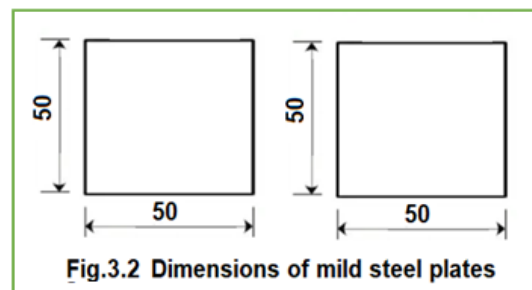
Fig.3.2 Dimensions of mild steel plates

Try

1. Construction of the tee joint using the mild steel plates provided, as shown in Fig. 3.3
2. As illustrated in Fig. 3.4, creating the corner (L) joint using the provided mild steel plates.

4.

Fig.3.3 Tee joint

Fig.3.4 Corner joint
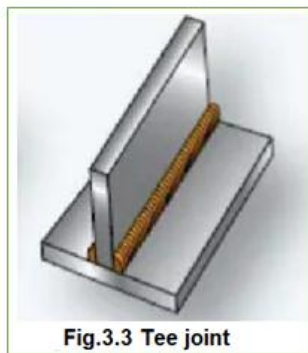
Introduction to sheet metal

Sheet metal work has its own significance in the engineering work. Many products, which fulfill the household needs, decoration work and various engineering articles, are produced from sheet metals. Common examples of sheet metal work are hoopers, canisters, guards, covers, pipes, hoods, funnels, bends, boxes etc. Such articles are found less expensive, lighter in weight and in some cases sheet metal products replace the use of castings or forgings.

4.1. Experiments on sheet metal forming

1. Create the rectangular tray as depicted in Fig. 4.1.

Fig.4.1 Dimensions of GI sheet
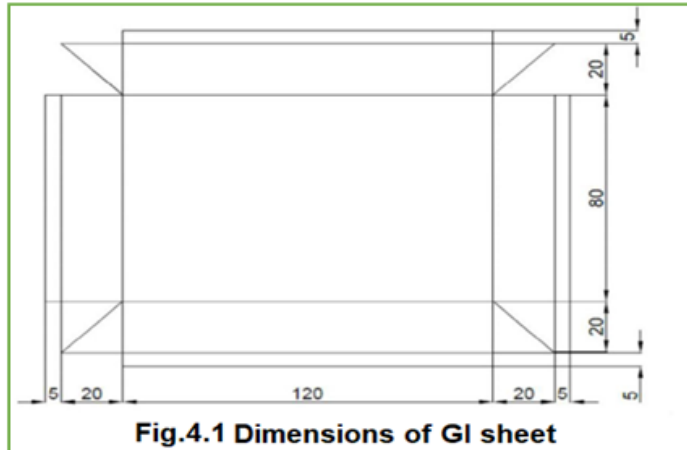
2. As illustrated in Fig.4.2, prepare the developing surface and create cylindrical tin.

Fig.4.2 Dimensions of GI sheet
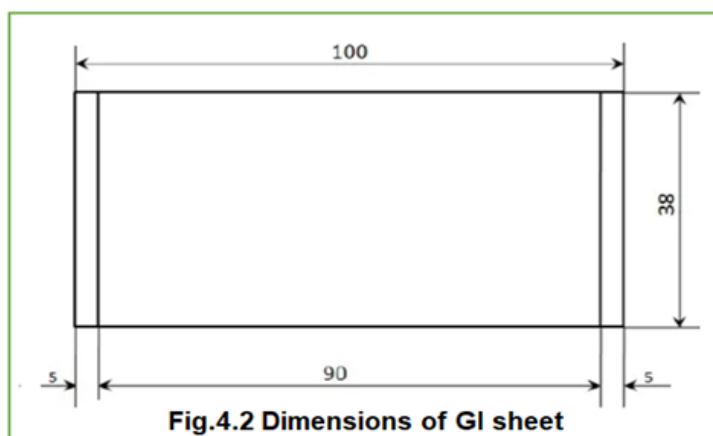
Try

1. Construct the open scoop as depicted in Fig. 4.3

2. create the hexagonal prism as shown in Fig.4.4

Fig.4.4 Surface development of hexagonal prism
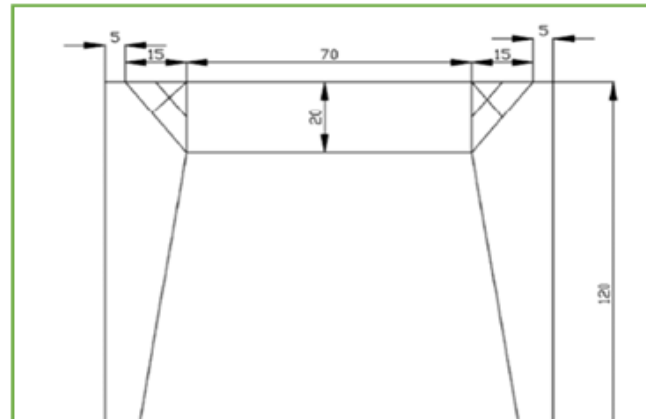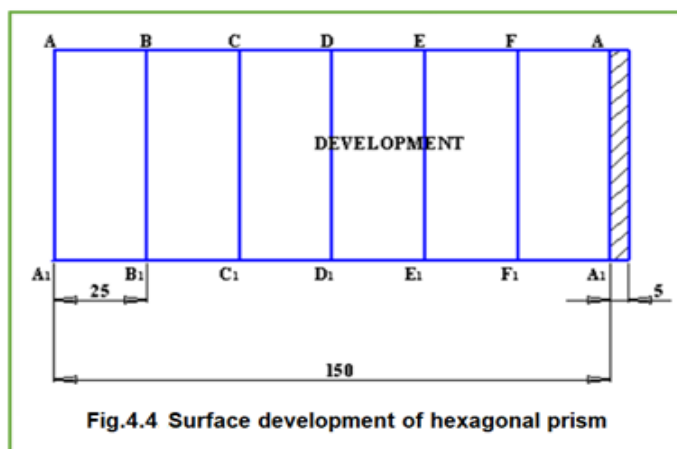
5. Introduction to black smithy

Black smithy or Forging is an oldest shaping process used for the producing small articles for which accuracy in size is not so important. The parts are shaped by heating them in an open fire or hearth by the blacksmith and shaping them through applying compressive forces using hammer. Thus forging is defined as the plastic deformation of metals at elevated temperatures into a predetermined size or shape using compressive forces exerted through some means of hand hammers, small power hammers, die, press or upsetting machine. It consists essentially of changing or altering the shape and section of metal by hammering at a temperature of about 980°C, at which the metal is entirely plastic and can be easily deformed or shaped under pressure. The shop in which the various forging operations are carried out is known as the smithy or smith's shop.

5.1. Experiments on black smithy
1. Make the s-hook as depicted in Fig. 5.1 using the mild steel rod provided.
2. Construct the J-hook using the given mild steel rod as indicated in Fig. 5.2.

3.

Fig.5.1 Dimensions of S-hook

Fig.5.2 Dimensions of J-hook
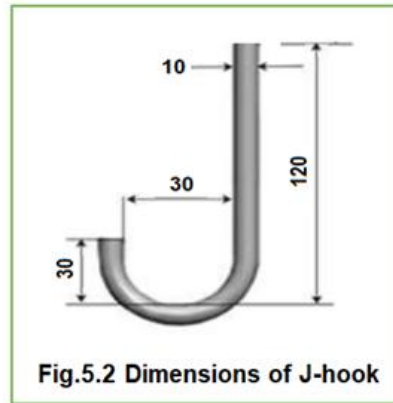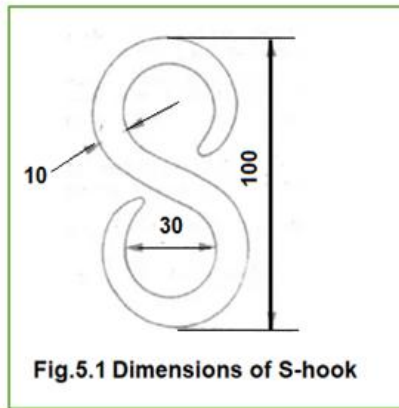
Try

1 Create the C - hook with the given mild steel rod as shown in Fig. 5.3
2 Prepare the U - bend with the given mild steel rod as shown in Fig. 5.4

Fig.5.3 Dimensions of C-hook

Fig.5.4 Dimensions of U-hook
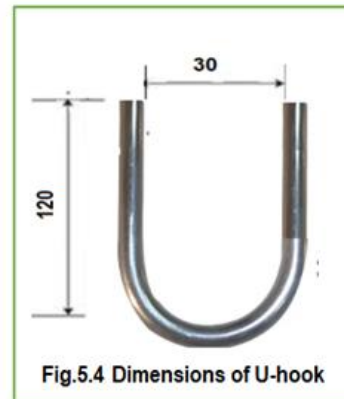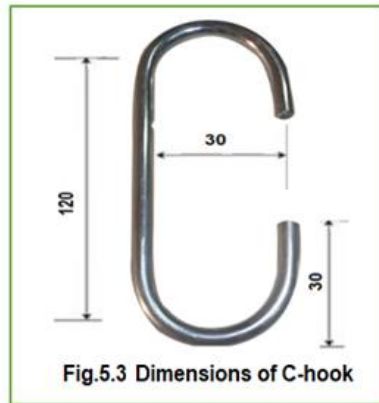
6. Introduction to plumbing

Plumbing is a skilled trade of working with pipes or tubes and plumbing fixtures. The process is mainly used for the supply of drinking water and the drainage of waste water, sometimes mixed with waste floating materials in a living or working place. A plumber is someone who installs or repairs piping systems, plumbing fixtures and equipment such as valves, washbasins, water heaters, waterclosests, etc. Thus it usually refers to a system of pipes and fixtures installed in a building for the distribution of water and the removal of waterborne wastes.

6.1. Experiments and demonstration on plumbing

1.Form of PVC pipe fitting through various components as shown in Fig. 6.1

Fig.6.1 PVC components for pipe fittings
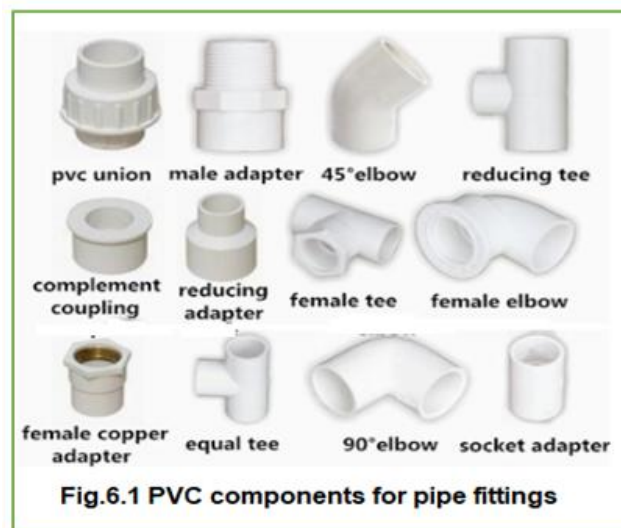
2. Form of GI pipe fitting with various components, as shown in Fig. 6.2

Fig.6.2 GI componets for pipe fittings

Try

1. Form of PVC pipe fitting with reducer for water tap with different components as shown in Fig. 6.1
2. Form of GI pipe fitting with different components as shown in Fig. 6.2 for different fluids.

7. Introduction to moulding

Moulding is the process of manufacturing by shaping liquid or pliable raw material using a rigid frame called a mold or matrix. This itself may have been made using a pattern or model of the final object.

A mould is a hollowed-out block that is filled with a liquid or pliable material such as plastic, glass, metal, or ceramic raw material. The liquid hardens or sets inside the mould, adopting its shape. A mould is a counterpart to a cast. The very common bi-valve moulding process uses two moulds, one for each half of the object.

7.1. Experiments on mechanical components moulding (casting process)

1. Making of flange mould using a given pattern as shown in Fig.7.1

Fig.7.1 Flange coupling pattern
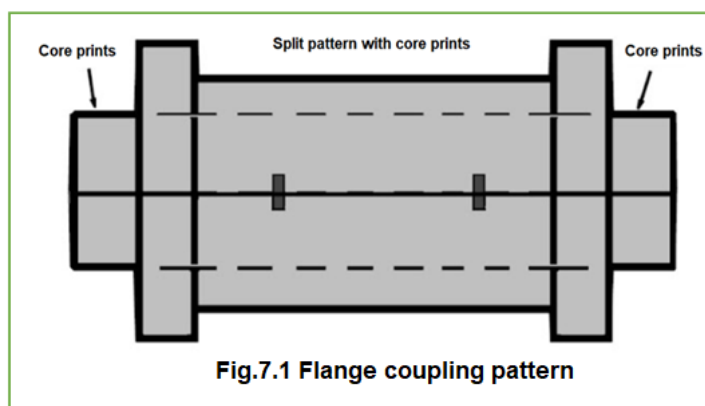
2. Utilizing the provided pattern, create the bearing housing mould as shown in Fig. 7.2.

Fig.7.2 Bearing housing
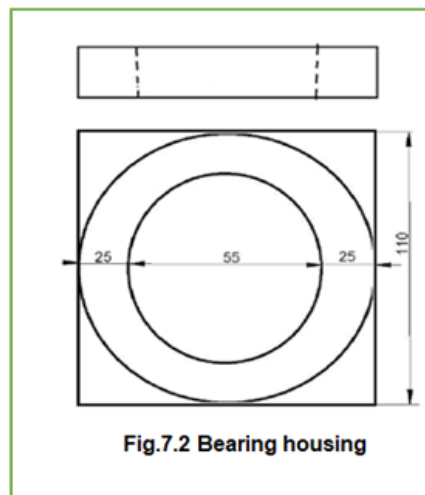
Try

1. Making of dumble using a given pattern as shown in Fig.7.3
2. Using a single piece pattern, create a one-stepped shaft as shown in Fig. 7.4.

Fig.7.3 Dumble mould pattern

Fig.7.4 Single stpeped shaft
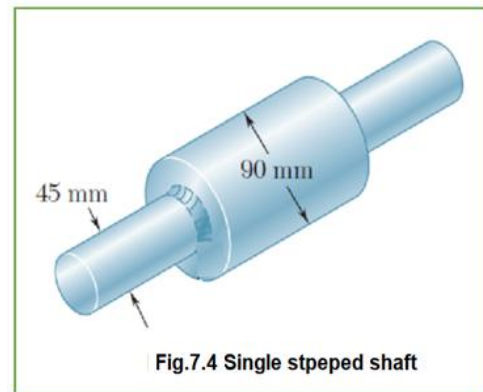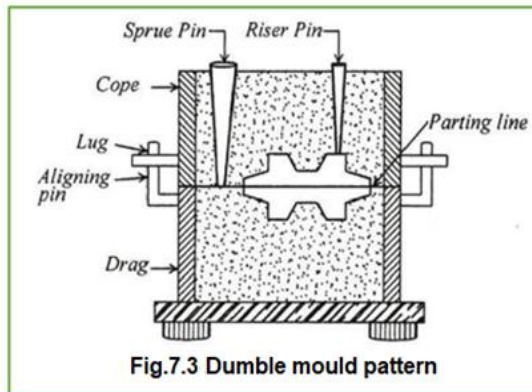
8. Introduction to concrete moulding and plaster of paris

Concrete is characterized by the type of aggregate or cement used, by the specific qualities it manifests, or by the methods used to produce it. In ordinary structural concrete, the character of the concrete is largely determined by a water-to-cement ratio. The lower the water content, all else being equal, the stronger the concrete. The mixture must have just enough water to ensure that each aggregate particle is completely surrounded by the cement paste, that the spaces between the aggregate are filled, and that the concrete is liquid enough to be poured and spread effectively.

Plaster of Paris is a white powder made from gypsum that mixes with water to form a paste that hardens quickly and is used chiefly for casts and moulds. It can be effectively worked with metal apparatuses or even abrasive sheets and can be shaped as per requirements. It is often applied in the form of a quick-setting paste with water.

8.1. Experiment on concrete/cement cube moulding and demonstration on plaster of paris mould making

1. Preparation of concrete cube by moulding technique as shown in Fig.8.1

Fig.8.1 Dimensions of concrete cube
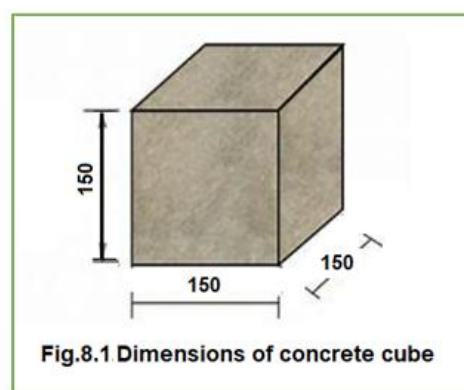
2. Demonstration on plaster of paris mould making.

Try

1. Preparation of any house hold specimens by plaster of paris mould making as shown in Fig. 8.2
2. Preparation of any intricate article by plaster of paris mould making as shown in Fig. 8.3

Fig.8.2 Plaster of paris House hold specimens

Fig.8.3 Plaster of paris intricate article

9. Introduction to hard soldering

Hard (silver) soldering (>450 °C) – Brass or silver is the bonding metal used in this process, and requires a blowtorch to achieve the temperatures at which the solder metals. Hard soldering is used to join precision components such as ferrous, brass, and copper.

9.1. Experiments on hard soldering

1. Soldering of two mild steel plates as shown in Fig. 9.1
2. Hard soldering of engine valve tappet as shown in Fig. 9.2

Fig.9.1 Soldering of mild steel plates

Fig.9.2 Engine valve tappet

Try

1. Hard soldering of copper with brass as shown in Fig.9.3
2. Hard soldering of stainless steel with brass as shown in Fig.9.4

Fig.9.3 Hard soldering of copper with brass

Fig.9.4 Hard soldering of stainless steel with brass

10. Demonstration on Computer Numerically Controlled (CNC) lathe

CNC turning is a highly precise and efficient subtractive machining process that works on the principle of the lathe machine. It involves placing the cutting tool against a turning workpiece to remove materials and give the desired shape.

Fig.10.1 CNC lathe

1. Demonstration of the plain turning process on a CNC lathe as shown in Fg.10.1
2. Demonstration of facing operations on a CNC lathe as shown in Fg.10.1.

11. Demonstration on Computer Numerically Controlled (CNC) milling

CNC milling involves cutting a prismatic workpiece using multipoint cutting tools producing precision components used in automotive and aeronautical industries.

Fig.11.1 CNC machining centre

1. Demonstration of plain milling (facing) on CNC milling as shown in Fig.11.1
2. Demonstration of precision slotting on CNC milling as shown in Fig.11.1.

12. Demonstration on 3D printing machine

3D printing or additive manufacturing enables to produce geometrically complex objects, shapes and textures. It often uses less material than traditional manufacturing methods and allows the production of prototypes / products that are not possible to produce economically with conventional manufacturing.
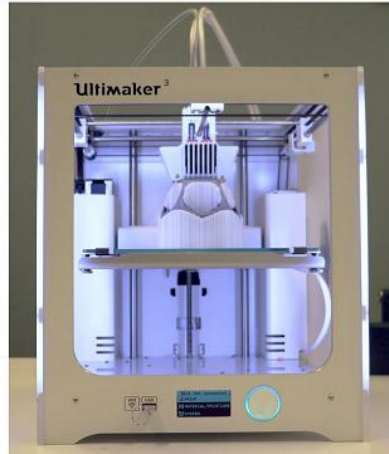
Fig.12.1 3D printer

1. Demonstration of 3D printing machine as shown in Fig.12.1 using Acrylonitrile butadiene styrene (ABS) material
2. Demonstration of 3D printing machine as shown in Fig.12.1 using Polylactic acid (PLA) material.

13. Demonstration on 6- axis robot

Robots have seen in recent years an expansion of their field of use with new requirements related to the increasing use of composites. The robots are then considered for machining operations (polishing, cutting, drilling etc.) that require high performance in terms of position, orientation, followed by trajectory precision and stiffness. The evolution of the performance of robots and programming software provides new machining solutions. For complex parts, six axis robots offer more accessibility than a machining center CNC 5 axis and allow the integration of additional axes to extend the workspace.

Fig.13.1 6-Axis robot

1. Demonstration of the 6 – axis aristo robot as shown in Fig.13.1.
2. Demonstration of aristo sim software for robot movements and control.

14. Demonstration on cylindrical grinding machine

Most commonly, cylindrical grinding is used for grinding pieces with a central axis of rotation, like rods and cylinders. This process involves using a cylindrical grinder, which is a type of machinery categorized by rotation style and wheel device.

A grinding machine uses an abrasive product usually a rotating wheel to shape and finish a workpiece by removing metal and generating a surface within a given tolerance. A grinding wheel is made with abrasive grains bonded together. Each grain acts as a cutting tool, removing tiny chips from the workpiece.

Fig.14.1 Cylindrical grinding machine

1. Demonstration of grinding process on a cylindrical grinding machine as shown in Fig.14.1
2. Demonstration of shaft grinding process on a cylindrical grinding machine as shown in Fig.14.1

V. TEXT BOOKS:

1. Hajra Choudhury S.K., Hajra Choudhury A.K. and NirjharRoy S.K., *"Elements of Workshop Technology"*, Media promoters and publishers private limited, Mumbai, 4th Edition ,2020.
2. Kalpakjian S, Steven S. Schmid, *"Manufacturing Engineering and Technology"*, Pearson Education India Edition, 7th Edition, 2019.
3. Gowri P. Hariharan, A. Suresh Babu," *Manufacturing Technology – I*", Pearson Education, 3rd Edition, 2018.

VI. REFERENCE BOOKS:

1. Gowri P. Hariharan, A. Suresh Babu, *"Manufacturing Technology – I"*, Pearson Education, 5th Edition, 2018.
2. Roy A. Lindberg, *"Processes and Materials of Manufacture",* Prentice Hall India, 4th Edition, 2017.
3. Rao P.N., "*Manufacturing Technology"*, Vol. I and Vol. II, Tata McGraw-Hill House, 2017.

VII. ELECTRONICS RESOURCES:

1. https://elearn.nptel.ac.in/shop/iit-workshops/ongoing/additive-manufacturing-technologies-for-practicing-engineers/.
2. https://akanksha.iare.ac.in/index?route=course/details&course_id=337

VIII. MATERIALS ONLINE:

1. Course Template
2. Laboratory manual

COURSE CONTENT

ENGINEERING CHEMISTRY							
I Semester: CSE/ IT **II Semester: AE / ME / CE / ECE / EEE/ CSE (AI & ML) /CSE(DS)**							
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
AHSE03	**Foundation**	**L**	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
		3	-	-	3	40	60	100
Contact Classes: 48	**Tutorial Classes: Nil**	**Practical Classes: Nil**				**Total Classes: 48**		
Prerequisite: Basic principles of chemistry								

I. COURSE OVERVIEW:

The course focuses on the fundamental concepts of chemistry and then builds an interface with their industrial applications. It deals with the water purification processes, electrochemical principles in batteries, corrosion of metallic structures and preventive methods to control corrosion in metals, engineering materials such as plastics, fibers and elastomers, biodegradable polymers, renewable and non-renewable energy resources, nanomaterials, lubricants, biosensors and spectroscopic techniques leading to diverse applications across various fields, It cultivates the students to identify chemistry in each piece of finely engineered products used i n industries.

II. COURSES OBJECTIVES:
The students will try to learn

V. The different parameters to remove causes of hardness of water and their reactions towards complexometric method.
VI. The concepts of electrochemical principles and causes of corrosion in the new developments and breakthroughs efficiently in engineering and technology.
VII. The fundamental knowledge of conventional and non conventional energy sources and their applications in engineering.
VIII. The different types of materials with respect to mechanisms and its significance in industrial applications.

III. COURSE OUTCOMES:
At the end of the course students should be able to:

CO1   Interpret the water quality characteristics for its usage in domestic and industrial purposes.
CO2   Use complexometry for calculation of hardness of water to avoid industrial problems.
CO3   Implement the principles of electrochemical systems to control the corrosion in metals.
CO4   Extend the applications of polymers based on their degradability and properties.
CO5   Choose the appropriate fuel based on their calorific value for energy efficient processes.
CO6   Predict the knowledge on viability of advanced materials for technological improvements in various sectors.

IV. COURSE CONTENT:

MODULE-I: WATER AND ITS TREATMENT (10)

Introduction: Hardness, types, degree of hardness and units ; estimation of temporary and permanent hardness of water by complexometric method, numerical problems; Potable water and its specifications (WHO), steps involved in treatment of potable water, disinfection of potable water by chlorination and breakpoint chlorination; Internal treatment of boiler feed water: Calgon conditioning, phosphate conditioning and colloidal conditioning; external treatment methods: Softening of water by ion-exchange processes; desalination of brackish water, reverse osmosis.

MODULE-II: ELECTROCHEMISTRY AND CORROSION (10)

Introduction: Electrode potential, standard electrode potential, Nernst equation (no derivation); Electrochemical cells: Galvanic cell, cell representation, EMF of cell, numerical problems; Batteries: classification of batteries, construction, working and applications of Zinc-air and Li-ion battery; Corrosion: Definition, Causes and effects of corrosion; Theories of corrosion: Chemical and electrochemical theories of corrosion; Corrosion control methods: Cathodic protection methods, sacrificial anode and impressed current methods.

MODULE-III: POLYMERS (9)

Polymers: Classification of polymers; types of polymerization-addition and condensation polymerization; Plastics, elastomers and fibers: Preparation, properties and applications of PVC, Buna-S and Nylon 6,6; Differences between thermoplastics and thermosetting plastics;

Conducting polymers: Definition, classification with examples, mechanism of conduction in trans poly acetylene and applications of conducting polymers; Biodegradable polymers: poly lactic acid and their applications.

MODULE–IV: ENERGY SOURCES (10)

Introduction and characteristics of good fuel; Fossil fuels: Introduction, classification, petroleum, refining of crude oil; Cracking: Definition, types of cracking, moving bed catalytic cracking. LPG and CNG composition and uses; Synthetic fuel: Fischer-Tropsch process; Alternative and non-conventional sources of energy: solar, wind and hydropower advantages and disadvantages; Calorific value: units, HCV and LCV and Dulongs formula, numerical problems.

MODULE-V: ADVANCED FUNCTIONAL MATERIALS (9)

Nanomaterials: Introduction, preparation of nanomaterials by sol-gel method, chemical reduction method and applications of nanomaterials. Biosensors: Definition, Amperometric glucose monitor sensor; IR spectroscopy in night vision-security; Pollution Under Control, CO sensor, Passive Infrared detection; Raman spectroscopy application, Tumour detection in medical applications; Lubricants: characteristics of a good lubricant; properties of lubricants: viscosity, flash and fire point, cloud and pour point.

V. TEXT BOOKS:

3. JAIN &JAIN, P.C. Jain, Monika Jain, *Engineering Chemistry* , Dhanpat Rai publishing Company (P) limited, 17th edition, 2022.
4. Shashi Chawla, *Text Book of Engineering Chemistry*, Dhanat Rai and Company (P) Limited, 1st Edition, 2017.

VI. REFERENCE BOOKS:

1. Ramadevi, Dr, P Aparna and Rath, Cengage learning, 13th edition, 2025.
2. Donald. J Leo, Wiley, Engineering analysis of smart material systems, 1st Edition, 2007.
3. **Nitin K Puri, Nanomaterials Synthesis Properties and Applications, I K international publishing house**
pvt Ltd,1st edition **2021.**

VII. ELECTRONICS RESOURCES:

6. Engineering chemistry (NPTEL Web-book), by B. L. Tembe, Kamaluddin and M. S.Krishnan.http://www.cdeep.iitb.ac.in/webpage_data/nptel/Core%20Science/Engineering%20Chemistry%201/About- Faculty.html
7. https://books.google.co.in/books?id=R1JtyILNIsAC&pg=PR3&source=gbs_selected_pages&cad=3#v=onepage&q&f=false
8. https://books.google.co.in/books?id=eQTLCgAAQBAJ&pg=SA1PA53&source=gbs_selected_pages&cad=3#v=onepage&q&f=false

VIII. MATERIALS ONLINE

12. Course template
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17. Assignments
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COURSE CONTENT

ORDINARY DIFFERENTIAL EQUATIONS AND VECTOR CALCULUS

II Semester: AE / ME / CE / ECE / EEE / CSE / CSE (AI&ML) / CSE (DS) / IT

Course Code	Category	Hours/Week			Credits	Maximum Marks		
		L	T	P	C	CIA	SEE	Total
AHSE08	Foundation	3	-	-	3	40	60	100
Contact Classes: 48	Tutorial Classes: Nil	Practical Classes: Nil				Total Classes: 48		
Prerequisite: Basic Principles of Matrices and Calculus								

I. COURSE OVERVIEW:

This course serves as a foundation course on differential equations and vector calculus. It includes techniques for solving ordinary differential equations, partial differential equations, vector differentiation and vector integration. It is designed to extract the mathematical developments, skills, from basic concepts to advance level of engineering problems to meet the technological challenges.

II. COURSE OBJECTIVES:
The students will try to learn:

I	The analytical methods for solving first and higher order differential equations with constant coefficients.
II	The analytical methods for formation and solving partial differential equations.
III	The physical quantities of vector valued functions involved in engineering field.
IV	The logic of vector theorems for finding line, surface and volume integrals.

III. COURSE OUTCOMES:
At the end of the course students should be able to:

CO1	Utilize the methods of differential equations for solving the orthogonal trajectories and Newton's law of cooling. cooling.
CO2	Solve the higher order linear differential equations with constant coefficients by using method of variation of parameters.
CO3	Make use of analytical methods for PDE formation to solve boundary value problems.
CO4	Identify various techniques of Lagrange's method for solving linear partial differential equations which occur in science and engineering.
CO5	Interpret the vector differential operators and their relationships for solving engineering problems.
CO6	Apply the integral transformations to surface, volume and line of different geometrical models in the domain of engineering.

IV. COURSE CONTENT:

MODULE-I: FIRST ORDER ORDINARY DIFFERENTIAL EQUATIONS (09)
Exact differential equations, equations reducible to exact differential equations, linear and Bernoulli's equations, orthogonal trajectories (only in cartesian coordinates). Applications: Newton's law of cooling, law of natural growth and decay.

MODULE-II: ORDINARY DIFFERENTIAL EQUATIONS OF HIGHER ORDER (10)
Higher order linear differential equations with constant coefficients: non-homogeneous terms of the type $e^{ax}, \sin ax, \cos ax,$ polynomials in $x, e^{ax}V(x)$ and $x\,V(x),$ method of variation of parameters.

MODULE-III: LAPLACE TRANSFORMS (10)
Laplace transforms: Laplace transform of standard functions, first shifting theorem, Laplace transforms of functions multiplied by 't' and divided by 't', Laplace transforms of derivatives and integrals of function, evaluation of integrals by Laplace transforms, Laplace transform of periodic functions.

Inverse Laplace transform by different methods, Convolution theorem (without proof). Applications: solving initial value problems by Laplace transform method

MODULE–IV: VECTOR DIFFERNTIATION (09)
Vector point functions and scalar point functions, gradient, divergence and curl, directional derivatives, vector identities, scalar potential functions, solenoidal and irrotational vectors.
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MODULE–V: VECTOR INTEGRATION (10)
Line, surface and volume integrals. theorems of Green, Gauss and Stokes (without proofs) and their applications.

V. TEXT BOOKS:
1. B. S. Grewal, *Higher Engineering Mathematics*, 44/e, Khanna Publishers, 2017.
2. Erwin Kreyszig, *Advanced Engineering Mathematics*, 10/e, John Wiley & Sons, 2011.

VI. REFERENCE BOOKS:
1. R. K. Jain and S. R. K. Iyengar, *Advanced Engineering Mathematics*, 3/ed, Narosa Publications, 5th Edition, 2016.
2. George B. Thomas, Maurice D. Weir and Joel Hass, Thomas, *Calculus*, 13/e, Pearson Publishers, 2013.
3. N.P.Bali and Manish Goyal, *A text book of Engineering Mathematics*, Laxmi Publications, Reprint, 2008
4. Dean G. Duffy, *Advanced Engineering Mathematics with MATLAB*, CRC Press.
5. Peter O'Neil *Advanced Engineering Mathematics*, Cengage Learning.
6. B.V. Ramana, *Higher Engineering Mathematics*, McGraw Hill Education.

VII. ELECTRONIC RESOURCES:
1. Engineering Mathematics - I, By Prof. Jitendra Kumar
   |https://onlinecourses.nptel.ac.in/noc23_ma88/preview
2. Advanced Calculus for Engineers, By Prof. Jitendra Kumar, Prof. Somesh Kumar
   https://onlinecourses.nptel.ac.in/noc23_ma86/preview
3. http://www.efunda.com/math/math_home/math.cfm
4. http://www.ocw.mit.edu/resourcs/#Mathematics
5. http://www.sosmath.com
6. http://www.mathworld.wolfram.com

VIII. MATERIAL ONLINE:
12. Course template
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COURSE CONTENT

NETWORK ANALYSIS AND SYNTHESIS							
II Semester: EEE / ECE							
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
		L	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
AEEE04	**Foundation**	3	0	0	3	40	60	100
Contact Classes: 48	**Tutorial Classes: Nil**	**Practical Classes: Nil**				**Total Classes: 48**		
Prerequisite: Matrices and Calculus and Electrical Circuits								

I. COURSE OVERVIEW:
This course covers transient and steady-state analysis of RL, RC, and RLC circuits in both series and parallel configurations. It introduces Laplace transform techniques for circuit analysis and applications. The course also covers two-port network parameters and their interconnections. Additionally, it explores filter design concepts, including low-pass, high-pass, band-pass, and band-stop filters, and attenuators and network synthesis.

II. COURSE OBJECTIVES:
The students will try to learn:
I.   The RL, RC, and RLC circuits under different excitations using integro-differential and Laplace transform approaches.
II.   The two-port electrical networks and apply network topology concepts like tie-set and cut-set matrices for circuit analysis.
III. The various filter and attenuator configurations for frequency-selective and signal conditioning applications.
IV.   The electrical networks using driving-point functions, positive real functions, and classical synthesis methods such as Foster and Cauer forms.

III. COURSE OUTCOMES:
The students will try to learn:
CO1   Observe the response of transient and steady state analysis of RL, RC and RLC circuits (Series and Parallel).
CO2   Examine the behavior of circuits using Laplace transforms
CO3   Synthesize and manipulate abstruse network topology constructs to derive and interpret tie-set and cut-set matrices for intricate electrical networks.
CO4   Design and critically evaluate multifaceted constant-K and M-derived filter architectures across diverse frequency spectra, employing advanced network synthesis principles.
CO5   Apply different types of attenuators and equalizers to control signal strength and improve sound or signal quality in networks.
CO6   Learn to analyze and design different network types using impedance, admittance, poles, and zeros, and apply methods to create LC, RC, and RL circuits.

IV. COURSE CONTENT:

MODULE-I: TRANSIENT ANALYSIS (10)
Significance of Initial conditions of R, L and C elements.
Transient response of series RL, RC and RLC circuits using integro-differential approach for DC and Sinusoidal excitations.
Transient response of parallel RL, RC and RLC circuits using integro-differential approach for DC and Sinusoidal excitations.

MODULE-II: ELECTRICAL CIRCUIT ANALYSIS USING LAPLACE TRANSFORMS (10)
Laplace Transforms of step, ramp, exponential, impulse functions (inputs).
Transient response of series RL, RC and RLC circuits using Laplace Transforms approach for DC and Sinusoidal excitations.
Transient response of parallel RL, RC and RLC circuits using Laplace Transforms approach for DC and Sinusoidal excitations.

MODULE-III: TWO PORT NETWORK PARAMETERS AND NETWORK TOPOLOGY (09)
Two port network parameters: Open circuit impedance, short-circuit admittance, Transmission, Hybrid parameters & inter-relationships, Series, parallel and cascade connection of two port networks

Network Topology: Graph, tree, chord, Tie-set, cut-set, incident matrices, Problems on Tie-set and cut-set matrices.

MODULE-IV: FILTERS AND ATTENUATORS (10)
Filters: Classification of Filters, Filter Networks, Constant-K Filters-Low pass, high pass, Band pass, band-stop filters, M-derived Filters- T and π filters- Low pass, high pass.
Attenuators: Types – T, π , L, Bridge T and lattice ,Asymmetrical Attenuators T, π , L Equalizers- Types- Series, Shunt, Constant resistance, bridge T attenuation, bridge T phase, Lattice attenuation, lattice Phase equalizers

MODULE-V: NETWORK SYNTHESIS (09)
Network Synthesis: Driving point impedance and admittance, transfer impedance and admittance, network functions of Ladder and non-ladder networks, Poles, Zeros analysis of network functions, Hurwitz polynomials, Positive Real Functions, synthesis of LC, RC and RL Functions by foster and causer methods.

V. TEXT BOOKS:
1. Van Valkenburg M.E, "Network Analysis", Prentice Hall of India, 3rd Edition, 2000.
2. Ravish R Singh, "Network Analysis and Synthesis", McGraw Hill, 2nd Edition, 2019.

VI. REFERENCE BOOKS:
1. B. Subramanyam, "Electric Circuit Analysis", Dreamtech Press & Wiley, 2021.
2. James W.Nilsson, Susan A.Riedel, "Electric Circuits", Pearson, 11th Edition, 2020.
3. A Sudhakar, Shyammohan S Palli, "Circuits and Networks: Analysis and Synthesis", McGraw Hill, 5th Edition, 2017.
4. Jagan N.C, Lakshrninarayana C., "Network Analysis", B.S. Publications, 3rd Edition, 2014.
5. William Hayt H, Kimmerly Jack E. and Steven Durbin M, "Engineering Circuit Analysis", McGraw Hill, 6th Edition, 2002.
6. Chakravarthy A., "Circuit Theory", Dhanpat Rai & Co., First Edition, 1999.

VII. ELECTRONIC RESOURCES:
1. https://nptel.ac.in/courses/108/104/108104139/
2. https://www.researchgate.net
3. https://www.electrical4u.com
4. https://www.iare.ac.in

VIII. MATERIALS ONLINE:
1. Course template
2. Tutorial question bank
3. Tech talk topics
4. Open end experiments
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7. Model question paper - I
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COURSE CONTENT

DATA STRUCTURES							
II Semester: AE / ME / CE / ECE / EEE / CSE / IT / CSE (AI&ML) / CSE (DS)							
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		

Course Code	**Category**	**L**	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
ACSE05	**Core**	3	-	-	3	40	60	100
Contact Classes: 48	**Tutorial Classes: Nil**	**Practical Classes: Nil**				**Total Classes: 48**		
Prerequisite: Essentials of Problem Solving								

I. COURSE OVERVIEW:

The course covers some of the general-purpose data structures and algorithms, and software development. Topics covered include managing complexity, analysis, static data structures, dynamic data structures and hashing mechanisms. The main objective of the course is to teach the students how to select and design data structures and algorithms that are appropriate for problems that they might encounter in real life. This course reaches to student by power point presentations, lecture notes, and lab which involve the problem solving in mathematical and engineering areas.

II. COURSES OBJECTIVES:

The students will try to learn

I. The skills needed to understand and analyze performance trade-offs of different algorithms / implementations and asymptotic analysis of their running time and memory usage.
II. The basic abstract data types (ADT) and associated algorithms: stacks, queues, lists, tree, graphs, hashing and sorting, selection and searching.
III. The fundamentals of how to store, retrieve, and process data efficiently.
IV. The implementing these data structures and algorithms in Python.
V. The essential for future programming and software engineering courses.

III. COURSE OUTCOMES:

At the end of the course students should be able to:

CO 1 Interpret the complexity of the algorithm using the asymptotic notations.
CO 2 Select the appropriate searching and sorting technique for a given problem
CO 3 Construct programs on performing operations on linear and nonlinear data structures for organization of a data
CO 4 Make use of linear data structures and nonlinear data structures solving real-time applications.
CO 5 Describe hashing techniques and collision resolution methods for accessing data with respect to performance
CO 6 Compare various types of data structures; in terms of implementation, operations and performance.

IV. COURSE CONTENT:

MODULE – I: INTRODUCTION TO DATA STRUCTURES, SEARCHING AND SORTING (09)

Basic concepts: Introduction to data structures, classification of data structures, operations on data structures, Algorithm Specification, Recursive algorithms, Data Abstraction, Performance analysis- time complexity and space complexity, Introduction to Linear and Non Linear data structures,Searching techniques: Linear and Binary search, Uniform Binary Search, Interpolation Search, Fibonacci Search; Sorting techniques: Bubble, Selection, Insertion, and Quick, Merge, Radix and Shell Sort and comparison of sorting algorithms.

MODULE – II: LINEAR DATA STRUCTURES (09)

Stacks: Stack ADT, definition and operations, Implementations of stacks using array, applications of stacks, Arithmetic expression conversion and evaluation; Queues: Primitive operations; Implementation of queues using

Arrays, applications of linear queue, circular queue and double ended queue (deque).

MODULE – III: LINKED LISTS (09)

Linked lists: Introduction, singly linked list, representation of a linked list in memory, operations on a single linked list; Applications of linked lists: Polynomial representation and sparse matrix manipulation.

Types of linked lists: Circular linked lists, doubly linked lists; Linked list representation and operations of Stack,linked list representation and operations of queue.

MODULE – IV: NON LINEAR DATA STRUCTURES (09)

Trees: Basic concept, binary tree, binary tree representation, array and linked representations, binary tree traversal, binary tree variants, threaded binary trees, application of trees, Graphs: Basic concept, graph terminology, Graph Representations - Adjacency matrix, Adjacency lists, graph implementation, Graph traversals – BFS, DFS, Application of graphs, Minimum spanning trees – Prims and Kruskal algorithms.

MODULE – V: BINARY TREES AND HASHING (09)

Binary search trees: Binary search trees, properties and operations; Balanced search trees: AVL trees; Introduction to M- Way search trees, B trees; Hashing and collision: Introduction, hash tables, hash functions,collisions, applications of hashing.

V. TEXT BOOKS:

1. Rance D. Necaise, "Data Structures and Algorithms using Python", Wiley Student Edition.
2. Benjamin Baka, David Julian, "Python Data Structures and Algorithms", Packt Publishers, 2017.

VI. REFERENCE BOOKS:

1. S. Lipschutz, "Data Structures", Tata McGraw Hill Education, 1st edition, 2008.
2. D. Samanta, "Classic Data Structures", PHI Learning, 2nd edition, 2004.

VII. ELECTRONIC RESOURCES:

1. https://www.tutorialspoint.com/data_structures_algorithms/algorithms_basics.htm
2. https://www.codechef.com/certification/data-structures-and-algorithms/prepare
3. https://www.cs.auckland.ac.nz/software/AlgAnim/dsToC.html
4. https://online-learning.harvard.edu/course/data-structures-and-algorithms

VIII. MATERIALS ONLINE

1   Course template
2   Tutorial question bank
3   Tech talk topics
4   Assignments
5   Definitions and terminology
6   Open ended experiments
7   Model question paper-I
8   Model question paper-II
9   Lecture notes
10 Power point presentations
11 ELRV videos

COURSE CONTENT

ESSENTIALS OF PROBLEM SOLVING							
I Semester: CSE / IT / CSE (AI&ML) / CSE (DS) **II Semester:** ECE / EEE							
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
ACSE02	**Foundation**	**L**	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
		3	0	0	3	40	60	100
Contact Classes: 48	**Tutorial Classes: Nil**	**Practical Classes: Nil**				**Total Classes: 48**		
Prerequisite: There is no prerequisite to take this course								

I. COURSE OVERVIEW:

This course aims to provide exposure to problem solving through programming. Useful graph theory concepts, numerical techniques, and their applications to real world problems are discussed. Graph theoretical notions and the use of algorithms, both in the mathematical theory of graphs and its applications are discussed. Student will also learn how to implement and interpret numerical solutions by writing a well-designed computer programs in regard to their efficiency and suitability for real-life applications.

II. COURSES OBJECTIVES:

The students will try to learn
I. The fundamental concepts of graph theory and its properties.
II. The basics related to paths and cycles using Eulerian and Hamiltonian cycles.
III. The applications of graph colouring and traversal algorithms for solving real-time problems.
IV. The numerical methods to solve algebraic equations.

III. COURSE OUTCOMES:

At the end of the course students should be able to:

CO1   Outline the graph terminologies, graph representation, and relate them to practical examples.

CO2   Build efficient graph routing algorithms for various optimization problems on graphs.

CO3   Use effective techniques from graph theory to solve problems in networking and telecommunication.

CO4   Interpret the fundamental concepts of polynomials, roots of equations and solve corresponding problems using computer programs.

CO5   Apply the knowledge of numerical methods to solve algebraic and transcendental equations arising in real-life situations.

CO6   Solve numerical integrals and ordinary differential equations to simulate discrete time algorithms.

IV. COURSE CONTENT:

MODULE - I GRAPH THEORY (08)
Graph terminology, digraphs, weighted graphs, complete graphs, graph complements, bipartite graphs, graph combinations, isomorphisms, matrix representations of graphs, incidence and adjacency matrices, degree sequence.

MODULE - II GRAPH ROUTES (10)
Eulerian circuit: Konigsberg bridge problem, touring a graph; Eulerian graphs, Hamiltonian cycles, the traveling salesman problem; Shortest paths: Dijkstra's algorithm, walks using matrices.

MODULE - III GRAPH COLORING AND GRAPH ALGORITHMS (10)
Four color theorem, vertex coloring, edge coloring, coloring variations, first-fit coloring algorithm.

Graph traversal: depth-first search, bread-first search and its applications; Minimum spanning trees: Kruskal's and Prim's algorithm, union-find structure.

MODULE - IV: ALGEBRAIC AND TRANSCENDENTAL EQUATIONS (10)
Algebraic equations, method of false position, bisection method, iteration method, Newton-Raphson method, Secant method, Ramanujan's Method, Muller's method (Approximation up to 2 decimals only).

MODULE - V: NUMERICAL INTEGRATION AND ORDINARY DIFFERENTIATIAL EQUATIONS (10)
Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule, Solution by Taylor's series, Euler's method of solving an ordinary differential equation numerically, Runge-Kutta's second order method of solving ordinary differential equations (Approximation up to 2 decimals only).

V. TEXT BOOKS:
4. Karin R Saoub, *Graph Theory: An Introduction to Proofs, Algorithms, and Applications*, 1st edition, Chapman and Hall, 2021.
5. S S Sastry, *Introductory Methods of Numerical Analysis*, 5th edition, 2012.

VI. REFERENCE BOOKS:
1. Mahinder Kumar Jain, *Numerical Methods: For Scientific and Scientific Computation*, New Age International Pvt. Ltd., 7th edition, 2019.
2. P Kandasamy, K Thilagavathy, K Gunavathi, *Numerical Methods*, S Chand and Company, 2006.
3. R Balakrishnan, K Ranganathan, *A Textbook of Graph Theory*, Springer Exclusive, 2nd edition, 2019.
4. Jann Kiusalaas, *Numerical Methods in Engineering with Python*, Cambridge University Press, 2nd edition 2010.
5. Gary Chartrand, Ping Zhang, *A First Course in Graph Theory*, Dover Publications Inc., 2012.
6. James F. Epperson, *An Introduction to Numerical Methods and Analysis*, Wiley, 2nd edition, 2013.

VII. ELECTRONICS RESOURCES:
1. https://www.geeksforgeeks.org/numerical-methods-and-calculus-gq/
2. https://www.geeksforgeeks.org/program-for-bisection-method/
3. https://ocw.mit.edu/courses/2-993j-introduction-to-numerical-analysis-for-engineering-13-002j-spring-2005/pages/lecture-notes/
4. https://www.tutorialspoint.com/graphs-and-its-traversal-algorithms
5. https://web.mit.edu/urban_or_book/www/book/chapter6/6.4.4.html
6. https://www.hackerearth.com/practice/algorithms/graphs/minimum-spanning-tree/tutorial/
7. https://www.codingninjas.com/studio/library/euler-and-hamilton-paths

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COURSE CONTENT

ENGINEERING CHEMISTRY LABORATORY								
I Semester: CSE / IT								
II Semester: AE / ME / CE / ECE / EEE / CSE (AI&ML) / CSE (DS)								
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
AHSE06	**Foundation**	**L**	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
		-	-	2	1	40	60	100
Contact Classes: Nil	**Tutorial Classes: Nil**	**Practical Classes: 36**				**Total Classes: 36**		
Prerequisite: Basic Principles of Chemistry								

I. COURSE OVERVIEW:

The course encourages introducing analytical tools in an Engineering perspective. The course efforts to provide the basic knowledge of analytical methodology, outlines the importance of volumetric analysis, comprehensive instrumental analysis for properties of fuels, colorimetric analysis and spectroscopic analysis. This practical approach gives the essence of analytical chemistry for skill development in determinations of materials properties and its viability in the industry.

II. COURSES OBJECTIVES:
The students will try to learn:

V   The quantitative analysis to know the strength of unknown solutions by instrumental methods.
VI   The troubles of hard water and its estimation by analytical techniques.
VII The applications of appropriate lubricant for finely tuned machinery.
VIII   The basic knowledge on quantity of light absorbed by the materials.

III. COURSE OUTCOMES:
After successful completion of the course students should be able to:

CO1   Use analytical techniques like conductometry and pH metry to recognize the electrical properties of solutions

CO2   Utilize the potentiometer to characterize and measure the electrical potential of an analyte

CO3   Implement the principles of water analysis for domestic and industrial applications.

CO4   Synthesize the polymeric materials from monomers with polymerization process

CO5   Select different types of lubricants to know its properties for the proper lubrication of machinery in industries.

CO6   Identify the absorption tendency of solids or liquids by using colorimetry

IV. COURSE CONTENT:

1. GETTING STARTED EXERCISES

1.1 Introduction to Chemistry Laboratory

The fundamental concepts and theories required for carrying out qualitative and quantitative analysis. Detailed explanation on the analytical techniques used for qualitative analysis. Emphasis on instrumental method of analysis and its advantages over conventional methods.

    i.   Types of analysis

    ii.   Difference between qualitative and quantitative analysis

    iii.   Common techniques of qualitative and quantitative analysis

    iv.   Introduction to instrumental method of analysis

    v.   Introduction to basic techniques and handling of common apparatus

    vi.   Discussion of Material Safety Data Sheet (MSDS) of chemicals

    vii.   Identification of toxic signs and safety procedures of chemical laboratory

1.2 Safety Guidelines to Chemistry Laboratory

The chemistry laboratory must be a safe place in which to work and learn about chemistry.

    i.   Wear a chemical-resistant apron.

    ii.   Be familiar with your lab work sheet before you come to lab. Follow all written and verbal instructions carefully. Observe the safety alerts in the laboratory directions. If you do not understand a direction or part of a procedure, ask the teacher before proceeding.

    iii.   When entering the laboratory room, do not touch any equipment, chemicals, or other materials without being instructed to do so. Perform only those experiments authorized by the instructor.

    iv.   If you take more of a chemical substance from a container than you need, you should not return the excess to the container. This might cause contamination of the substance remaining. Dispose of the excess as your instructor directs.

    v.   Never smell anything in the laboratory unless your teacher tells you it is safe. Do not smell a substance by putting your nose directly over the container and inhaling. Instead, waft the vapors toward your nose by gently fanning the vapors toward yourself.

    vi.   Do not directly touch any chemical with your hands. Never taste materials in the laboratory.

    vii.   Work areas should be kept clean and tidy at all times. Always replace lids or caps on bottles and jars.

1.3 Data recording and reports

Students must record their experimental values in the provided tables in this laboratory manual and reproduce them in the laboratory worksheets. Worksheets are integral to recording the methodology and results of an experiment. In engineering practice, the laboratory worksheets serve as a valuable reference to the technique used in the laboratory. Note that the data collected will be an accurate and permanent record of the data obtained during the experiment and the analysis of the results.

2. CONDUCTOMETRY

2.1 Estimation of the concentration of strong acid using conductometer
  i. The basic principle of conductometric titrations
 ii. Titration of unknown solution of acid with base
iii. Graphical plots on volume of titrant vs. conductance

3. CONDUCTOMETRY

3.1 Estimation of concentration of strong and weak acid in an acid mixture using conductometer

  i. The basic principle of conductometric titrations
 ii. Titration of unknown solution of mixture of acid with base
 ii. Graphical plots on volume of titrant vs. conductance

4. POTENTIOMETRY

4.1 Estimation of iron content of the given solution by $K_2Cr_2O_7$ using potentiometer
  i. The basic principle of potentiometric titrations
 ii. Titration of Mohr's salt with potassium dichromate
iii. Graphical plots on volume of titrant vs. potential

5. POTENTIOMETRY

5.1 Estimation of concentration of hydrochloric acid using potentiometer
  i. The basic principle of conductometric titrations
 ii. Titration of unknown solution of acid with base
iii. Graphical plots on volume of titrant vs. conductance

6. pH METRY

6.1 Determination of strength of given hydrochloric acid using pH meter
 i. The basic principle of pH metry
 ii. Titration of unknown solution with standard acid
iii. Graphical plots on volume of titrant vs. pH to obtain equivalence point

7. MEASUREMENT OF TOTAL DISSOLVED SOLIDS IN WATER

7.1 Measurement of total dissolved solids (TDS) in different water samples
  i. Specifications of potable water
  i. Measure the total dissolved solids in different water samples by TDS meter

8. COMPLEXOMETRY METHOD

8.1 Estimate the total hardness of water by EDTA
 i. Principle of complexometric titration
 ii Titration of water samples by using EDTA to find the total hardness in water.

9. PRECIPITATION METHOD

9.1 Determination of chloride content in water by Argentometry
 i. Principle of Argentometric titration
 ii. Titration of water samples by using $AgNO_3$ to find the chloride content in water.

10 PREPARATION OF POLYMER

10.1 Preparation of Thiokol rubber by using sodium polysulphide.
i.   Significance of artificial rubbers in industries
ii. Synthesize the Thiokol rubeer by using sodium polysulphide and ethylene dichloride

11. VISCOSITY OF LUBRICANT

11.1 Determine the viscosity of the lubricants using Ostwald's viscometer
i.   The principle of viscosity of lubricant
ii. Significance of viscosity index of lubricant
iii Viscosity of given lubricant by using Ostwald's viscometer

12. PROPERTIES OF LUBRICANTS

12.1 Determine the flash and fire points of lubricants
i.   Significance of flash and fire point of lubricant in industries
ii. Flash and Fire points of a given lubricant by using Pensky Martens flash point apparatus

13.   CLOUD AND POUR POINT OF LUBRICANTS

13.1   Determination of cloud and pout point of lubricants
i.   Significance of cloud and pout point of lubricant in industries
ii. Cloud and pour point of given lubricants by using cloud and pour point tester.

14.   COLORIMETRY
14.1   Estimate the metal ion concentration using colorimeter
i.   Complexation of metal ion with ligands
ii. Detection of absorbance of the colored metal -ligand complex solution
iii Graphical determination of concentration of the metal ions in the solution

V. TEXTBOOKS:

1. K. Mukkanti et. al, Practical *Engineering Chemistry*, B.S. Publications, Hyderabad.
2. Vogel's, *Quantitative chemical analysis*, prentice Hall, 6th Edition, 2009.

VI. REFERENCE BOOKS:

1. Solanki, M. K. Engineering Chemistry Laboratory Manual. (Edu creation Publishing, 2019).
2. Jeffery, G. H. in TEXTBOOK OF QUANTITATIVE CHEMICAL ANALYSIS (ed John Wiley and Sons) (1989).
3. Gary-D-Christian, P. K. S. D., Kevin A. Schug. Analytical-Chemistry-by-Gary-D-Christian. 7 edn, Vol. 7 826 (Wiley, 2014).
4. Budinski, Kenneth G., Engineering materials: properties and selection, 5th edition, Prentice-Hall, 1996, pg.423.
5.   B. Ramadevi and P. Aparna, S Chand publications, *lab manual for engineering chemistry*, S Chand publications, NewDelhi,1st Edition 2022.

VII. ELECTRONICS RESOURCES:
6. https://nptel.ac.in/translation
7. https://nptel.ac.in/courses/115105120
8. https://archive.nptel.ac.in/courses/122/101/122101001/#

VIII. MATERIALS ONLINE
1. Chemistry Lab Course Template
2. Chemistry Lab Manual

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

NETWORK ANALYSIS AND SYNTHESIS LABORATORY							
II Semester: EEE / ECE							
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**	

Course Code	**Category**	**L**	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
AEEE05	**Foundation**	0	0	2	1	40	60	100

Contact Classes: Nil	**Tutorial Classes: Nil**	**Practical Classes: 45**	**Total Classes: 45**
Prerequisite: Matrices and Calculus and Electrical Circuits			

I. COURSE OVERVIEW:

The Network Analysis and Synthesis Laboratory provides hands-on experience in designing and analyzing electrical systems using various network theorems. Students learn to measure three-phase active and reactive power, study resonance, and evaluate circuit responses through simulation tools. The lab covers experiments on resonance, time response analysis, two-port networks, power measurement, coupled circuits, filters, and fundamental theorems. It equips students with practical skills to analyze complex DC and AC circuits and apply theoretical concepts effectively.

II. COURSE OBJECTIVES:
The students will try to learn:

I.   The RL, RC, and RLC circuits under different excitations using integro-differential and Laplace transform approaches.
II.   The two-port electrical networks and apply network topology concepts like tie-set and cut-set matrices for circuit analysis.
III. The various filter and attenuator configurations for frequency-selective and signal conditioning applications.
IV.   The electrical networks using driving-point functions, positive real functions, and classical synthesis methods such as Foster and Cauer forms.

III. COURSE OUTCOMES:
The students will try to learn:

CO1   Simulate and analyze electrical circuits to verify resonance phenomena, network theorems, and power measurement techniques.
CO2   Evaluate time and frequency domain responses of RL, RC, and filter circuits using circuit simulation tools.
CO3   Determine and interpret two-port network parameters for diverse interconnection configurations.
CO4   Measure active, reactive, and three-phase power in balanced star and delta connected systems.
CO5   Analyze coupling effects in magnetically coupled circuits through coefficient, self, and mutual inductance calculations.
CO6   Validate classical theorems and compensation principles for optimizing circuit performance.

NETWORK ANALYSIS AND SYNTHESIS LABORATORY

Dos

1) For safety purpose the students should compulsory wear leather shoes.

2) Students should come in uniform prescribed.

    i. For boys, half sleeve shirts, tucked in trousers

    ii. For ladies, half sleeve overcoat, hair put inside the overcoat

3) After giving connections, staff members should be asked to verify the circuit connections.

4) Before staring the circuit connections check whether the circuit breaker is in OFF condition.

5) Circuit should be switched ON only after getting permission from the staff member.

6) To be careful with moving parts in the machine.

7) To come prepared with procedure relevant to the experiment.

8) Unplug electrical equipment after use.

Dont's

1) Don't assume that the power is disconnected.

2) Don't attempt to repair electrical equipment.

3) Don't come with any ornaments when working with electrical machines.

4) Don't use an earth connection as a neutral.

5) Don't touch any parts unnecessarily.

6) Don't keep any fluids and chemicals nearing instruments and circuits.

IV. COURSE CONTENT:

EXERCISES ON NETWORK ANALYSIS AND SYNTHESIS LABORATORY

Note: Students are encouraged to bring their own laptops for laboratory practice sessions.

1. Verification of Series and Parallel Resonance using any circuit simulation software.

1.1 Series resonance

Study the frequency response characteristics of series resonance circuit of Circuit – 19 and hence to determine the inductance, bandwidth and quality factor of the circuit. Where R = 1 kΩ, L = 10 mH, C = 0.1 μF.

Circuit – 1

Try
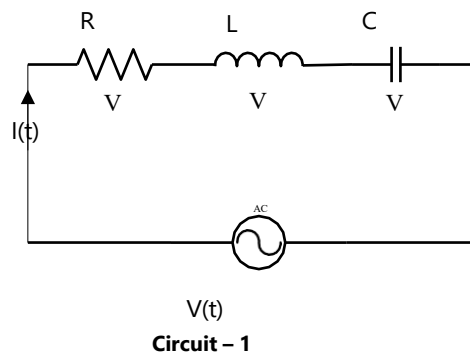
1. Use Simulink to simulate Circuit–19 and plot the waveforms V_R, V_L and V_C verses frequency.
2. For series resonant circuit find I, V_R, V_L and V_C at resonance when V = 10 V, R = 2 Ω, X_L = 10 Ω and X_C = 10 Ω.
3. If the resonant frequency is 5000 Hz, find bandwidth.

1.2 Parallel resonance

Study the frequency response characteristics of parallel resonance circuit of Circuit – 20 and hence to determine the inductance, bandwidth and quality factor of the circuit. Where R = 1k Ω, L = 10 mH, C = 0.1 μF.

Circuit – 2

Try
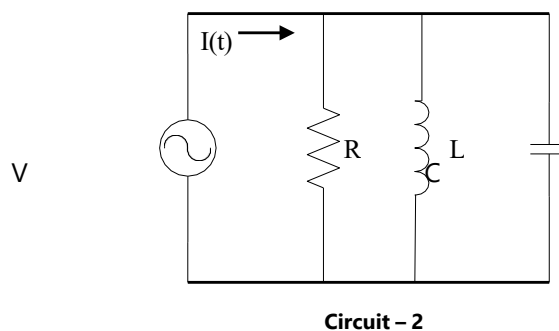
1. Use Simulink to simulatiate parallel resonance circuit of circuit – 20 and plot magnitude of response vs frequency. Consider the frequency range 600 HZ to 2,500 HZ increments of 100 HZ and compare with the experimental plot

2. Determination of Time response of first order RL and RC circuit for periodic non – sinusoidal input- Time Constant and Steady-state error using any circuit simulation software.

Examine the time varying characteristics of series RL, RC and RLC circuits for given values of R, L and Cusing MATLAB software.

2.1 Time Response of Series RL

In this MATLAB program:

I.   Circuit parameters (resistance, inductance, and applied voltage) are defined.

II. The time constant (τ) is calculated as L / R.

III. A symbolic variable **t** is defined for time.

IV. The differential equation representing the transient response of the RL circuit is defined using **diff** and ==.

V.   The **dsolve** function is used to solve the differential equation symbolically.

VI. A time vector ('**t_span**') is created for the simulation.

VII. IL(t) is numerically evaluated for the given time vector.

VIII. The transient response is plotted.

Hints

```
% Define circuit parameters
R = 100; % Resistance in ohmsL =
0.5; % Inductance in henrys
Vin = 10; % Applied voltage in volts

% Calculate the time constant τtau = L /
R;

% Define the symbolic variable for timesyms t

% Define the differential equation for the current IL(t)IL = sym('IL(t)');
eqn = L * diff(IL, t) + R * IL == Vin;

% Solve the differential equation IL_solution =
dsolve (eqn, IL); IL_solution=
simplify(IL_solution);

% Create a time vector and evaluate IL(t
time = 0:0.01:2*tau; % Adjust the time span as needed
IL_numeric = double (subs (IL_solution, t, time));

% Plot the transient responseplot
(time, IL_numeric); xlabel ('Time
(s)');
ylabel ('Current (A)');
title ('Transient Response of RL Circuit');grid on;
```

Circuit Parameters:

Given the following values:

I. Resistor (R): 150 ohms

II. Inductor (L): 0.3 H

III. Applied Voltage (V_in): 12

Calculate the time constant (τ) of the RL circuit.

Transient Analysis:

I. Write down the first-order differential equation governing the transient response of the RL circuit in terms of the current (I_L) through the inductor.

II. Solve the differential equation symbolically to obtain the expression for I_L(t) as a function of time (t).

MATLAB Simulation:

Write MATLAB code to:

I.   Define the circuit parameters (R, L, and Vin).

II. Simulate the transient response of the RL circuit using the 'lsim' function. Use a time vector from 0 to 5τ with a suitable time step.

III. Plot the transient response of the current ('lL) as a function of time. Label the axes appropriately.

Time Constant Verification:

I.   Calculate the time constant τ numerically from the transient response obtained in question 2.1(c).

II. Compare the numerically calculated time constant with the value obtained in question.

III. Explain any differences or similarities.

Analysis:

Based on the transient response plot obtained in question iii, discuss the behavior of the current in the RL circuit as it responds to the voltage step input. Specifically, explain the time constant, the initial current, and the behavior as time progresses.

2.2 Time Response of Series RC

In this MATLAB code:

1. Circuit parameters such as resistance (R), capacitance (C), and applied voltage (Vin) are defined.

2. The time constant (τ) is calculated as R * C.

3. A symbolic variable t is defined for time.

4. The differential equation representing the transient response of the RC circuit is defined using diff and ==.

5. The dsolve function is used to solve the differential equation symbolically.

6. A time vector (t_span) is created for the simulation.

7. Vc(t) is numerically evaluated for the given time vector.

8. The transient response is plotted, showing how the voltage across the capacitor changes over time in response to a step input voltage.

You can adjust the time span in time span to observe the transient response for the desired duration.

Hints

```
Define circuit parametersR =
  100; % Resistance in ohms
= 0.1; % Capacitance in farads Vin = 5; %
  Applied voltage in volts

Calculate the time constant τtau = R
  * C;

Define the symbolic variable for timesyms t

Define the differential equation for the voltage VC(t) across the capacitorVC = sym('VC(t)');
n = R * diff (VC, t) + VC == Vin;

Solve the differential equation symbolically
  VC_solution = dsolve (eqn, VC);
C_solution = simplify(VC_solution);

      % Create a time vector
span = 0:0.01:5*tau; % Adjust the time span as needed

Evaluate VC(t) for the given time vector VC_numeric =
  double (subs (VC_solution, t, t_span));

Plot the transient responseplot
  (t_span, VC_numeric); xlabel
  ('Time (s)');
abel ('Voltage across Capacitor
  (V)'); title ('Transient Response of
  RC Circuit');grid on;
```

Try

Circuit Parameters:

Given the following values:

I.   Resistor (R): 220 ohms

II. Inductor (L): 0.01 F

III. Applied Voltage (Vin): 10 V

Calculate the time constant (τ) of the RC circuit.
b. Transient Analysis:
I.   Write down the first-order differential equation governing the transient response of the RC circuit in terms of the voltage (Vc) across the capacitor.
II. Solve the differential equation symbolically to obtain the expression for Vc(t) as a function of time (t).

c.   MATLAB Simulation:
Write MATLAB code to:
I.   Define the circuit parameters (R, C, and Vin).
II. Simulate the transient response of the RC circuit using the 'lL' function. Use a time vector from 0 to 5τ with a suitable time step.
III. Plot the transient response of the voltage across the capacitor (Vc) as a function of time. Label the axes appropriately.

I. Calculate the time constant τ numerically from the transient response obtainedin question 2.2c.

II. Compare the numerically calculated time constant with the value obtained in question 2.2(a). Explain any differences or similarities.

e. Analysis:

Based on the transient response plot obtained in question c(iii), discuss the behavior of the current in the RL circuit as it responds to the voltage step input. Specifically, explain the time constant, the initial current, and the behavior as time progresses.

3.1 Determination of Two port network parameters – Z, Y, Transmission and Hybrid parameters

Calculate Z-parameters and Y-parameters for Circuit – 22, and analyze the network's response to different conditions (open and short circuits). Where $R_1 = 100\ \Omega$, $R_2 = 220\ \Omega$, $R_3 = 1k\ \Omega$ and $R_4 = 150\ \Omega$.
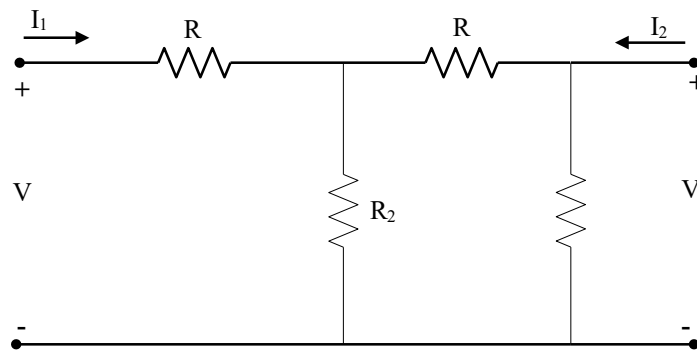
Circuit-3

Try

1. Use Simulink to simulate Circuit–22 for determining the Z and Y parameters and compare the values to those you obtained from your experiment.
2. Calculate Z parameters and convert in terms of Y parameters for Circuit – 23. Where $R_1 = 100\ \Omega$, $R_2 = 220\ \Omega$, $R_3 = 1k\ \Omega$, $R_4 = 150\ \Omega$ and $R_5 = 82\ \Omega$.
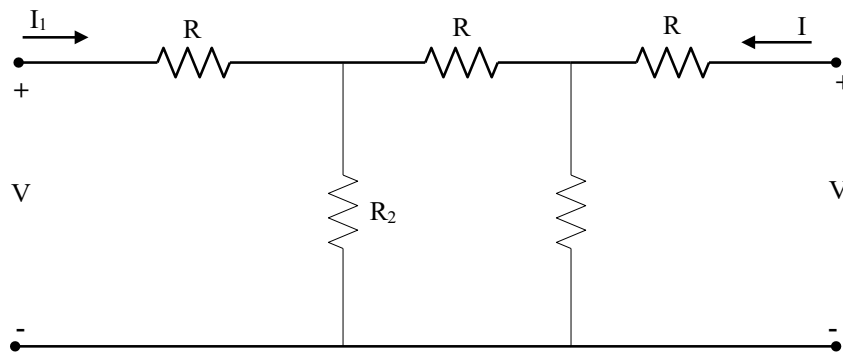
Circuit – 4

3.2 Exercise on H and ABCD Parameters

Calculate H and ABCD parameters for Circuit – 24, and analyze voltage gain and impedance transformation. Where $R_1 = 100\ \Omega$, $R_2 = 220\ \Omega$, $R_3 = 1k\ \Omega$ and $R_4 = 150\ \Omega$.

Circuit-5

Try
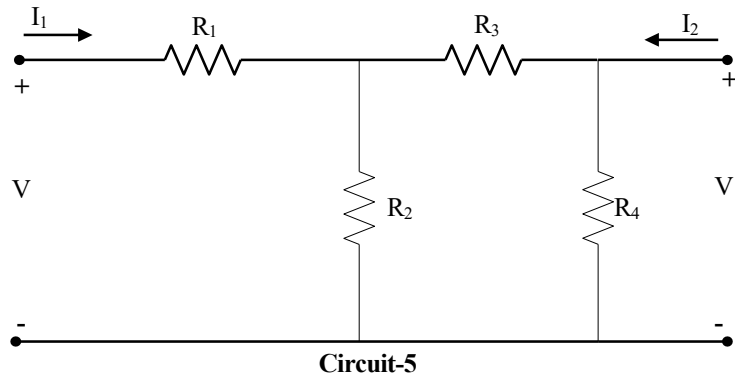
1. Use Simulink to simulate Circuit – 24 for determining the H and ABCD parameters and compare the values to those you obtained from your experiment.
2. Calculate H parameters and convert in terms of Y parameters for Circuit – 25. Where $R_1 = 100\ \Omega$, $R_2 = 220\ \Omega$, $R_3 = 1k\ \Omega$, $R_4 = 150\ \Omega$ and $R_5 = 82\ \Omega$.

Circuit – 6
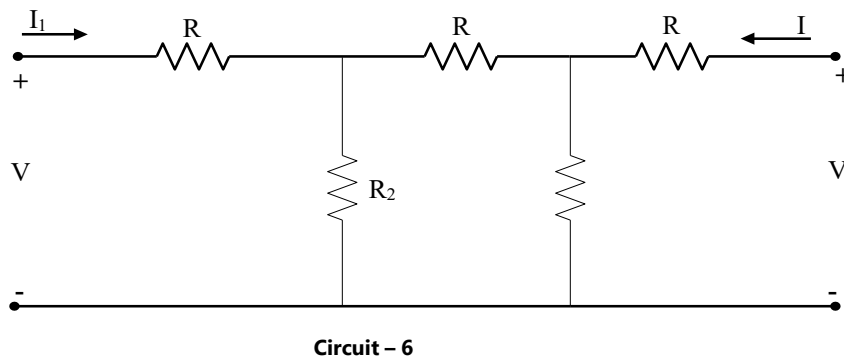
4. Measurement of 3-phase power in Balanced Star connected load using Two-Wattmeter method.

To simulate and measure the total power of a balanced 3-phase star-connected load using the two-wattmeter method.

a. balanced 3-phase star-connected load

Circuit – 7
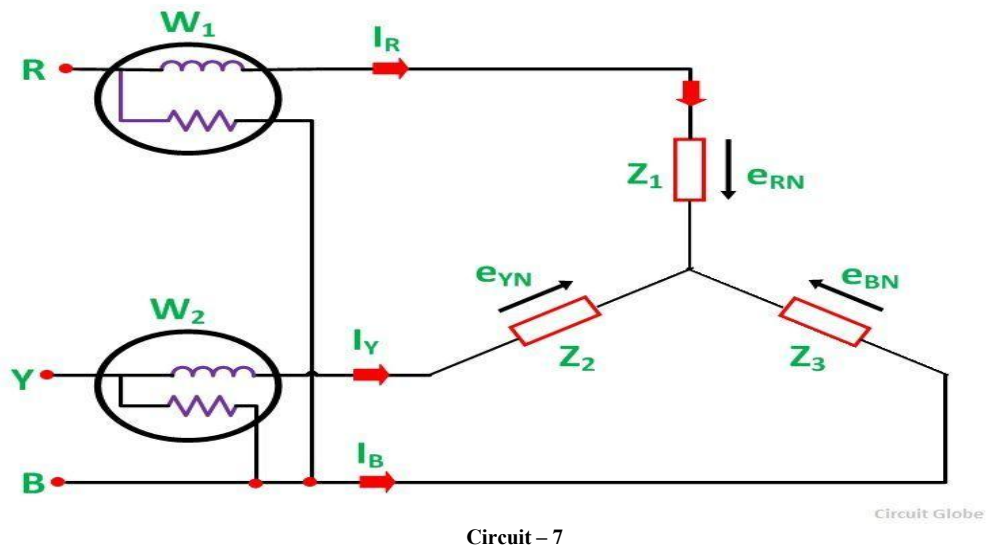
% Theoretical two-wattmeter values for balanced Y load
Vll = 400;   % V (line-to-line)
Zmag = 10;   % magnitude of per-phase impedance (Ohm)
phi_deg = 30;   % load power factor angle in degrees (positive = lagging)

Vph = Vll/sqrt(3);
I = Vph / Zmag;   % line current magnitude

% Wattmeter formulas
W1 = Vll * I * cosd(phi_deg - 30);
W2 = Vll * I * cosd(phi_deg + 30);
P_total = W1 + W2; % should equal sqrt(3)*Vll*I*cos(phi_deg)

fprintf('I = %.4f A\n', I);
fprintf('W1 = %.3f W\nW2 = %.3f W\nP_total = %.3f W\n', W1, W2, P_total);

Expected printed result (approx):

I = 23.0940 A
W1 = 9237.604 W
W2 = 4618.802 W
P_total 13856.406 W

5. Determination of Co-efficient of coupling, self and mutual inductance in magnetic Coupled Circuits

To determine the self-inductance (L1, L2) of two coils, the mutual inductance (M) between them, and the Coefficient of coupling (k) in a magnetically coupled circuit.
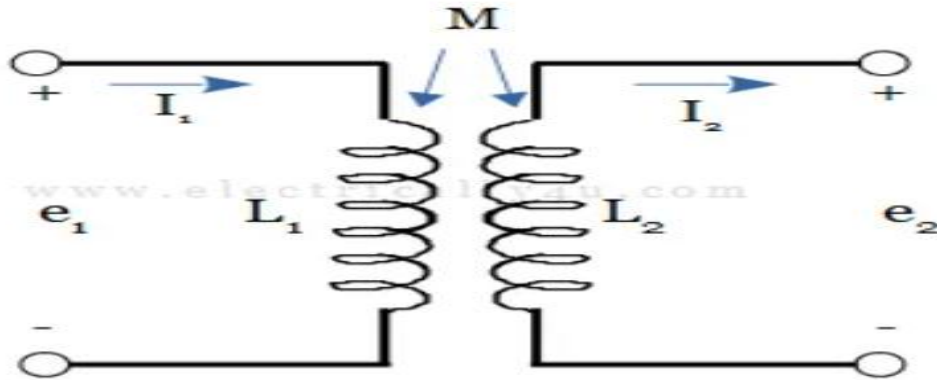
Circuit –8

```
MATLAB code

% coupled_inductor_test.m
% Simulate two coupled inductors, series aiding and series opposing,
% compute La, Lo, M, k from simulation.

clear; close all; clc;

% PARAMETERS (example)
L1 = 10e-3;   % H
L2 = 20e-3;   % H
k  = 0.8;     % coupling coefficient (true, for simulation)
M_true = k*sqrt(L1*L2);

R_series = 0.01;   % small series resistance to aid numeric stability (ohm)
Vamp = 5;          % source amplitude (V)
f = 50;            % frequency (Hz)
w = 2*pi*f;

% time vector
T = 1/f;
t = linspace(0,5*T,20000);   % simulate 5 cycles, high resolution

% Helper: simulate series connection with given sign (+1 aiding, -1 opposing)
simulate_series = @(sign) simulate_two_coils(L1,L2,M_true,sign,R_series,Vamp,w,t);

% Simulate aiding (+1) and opposing (-1)
[data_a] = simulate_series(+1);
[data_o] = simulate_series(-1);

% compute RMS voltages and currents after transients (last cycle)
last_cycle_idx = find(t >= 4*T);
```

```matlab
  Vrms = rms(Vamp*sin(w*t(last_cycle_idx)));
Irms_a = rms(data_a.i_series(last_cycle_idx));
Irms_o = rms(data_o.i_series(last_cycle_idx));

% Equivalent inductances:
La = Vrms/(w*Irms_a);
Lo = Vrms/(w*Irms_o);

% Compute M and k from La and Lo (and known L1,L2)
M_calc = (La - Lo)/4;
Lsum = (La + Lo)/2;
k_calc = M_calc / sqrt(L1*L2);

% Display results
fprintf('Given L1 = %.6f H, L2 = %.6f H, k(true) = %.3f\n', L1, L2, k);
fprintf('True M = %.6e H\n', M_true);
fprintf('Measured La = %.6e H\n', La);
fprintf('Measured Lo = %.6e H\n', Lo);
fprintf('Calculated M = %.6e H\n', M_calc);
fprintf('Calculated k = %.6f\n', k_calc);

% Plot steady waveforms (last cycle)
figure;
subplot(3,1,1);
plot(t(last_cycle_idx), data_a.i_series(last_cycle_idx));
title('Series Current (aiding) - last cycle'); xlabel('t (s)'); ylabel('I_A (A)');

subplot(3,1,2);
plot(t(last_cycle_idx), data_o.i_series(last_cycle_idx));
title('Series Current (opposing) - last cycle'); xlabel('t (s)'); ylabel('I_O (A)');

subplot(3,1,3);
plot(t(last_cycle_idx), Vamp*sin(w*t(last_cycle_idx)));
title('Source Voltage - last cycle'); xlabel('t (s)'); ylabel('V (V)');

% ------------------------
% Local function: simulate two coupled coils connected in series
function out = simulate_two_coils(L1,L2,M,sign,Rs,Vamp,w,t)
    % state variables: i1, i2  (currents through coil1, coil2)
    % Equations (flux linkages):
    % v1 = L1 di1/dt + M d i2/dt + R1 i1 (R1 assumed small)
    % v2 = M d i1/dt + L2 di2/dt + R2 i2
    %
    % But for series connection we combine so that the single series
    % current i_series flows through coil1 and coil2 in a specific polarity.
    % We'll simulate loop with i_series and differential equations for flux.
    %
    % Simpler approach: Build coupled inductance matrix and compute d/dt currents
    %
    % Inductance matrix:
    Lmat = [L1, sign*M; sign*M, L2];
```

```
    Rmat = [Rs, 0; 0, Rs];
    % For series connection with single source across series combination:
    % The source drives series loop: v = [1 1] * (Lmat * di/dt + Rmat*i)
    % We'll simulate two currents satisfying same series current i1 = i2 = i_series
    % For small Rs we approximate i1 = i2 = i_series * [1;1]*0.5?
    % To properly capture mutual effect, simulate two-loop equations with a single
    % series source by enforcing i1 = i_series and i2 = i_series with sign on dot.
    % To avoid complexity, simulate two-winding circuit as single series branch with
    % equivalent L_eq = L1 + L2 + 2*sign*M and R = 2*Rs.
    Leq = L1 + L2 + 2*sign*M;
    Req = 2*Rs;
    % Solve di/dt = (1/Leq)*(v(t) - Req*i)
    dt = t(2)-t(1);
    i = zeros(size(t));
    for idx = 2:length(t)
        v = Vamp*sin(w*t(idx));
        di_dt = (v - Req*i(idx-1))/Leq;
        i(idx) = i(idx-1) + di_dt*dt;
    end
    out.i_series = i;
end

% RMS helper
function r = rms(x)
    r = sqrt(mean(x.^2));
end
```

Try:

- Build model per section 1, set L1/L2/k as above.
- Run for a few cycles with a 50 Hz sine, measure series current for aiding & opposing connections.
- Compute the equivalent inductance using $L_{eq} = V_{rms}/(\omega I_{rms})$ from your logged signals.
- Then compute M and k as shown.

6. Frequency domain analysis of Low-pass filter and High-pass filters using circuit simulation software

To plot the characteristics of low-pass and high-pass filters using MATLAB, you can follow these steps and use the 'freqz' function for plotting the frequency response:

Hints

/** Design the Filters */

Design low-pass and high-pass filters using the **'fir1'** or **'fdesign'** functions. Here's an example using **'fir1'**:

% Design a low-pass filter
lowpass_order = 50; % Filter order
lowpass_cutoff_frequency = 0.2; % Cutoff frequency (normalized)lowpass_filter =
fir1(lowpass_order, lowpass_cutoff_frequency);

% Design a high-pass filter highpass_order
= 50; % Filter order
highpass_cutoff_frequency = 0.2; % Cutoff frequency (normalized)
highpass_filter = fir1(highpass_order, highpass_cutoff_frequency, 'high');

/** Plot the Frequency Response */

Plot the frequency response of the filters using the **'freqz'** function:

% Frequency response of the low-pass filterfigure;
freqz (lowpass_filter, 1, 1024);
title ('Low-Pass Filter Frequency Response');
xlabel ('Normalized Frequency (\pi radians/sample)');ylabel
('Magnitude (dB)');

% Frequency response of the high-pass filterfigure;
freqz (highpass_filter, 1, 1024);
title ('High-Pass Filter Frequency Response');
xlabel ('Normalized Frequency (\pi radians/sample)');ylabel
('Magnitude (dB)');

In this code:
'freqz (lowpass_filter, 1, 1024)' calculates and plots the frequency response ofthe low-pass filter.
'freqz (highpass_filter, 1, 1024)' calculates and plots the frequency response of
the high-pass filter.

/ Display the Phase Response (Optional) */
If you also want to display the phase response, you can modify the **'freqz'** functionas follows:

```
% Phase response of the low-pass filterfigure;
[h, w] = freqz (lowpass_filter, 1, 1024);plot (w,
unwrap(angle(h)));
title ('Low-Pass Filter Phase Response');
xlabel ('Normalized Frequency (\pi radians/sample)');ylabel ('Phase
(radians)');

% Phase response of the high-pass filter
figure;
[h, w] = freqz (highpass_filter, 1, 1024);plot (w,
unwrap(angle(h)));
title ('High-Pass Filter Phase Response');
xlabel ('Normalized Frequency (\pi radians/sample)');ylabel ('Phase
(radians)');
```

Try:
Problem 1: Filter Design

1. Design a low-pass filter with the following specifications:

- Filter Order: 40

- Cutoff Frequency: 0.2 (normalized frequency)

2. Design a high-pass filter with the following specifications:

- Filter Order: 30

- Cutoff Frequency: 0.3 (normalized frequency)

Problem 2: Frequency Response Plot

1. Plot the magnitude frequency response (in dB) of both the low-pass and high-pass filters.

- Use the **'freqz'** function to calculate and plot the frequency response.

- Label the x-axis as "Normalized Frequency (\pi radians/sample)" and the y-axis as"Magnitude (dB)."

2. Plot the phase frequency response (in radians) of both filters.

- Use the freqz function to calculate and plot the phase response.

- Label the x-axis as "Normalized Frequency (\pi radians/sample)" and the y-axis as"Phase (radians)."

Problem 3: Filtered Signal

1. Generate a noisy input signal using MATLAB. You can use the **'randn'** function to generaterandom noise and the **'sin'** function to generate a sinusoidal signal.

2. Apply both the low-pass and high-pass filters to the noisy signal to obtain filtered signals.

3. Plot the noisy input signal, the low-pass filtered signal, and the high-pass filtered signal on thesame graph.

Problem 4: Frequency Response Analysis

1. Analyze the frequency response plots and explain how the magnitude and phase characteristicsof the filters align with their designed specifications.

2. Describe the differences in filtering results between the low-pass and high-pass filters. Discusswhich frequencies are attenuated and which are passed through.

Problem 5: Submission

1. Prepare a report summarizing your filter design, frequency response analysis, and filtered signalresults.

2. Include the MATLAB code used for filter design, frequency response plotting, and signalprocessing in your report.

3. Provide explanations and interpretations of the results in the report.

7.1 **Verification** of Superposition and Maximum Power Transfer theorems using any circuit simulation software.

Investigate the current thought R_2 resistor using superposition theorem to multiple DC source
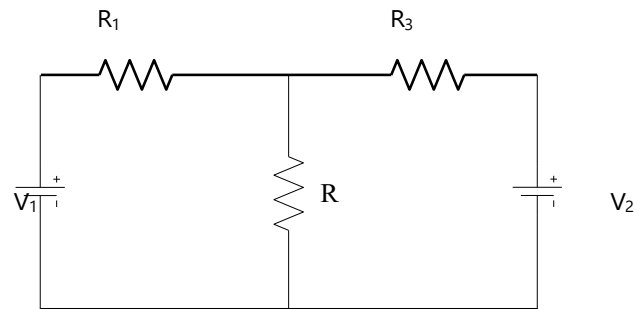
Circuit – 9

Try

1. Use Simulink to simulate the Circuit – 16 for determining the current through a resistor R_2 and compare this value to those you obtained from your experiment.
2. Find the current thought R_2 in Circuit – 16 using any circuit reduction technique and verify this value to those you obtained from the superposition theorem.
3. Find the current through the R_4 resistor using the superposition theorem for the Circuit – 17.

7.2 Exercise on Maximum Power Transfer Theorem

1. Find the value of R_L at which maximum power is transferred to the load in Circuit – 21.
2. Determine the maximum power transferred to the load. Where V = 10 V, R_1 = 100 Ω, R_2 = 220 Ω, R_3 = 1k Ω, R_4 = 150 Ω.
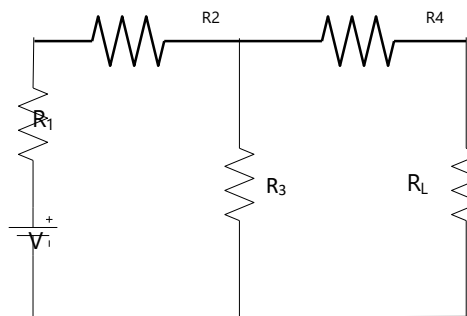
Circuit – 10

Try

1. If the internal resistance of a voltage source is adjustable, and the load resistor is fixed. Determine the range of source resistance values that will result in effective power transfer. Calculate the corresponding load power for each extreme of the source resistance range.
2. Use Simulink to simulate Circuit – 21 for determining the current thought R_L and compare this value to those you obtained from your experiment.
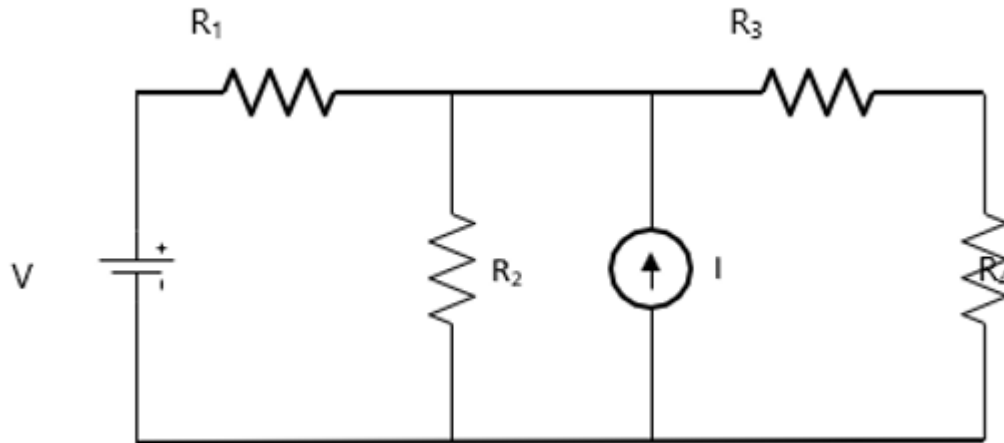
Circuit – 11

8. Verification of Thevenin's and Norton's theorems using any circuit simulation software.

8.1 Exercises on Thevenin's Theorem

1. Determine Thevenin's equivalent voltage (V_{th}) and resistance (R_{th}) at R_4 by applying Thevenin's theorem for Circuit – 13.
2. Determine load or unknown current through a R_4 resistor using Thevenin's equivalent circuit. Were $V = 10V$, $R_1 = 100\ \Omega$, $R_2 = 220\ \Omega$, $R_3 = 1k\ \Omega$ and $R_4 = 150\ \Omega$.
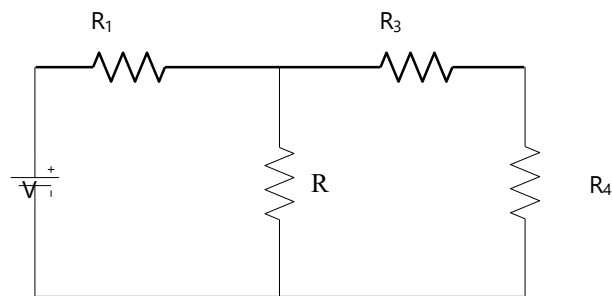
Circuit – 12

Try

1. Use Simulink to simulate the Circuit – 13 for determining the current thought R_4 resistor using Thevenin's theorem and compare this value to those you obtained from your experiment.
2. Find the current thought R_4 resistor using any circuit reduction technique and verify this value to those you obtained from Thevenin's theorem.
3. Find the current flowing through R_2 resistor in Circuit – 14 using Thevenin's theorem for the below circuit. Where $V_1 = 10\ V$, $V_2 = 5\ V$, $R_1 = 100\ \Omega$, $R_2 = 220\ \Omega$, $R_3 = 1k\ \Omega$.
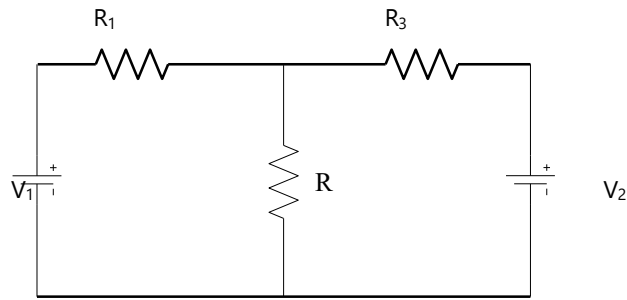
Circuit – 13

8.2   Exercises on Norton's Theorem

1. Find Norton equivalent current (I_N) and resistance (R_N) by considering $R_L = 150\ \Omega$ resistor for the Circuit – 15 by applying Norton's theorem.
2. Find load or unknown current through R_L resistor using Norton's equivalent circuit. Where V = 10 V, $R_1 = 100\ \Omega$, $R_2 = 220\ \Omega$ and $R_3 = 1k\ \Omega$.
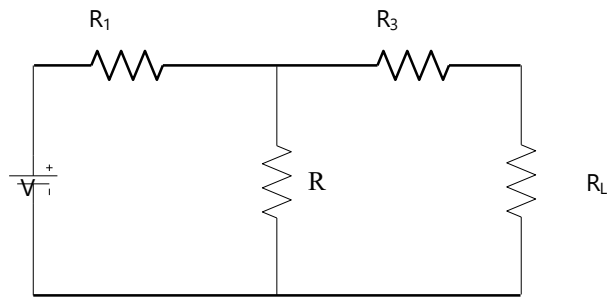
Circuit – 14

Try

1. Use Simulink to simulate the Circuit – 15 for determining the current through R_L resistor and compare this value to those you obtained from your experiment.
2. Find the current thought R_L using any circuit reduction technique and verify this value to those you obtained from Norton's theorem.

9. Measurement of Active Power for Delta-connected balanced loads.

To measure the active power consumed by a delta-connected balanced load in a three-phase system using the Two-Wattmeter Method.

The two-wattmeter method is widely used for measuring the active power in a three-phase system (balanced). For a delta-connected balanced load, the total active power is the algebraic sum of the readings of the two wattmeters:

P=W1+W2
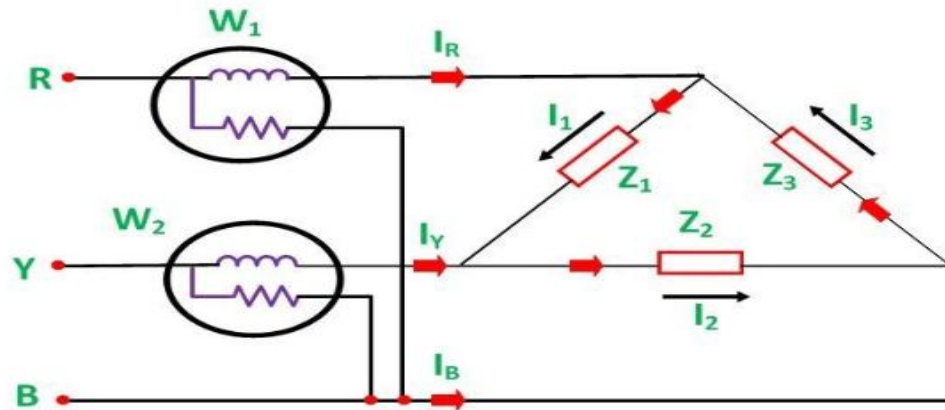
Circuit – 15

```
# Title: Measurement of Active Power in Delta Connected Balanced Load
# Method: Two Wattmeter Method
# Software: GLIMSim

BEGIN
 COMPONENTS:
  # Source
  Vsource3P  V1  R Y B  N  (3-phase balanced source, 400V, 50Hz)

  # Wattmeters
  Wattmeter   W1  R N LOAD1
  Wattmeter   W2  Y N LOAD2

  # Load - Delta Connected
  Impedance   Z1 R Y  (10+j5)   # Example load impedance per phase
  Impedance   Z2  Y B  (10+j5)
  Impedance   Z3  B R  (10+j5)

 CONNECTIONS:
  # Wattmeter W1: Current coil in R phase, potential coil across R-Y
```

```
        W1.I coil  R N
        W1.P coil  R Y
# Wattmeter W2: Current coil in Y phase, potential coil across Y-B
   W2.Icoil  Y N
   W2.Pcoil  Y B

   # Source connections
   V1.R  -> R
   V1.Y  -> Y
   V1.B  -> B
   V1.N  -> N

   # Load connections (Delta)
   Z1.p -> R
   Z1.n -> Y

   Z2.p -> Y
   Z2.n -> B

   Z3.p -> B
   Z3.n -> R

END

SIMULATION:
  RUN  TIME = 0.1s
  PLOT  W1.Power  W2.Power  (Wattmeter readings)
  PLOT  V1.VR, V1.VY, V1.VB (Source voltages)
  PLOT  I(R), I(Y), I(B)    (Line currents)

RESULT:
  Total Power = W1 + W2
```

Try

1. Two wattmeters (W1, W2) measure power.
2. The load is balanced Delta connected with impedance Z=(10+j5) Ω (example).
3. You can change the impedance values or supply voltage as per requirement.
4. Total power = W1 + W2.

10. Measurement of Reactive Power for Star and Delta connected balanced load

To measure the reactive power of star and Delta connected balanced load
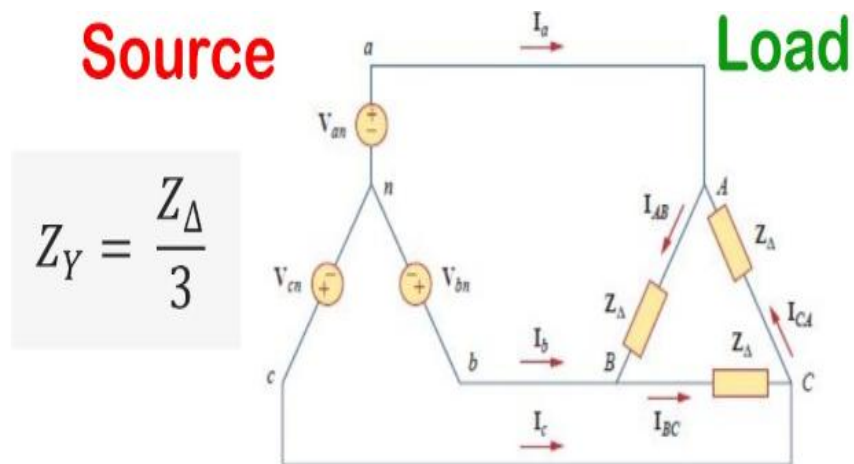
Circuit – 16

- In a star connection:
$$V_{ph} = \frac{V_{line}}{\sqrt{3}}$$
- In a delta connection:
$$V_{ph} = V_{line}$$
- Line current and phase current relationship in Delta load:
$$I_{line} = \sqrt{3} \cdot I_{ph}$$

Also, for equivalent conversion:

$$Z_Y = \frac{Z_\Delta}{3}$$

```
% Simulation of Star Connected Source supplying Delta Connected Load

clc;
clear all;

% Source line voltage (rms)
V_line = 400;   % Volts (3-phase balanced source)

% Phase voltage of star source
V_phase_Y = V_line / sqrt(3);

% Load Impedance (Delta connected)
Z_delta = 20 + 10j;  % example: 20 + j10 ohms

% Phase voltage across each delta branch
V_phase_delta = V_line;  % In delta, Vph = Vline

% Phase current of delta load
I_ph = V_phase_delta / Z_delta;

% Line current of delta load
I_line = sqrt(3) * I_ph;

% Power calculations
P_total = 3 * (V_phase_delta * conj(I_ph)); % total 3-phase power
Q_total = 3 * imag(V_phase_delta * conj(I_ph));
S_total = 3 * (V_phase_delta * conj(I_ph));

% Display results
disp('--- Star Connected Source feeding Delta Load ---');
disp(['Source Line Voltage = ', num2str(V_line), ' V']);
disp(['Load Impedance (Delta) = ', num2str(Z_delta), ' ohm']);
disp(['Delta Phase Current = ', num2str(abs(I_ph)), ' A']);
disp(['Line Current = ', num2str(abs(I_line)), ' A']);
disp(['Total Active Power = ', num2str(real(P_total)), ' W']);
disp(['Total Reactive Power = ', num2str(Q_total), ' VAR']);
disp(['Total Apparent Power = ', num2str(abs(S_total)), ' VA']);
```

11. Frequency domain analysis of Band-pass filters

Analyze the virtual instrumentation (VI) using control loops, arrays, charts and graphs in LabVIEW software

Hints

/** Open LabVIEW and create a new VI */

/** Place the following controls on the front panel */
- Numeric Control for Frequency (Hz)
- Numeric Control for Amplitude (V)
- Numeric Control for Duration (seconds)
- Waveform Chart (for displaying the original signal)
- Waveform Graph (for displaying the FFT result)

/ Create a FOR loop on the block diagram with the following elements inside it */**
- Numeric Constant (0) wired to the FOR loop iteration terminal
- Numeric Control for Duration wired to the count terminal of the FOR loop

/ Inside the FOR loop, generate a sinusoidal signal using the Sine Waveformfunction */**
- Place a Sine Waveform function inside the FOR loop
- Wire the Frequency control to the "Frequency (Hz)" input of the Sine Waveformfunction
- Wire the Amplitude control to the "Amplitude (V)" input of the Sine Waveformfunction
- Use the FOR loop iteration terminal to generate a time signal (0, 1 sampleperiod, 2 sample periods, etc.)
- Wire the time signal to the "Time (s)" input of the Sine Waveform function

/ Wire the output of the Sine Waveform function to a Build Array function tocreate an array of the generated signal */**

/ After the FOR loop, add a Peak Detector VI to detect peaks in the signal */**
- Place a Peak Detector VI on the block diagram
- Wire the output array to the "Input Array" input of the Peak Detector
- Set the "Threshold" parameter of the Peak Detector VI to a suitable value

/ Connect the output of the Peak Detector VI to the "Data" input of the WaveformChart to display the original signal with peaks highlighted */**

/ Place a Waveform Chart Clear function outside the FOR loop and wire it to thechart to clear the chart before displaying the new data */**

/ Create a WHILE loop with the following elements inside it */**
- A Waveform Graph Clear function to clear the graph for displaying FFT results
- An FFT function to compute the Fast Fourier Transform of the signal:
    - Wire the output array (from the Peak Detector) to the "Time Domain Signal"input of the FFT function
- A waveform chart to display the FFT result:
    - Wire the output of the FFT function to the "Amplitude Spectrum" input of thewaveform chart

/ Wire the output of the Waveform Chart Clear function inside the WHILE loop toclear the chart before displaying the new data */**

/ Run the VI to generate the sinusoidal signal, detect peaks, compute the FFT,and display the results on the charts */**

This LabVIEW example demonstrates the use of FOR and WHILE loops, charts (waveform chart and waveform graph), arrays, and analysis VIs (Peak Detector and FFT) in a signal processing application. Students can modify and extend this example to explore more complex signal processing and analysis tasks.

Try:

1. Obtain VI using for loop and While loop.
2. Obtain VI using charts and arrays.
3. Obtain VI using graphs.

12. Frequency domain analysis of Band-stop filters

Analyze the virtual instrumentation (VI) using control loops, arrays, charts and graphs in LabVIEW software

Hints

/**   Design the Filters */

Design low-pass and high-pass filters using the **'fir1'** or **'fdesign'** functions.Here's an example using **'fir1'**:

```
% Design a low-pass filter
lowpass_order = 50; % Filter order
lowpass_cutoff_frequency = 0.2; % Cutoff frequency (normalized)lowpass_filter =
fir1(lowpass_order, lowpass_cutoff_frequency);

% Design a high-pass filter highpass_order =
50; % Filter order
highpass_cutoff_frequency = 0.2; % Cutoff frequency (normalized)
highpass_filter = fir1(highpass_order, highpass_cutoff_frequency, 'high');
```

/** Plot the Frequency Response */

Plot the frequency response of the filters using the **'freqz'** function:

```
% Frequency response of the low-pass filterfigure;
freqz (lowpass_filter, 1, 1024);
title ('Low-Pass Filter Frequency Response');
xlabel ('Normalized Frequency (\pi radians/sample)');ylabel
('Magnitude (dB)');

% Frequency response of the high-pass filterfigure;
freqz (highpass_filter, 1, 1024);
title ('High-Pass Filter Frequency Response');
xlabel ('Normalized Frequency (\pi radians/sample)');ylabel
('Magnitude (dB)');
```

In this code:
'freqz (lowpass_filter, 1, 1024)' calculates and plots the frequency response of the low-pass filter.
'freqz (highpass_filter, 1, 1024)' calculates and plots the frequency response of the high-pass filter.

/ Display the Phase Response (Optional) */
If you also want to display the phase response, you can modify the **'freqz'** function as follows:

```
% Phase response of the low-pass filterfigure;
[h, w] = freqz (lowpass_filter, 1, 1024);plot (w,
unwrap(angle(h)));
title ('Low-Pass Filter Phase Response');
xlabel ('Normalized Frequency (\pi radians/sample)');ylabel ('Phase
(radians)');

% Phase response of the high-pass filter
figure;
[h, w] = freqz (highpass_filter, 1, 1024);plot (w,
unwrap(angle(h)));
title ('High-Pass Filter Phase Response');
xlabel ('Normalized Frequency (\pi radians/sample)');ylabel ('Phase
(radians)');
```

Try:
Problem 1: Filter Design

1. Design a low-pass filter with the following specifications:

   - Filter Order: 40

   - Cutoff Frequency: 0.2 (normalized frequency)

2. Design a high-pass filter with the following specifications:

   - Filter Order: 30

   - Cutoff Frequency: 0.3 (normalized frequency)

Problem 2: Frequency Response Plot

1. Plot the magnitude frequency response (in dB) of both the low-pass and high-pass filters.

   - Use the **'freqz'** function to calculate and plot the frequency response.

   - Label the x-axis as "Normalized Frequency (\pi radians/sample)" and the y-axis as"Magnitude (dB)."

   - Plot the phase frequency response (in radians) of both filters.

   - Use the freqz function to calculate and plot the phase response.

   - Label the x-axis as "Normalized Frequency (\pi radians/sample)" and the y-axis as"Phase (radians)."

Problem 3: Filtered Signal

1. Generate a noisy input signal using MATLAB. You can use the **'randn'** function to generaterandom noise and the **'sin'** function to generate a sinusoidal signal.

2. Apply both the low-pass and high-pass filters to the noisy signal to obtain filtered signals.

3. Plot the noisy input signal, the low-pass filtered signal, and the high-pass filtered signal on the same graph.

Problem 4: Frequency Response Analysis

1. Analyze the frequency response plots and explain how the magnitude and phase characteristics of the filters align with their designed specifications

2. Describe the differences in filtering results between the low-pass and high-pass filters. Discuss which frequencies are attenuated and which are passed through.

Problem 5: Submission

1. Prepare a report summarizing your filter design, frequency response analysis, and filtered signal results.

2. Include the MATLAB code used for filter design, frequency response plotting, and signal processing in your report.

3. Provide explanations and interpretations of the results in the report.

13. Determination of Time response of first order RL, RC circuit for periodic non – sinusoidal inputs - Time Constant and Steady state error.

Examine the time varying characteristics of series RL, RC and RLC circuits for given values of R, L and C using MATLAB software.

13.1 Time Response of Series RL

In this MATLAB program:

1. Circuit parameters (resistance, inductance, and applied voltage) are defined.

2. The time constant (τ) is calculated as L / R.

3. A symbolic variable **t** is defined for time.

4. The differential equation representing the transient response of the RL circuit is defined using **diff** and ==.

5. The **dsolve** function is used to solve the differential equation symbolically.

6. A time vector (**'t_span'**) is created for the simulation.

7. IL(t) is numerically evaluated for the given time vector.

8. The transient response is plotted.

Hints

```
% Define circuit parameters
R = 100; %  Resistance in  ohmsL = 0.5;
% Inductance in henrys
Vin = 10; % Applied voltage in volts

% Calculate the time constant τtau = L
/ R;

% Define the symbolic variable for timesyms t

% Define the differential equation for the current IL(t)IL = sym('IL(t)');
eqn = L * diff(IL, t) + R * IL == Vin;

% Solve the differential equation IL_solution =
dsolve (eqn, IL); IL_solution=
simplify(IL_solution);

% Create a time vector and evaluate IL(t
time = 0:0.01:2*tau; % Adjust the time span as needed
IL_numeric = double (subs (IL_solution, t, time));

% Plot the transient responseplot
(time, IL_numeric); xlabel ('Time
(s)');
ylabel ('Current (A)');
title ('Transient Response of RL Circuit');grid on;
```

Try:

Circuit Parameters:

Given the following values:

I.   Resistor (R): 150 ohms

II. Inductor (L): 0.3 H

III. Applied Voltage (V_in): 12 V

Calculate the time constant (τ) of the RL circuit.

Transient Analysis:

a. Write down the first-order differential equation governing the transient response of theRL circuit in terms of the current (I_L) through the inductor.

b. Solve the differential equation symbolically to obtain the expression for I_L(t) as afunction of time (t).

MATLAB Simulation:

Write MATLAB code to:

a. Define the circuit parameters (R, L, and Vin).

b. Simulate the transient response of the RL circuit using the 'l$_{sim}$' function. Use a timevector from 0 to 5τ with a suitable time step.

c. Plot the transient response of the current ('l$_L$) as a function of time. Label the axesappropriately.

Time Constant Verification:

a. Calculate the time constant τ numerically from the transient response obtained in question 2.1(c).

b. Compare the numerically calculated time constant with the value obtained in question.

c. Explain any differences or similarities.

Analysis:

Based on the transient response plot obtained in question iii, discuss the behavior of the current in the RL circuit as it responds to the voltage step input. Specifically, explain the time constant, the initial current, and the behavior as time progresses.

13.2 Time Response of Series RC

In this MATLAB code:

1. Circuit parameters such as resistance (R), capacitance (C), and applied voltage (Vin) are defined.

2. The time constant (τ) is calculated as R * C.

3. A symbolic variable t is defined for time.

4. The differential equation representing the transient response of the RC circuit is defined using diff and ==.

5. The dsolve function is used to solve the differential equation symbolically.

6. A time vector (t_span) is created for the simulation.

7. Vc(t) is numerically evaluated for the given time vector.

8. The transient response is plotted, showing how the voltage across the capacitor changes over time in response to a step input voltage.

You can adjust the time span in t_span to observe the transient response for the desired duration.

Hints

```
Define circuit parametersR =
  100; % Resistance in ohms
= 0.1; % Capacitance in farads Vin = 5; %
  Applied voltage in volts

Calculate the time constant τtau = R *
  C;

Define the symbolic variable for timesyms t

Define the differential equation for the voltage VC(t) across the capacitorVC = sym('VC(t)');
n = R * diff (VC, t) + VC == Vin;

Solve the differential equation symbolicallyVC_solution
  = dsolve (eqn, VC);
C_solution=simplify(VC_solution);

Create a time vector
span = 0:0.01:5*tau; % Adjust the time span as needed

Evaluate VC(t) for the given time vector VC_numeric = double
  (subs (VC_solution, t, t_span));

Plot the transient responseplot
  (t_span, VC_numeric); xlabel
  ('Time (s)');
abel ('Voltage across Capacitor (V)'); title ('Transient
  Response of RC Circuit');grid on;
```

Try:

Circuit Parameters:

Given the following values:

I.   Resistor (R): 220 ohms

II. Inductor (L): 0.01 F

III. Applied Voltage (Vin): 10 V

Calculate the time constant (τ) of the RC circuit.

f.   Transient Analysis:

    I.   Write down the first-order differential equation governing the transient response of theRC circuit in terms of the voltage (Vc) across the capacitor.

    II. Solve the differential equation symbolically to obtain the expression for Vc(t) as afunction of time (t).

g.   MATLAB Simulation:

Write MATLAB code to:

I.   Define the circuit parameters (R, C, and Vin).

II. Simulate the transient response of the RC circuit using the 'lL' function. Use a timevector from 0 to 5τ with a suitable time step.

III. Plot the transient response of the voltage across the capacitor (Vc) as a function oftime. Label the
   axes appropriately.

h. Time Constant Verification:

I.   Calculate the time constant τ numerically from the transient response obtainedin question 2.2c.

II. Compare the numerically calculated time constant with the value obtained inquestion 2.2(a). Explain any
    differences or similarities.

i.   Analysis:

Based on the transient response plot obtained in question c(iii), discuss the behavior of the current in the RL circuit
as it responds to the voltage step input. Specifically, explain the time constant, the initial current, and the behavior as
time progresses

14. Verification of Compensation theorem.

To verify Compensation Theorem using MATLAB/Simulink by measuring currents before and after

compensation in a simple resistive network.
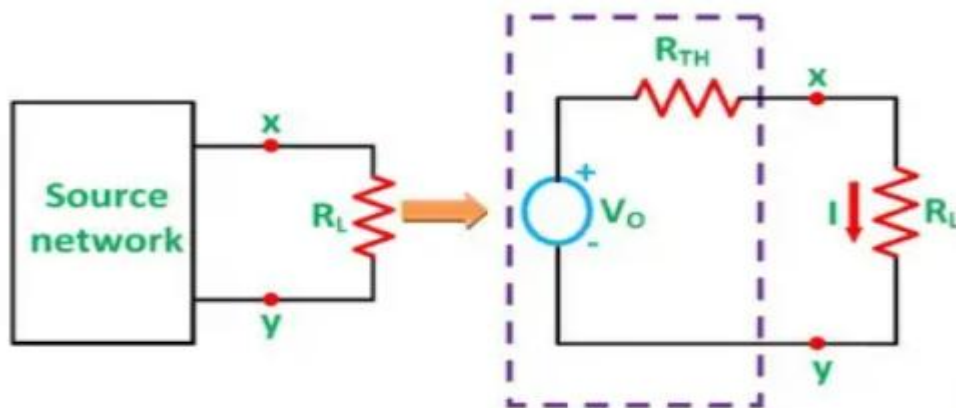
Circuit – 17

```
% Verification of Compensation Theorem
clc; clear;

% Given values
Vs = 10;       % Source voltage
R1 = 5;        % Series resistor
R2 = 10;       % Branch resistor
R3 = 10;       % Load resistor
dR = 5;        % Change in resistance

% Case 1: Original circuit
Req1 = R1 + (R2*R3)/(R2+R3);   % Equivalent resistance
I_total1 = Vs / Req1;          % Total current
V_R2 = I_total1 * (R2*R3)/(R2+R3); % Voltage across parallel
I_R2 = V_R2 / R2;              % Current through R2

fprintf('Original Current through R2 = %.3f A\n', I_R2);
% Case 2: Direct change in R2
R2_new = R2 + dR;
Req2 = R1 + (R2_new*R3)/(R2_new+R3);
I_total2 = Vs / Req2;
V_R2_new = I_total2 * (R2_new*R3)/(R2_new+R3);
I_R2_new = V_R2_new / R2_new;




fprintf('Current through R2 after direct change = %.3f A\n', I_R2_new);

% Case 3: Compensation Theorem
Vc = I_R2 * dR;     % Compensating voltage
Vs_comp = Vs + Vc;  % Modified source
Req3 = R1 + (R2_new*R3)/(R2_new+R3);
I_total3 = Vs_comp / Req3;
V_R2_comp = I_total3 * (R2_new*R3)/(R2_new+R3);
I_R2_comp = V_R2_comp / R2_new;

fprintf('Current through R2 using Compensation theorem = %.3f A\n', I_R2_comp);
```

Expected Output (approx.):

Original Current through R2 = 0.400 A
Current through R2 after direct change = 0.333 A
Current through R2 using Compensation theorem = 0.333 A

1. Open **MATLAB Simulink** → New Model.
2. Drag blocks:
   - Voltage Source (DC)
   - Resistors (R1, R2, R3)
   - Ground
   - Current Measurement (for branches)
   - Scope / Display
3. Connect them as per circuit.
4. Run first case with **original circuit** ($R_2 = 10\Omega$).
5. Then **modify R2 = 15 Ω** and add a compensating voltage source $V_c = I \cdot \Delta R$ in series with R2, where I is the original branch current.
6. Compare currents in both methods.

V. TEXT BOOKS:

1. A Chakrabarthy, "Circuit Theory", Dhanpat Rai Publications, 6th edition, 2006.
2. A Sudhakar, Shyammohan S Palli, "Circuits and Networks", Tata McGraw Hill, 4th edition,2010.

VI. REFERENCES

1. William Hayt, Jack E Kemmerly S.M. Durbin, "Engineering Circuit Analysis", Tata McGrawHill, 7th edition, 2010.
2. K S Suresh Kumar, "Electric Circuit Analysis", Pearson Education, 1st edition, 2013.
3. Rudrapratap, "Getting started with MATLAB: A Quick Introduction for Scientists andEngineers", Oxford University Press, 1st edition, 19994.

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

PROGRAMMING FOR PROBLEM SOLVING LABORATORY								
II Semester: AE / ME / CE / ECE / EEE / CSE / IT / CSE (AI&ML) / CSE (DS)								
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
ACSE07	Foundation	L	T	P	C	CIA	SEE	Total
		0	0	2	1	40	60	100
Contact Classes: Nil	**Tutorial Classes: Nil**	**Practical Classes: 45**				**Total Classes: 45**		
Prerequisite: There is no prerequisite to take this course								

I. COURSE OVERVIEW:

The course is designed with the fundamental programming skills and problem-solving strategies necessary to tackle a wide range of computational challenges. Through hands-on programming exercises and projects, students will learn how to write code, analyze problems and develop solutions using various programming languages and tools. The course will cover fundamental programming concepts and gradually progress to more advanced topics.

II. COURSES OBJECTIVES:

The students will try to learn

I   The fundamental programming constructs and use of collection data types in Python.
II   The ability to develop programs using object-oriented features.
III Basic data structures and algorithms for efficient problem-solving.
IV Principles of graph theory and be able to apply their knowledge to a wide range of practical problems across various disciplines.

III. COURSE OUTCOMES:

At the end of the course students should be able to:

CO1   Adapt programming concepts, syntax, and data structures through hands on coding exercises

CO2   Develop the ability to solve a variety of programming problems and algorithms using python

CO3   Implement complex and custom data structures to solve real-world problems.

CO4   Demonstrate proficiency in implementing graph algorithms to solve variety of problems and scenarios.

CO5   Develop critical thinking skills to solve the various real-world applications using graph theory.

CO6   Learn the importance of numerical methods and apply them to tackle a wide range of computational problems.

IV. COURSE CONTENT:

PROGRAMMING FOR PROBLEM SOLVING LABORATORY
CONTENTS

Note: Students are encouraged to bring their own laptops for laboratory practice sessions.

1. Getting Started Exercises

1.1 Bookstore Catalog

You are the owner of a bookstore and want to create a simple catalog to register books. You will start by entering the details of two books. For each book, read the title and author from the user and then display the details.

Input Format

The input consists of four lines:

The title of the first book (string)

The author of the first book (string)

The title of the second book (string)

The author of the second book (string)

Output Format

First Book Details:

Book Title: <title>

Author: <author>

Second Book Details:

Book Title: <title>

Author: <author>

Sample Test Case 1

Input

A Suitable Boy

Vikram Seth

A Fine Balance

Rohinton

Output

First Book Details:

Book Title: A Suitable Boy

Author: Vikram Seth

Second Book Details:

Book Title: A Fine Balance

Author: Rohinton

Sample Test Case 2

Input

The Namesake

Jhumpa

Sacred Games

Vikram

Output

First Book Details:

Book Title: The Namesake

Author: Jhumpa

Second Book Details:

Book Title: Sacred Games

Author: Vikram

1.2 Where Are You From?

You are creating a simple program that asks a person about their nationality and place of residence.

Your task is to read two inputs from the user:

1. The country the person comes from.

2. The country or city where the person currently lives.

Then, display three sentences describing this information.

Input Format

The first line of input contains the country the person comes from (string).

The second line of input contains the place where the person lives (string).

Output Format

Print three sentences in the following format:

I come from <country_of_origin>.

I live in <current_location>.

It's nice to meet someone from <country_of_origin>!

Sample Test Case 1

Input

India

Canada

Output

I come from India.

I live in Canada.

It's nice to meet someone from India!

Sample Test Case 2

Input

France

Germany

Output

I come from France.

I live in Germany.

It's nice to meet someone from France!

1.3 What's Your Favorite Song?

You are creating a simple Python program that asks a person about her favorite song and favorite singer.

Your task is to read two inputs from the user:

1. The name of her favorite song.

2. The name of her favorite singer.

Then, display three sentences describing this information.

Input Format

The first line of input contains the name of the favorite song (string).

The second line of input contains the name of the favorite singer (string).

Output Format

Print three sentences in the following format:

My favorite song is <song_name>.

It is sung by <singer_name>.

I can listen to <song_name> by <singer_name> all day!

Sample Test Case 1

Input

Sahiba

Aditya Rikhari

Output

My favorite song is Sahiba.

It is sung by Aditya Rikhari.

I can listen to Sahiba by Aditya Rikhari all day!

Sample Test Case 2

Input

Tum Ho Toh

Vishal Mishra

Output

My favorite song is Tum Ho Toh.

It is sung by Vishal Mishra.

I can listen to Tum Ho Toh by Vishal Mishra all day!

1.4 Quiz Grading System

A certain Computer Science professor gives 5-point quizzes that are graded on the following scale:

Score   Grade

5   A

4   B

3   C

2   D

1   F

0   F

Write a program that accepts a quiz score (an integer between 0 and 5) as input and prints out the corresponding letter grade.

Input Format

A single integer score (0 ≤ score ≤ 5) representing the quiz score.

Output Format

Print a single line containing the corresponding letter grade (A, B, C, D, or F).

Sample Test Case 1

Input

5

Output

A

Sample Test Case 2

Input

3

Output

C

1.5 Exam Grading System

A certain Computer Science professor gives 100-point exams that are graded on the following scale:

Score Range   Grade

90 – 100   A

80 – 89   B

70 – 79   C

60 – 69   D

Below 60   F

Write a program that accepts an exam score as input and prints out the corresponding letter grade.

Input Format

A single integer score (0 ≤ score ≤ 100) representing the exam score.

Output Format

Print a single line containing the corresponding letter grade (A, B, C, D, or F).

Sample Test Case 1

Input

95

Output

A

Sample Test Case 2

Input

78

Output

C

1.6 Acronym Generator

An acronym is a word formed by taking the first letters of the words in a phrase and making a new word from them. For example, RAM is an acronym for "random access memory."

Write a program that allows the user to enter a phrase, and then outputs the acronym for that phrase.

Note: The acronym should be in all uppercase letters, even if the words in the phrase are not capitalized.

Input Format

A single line of input containing a phrase (string) made up of one or more words.

Output Format

Print a single word — the acronym formed by taking the first letter of each word in the phrase and converting it to uppercase.

Sample Test Case 1

Input

Random Access Memory

Output

RAM

Sample Test Case 2

Input

Central Processing Unit

Output

CPU

1.7 Name Numerology Value Calculator

Numerologists claim to determine a person's character traits based on the numeric value of their name.

The value of a name is determined by summing up the values of each letter, where:

'a' = 1, 'b' = 2, 'c' = 3, ... up to 'z' = 26.

Example: The name "Rohith" has the value

18 + 15 + 8 + 9 + 20 + 8 = 78.

Write a program that accepts a single name as input and calculates its numeric value according to this rule.

Input Format

A single word (string) representing a person's name. The name may contain uppercase or lowercase letters.

Output Format

Print the numeric value of the given name as an integer.

Sample Test Case 1

Input

Rohith

Output

78

Sample Test Case 2

Input

Ragini

Output

58

1.8 Sentence Word Counter

A word is defined as any sequence of characters separated by spaces. The program should read the sentence from the user and print the total number of words in it. Write a program that counts the number of words in a sentence entered by the user.

Input Format

A single line of input containing a sentence (string).

Output Format

Print a single integer — the total number of words in the given sentence.

Sample Test Case 1

Input

I love programming in Python

Output

5

Sample Test Case 2

Input

AI is the future

Output

5

1.9 Average Word Length Calculator

A word is defined as any sequence of characters separated by spaces.

The average word length is calculated by dividing the total number of characters in all words by the number of words in the sentence.

Write a program that calculates the average word length in a sentence entered by the user.

Note: Ignore spaces when counting characters.

Input Format

A single line of input containing a sentence (string).

Output Format

Print the average word length as a floating-point number (you may round it to 2 decimal places).

Sample Test Case 1

Input

I love programming

Output

5.33

Explanation: Word lengths = [1, 4, 11]; Total = 16; Average = 16 / 3 = 5.33

Sample Test Case 2

Input

Python is fun

Output

3.67

Explanation: Word lengths = [6, 2, 3]; Total = 11; Average = 11 / 3 = 3.67

1.10 Future Value Calculator

Write a program futval.py that calculates and displays the future value of an investment over a specified number of years.

The program should prompt the user to enter:

1. The initial amount of investment (principal)

2. The annualized interest rate (as a decimal, e.g., 0.10 for 10%)

3. The number of years the money will be invested

The program should then display a formatted table showing the value of the investment at the end of each year, including year 0 (the initial amount).

Input Format

The first line contains a float — the initial amount of the investment.

The second line contains a float — the annualized interest rate (e.g., 0.05 for 5%).

The third line contains an integer — the number of years of the investment.

Output Format

The output should be a table with two columns:

Year — The year number starting from 0.

Value — The investment value at the end of that year (formatted with two decimal places and a dollar sign $).

Sample Test Case 1

Input

2000

0.10

7

Output

```
Year    Value
----------------
0       $2000.00
1       $2200.00
2       $2420.00
3       $2662.00
4       $2928.20
5       $3221.02
6       $3543.12
7       $3897.43
```

Sample Test Case 2

Input

1000

0.05

5

Output

```
Year    Value
----------------
0       $1000.00
1       $1050.00
2       $1102.50
3       $1157.63
4       $1215.51
```

5      $1276.28

Try:

1. **Chemical Lab**:- You are the manager of a lab. On a shelf there some jars containing chemicals. Write a list containing the names of the chemicals. One of the lab members comes to you and you ask what chemical she wants. You check in your system whether you have that chemical and reply accordingly.

2. **Travel Agency**:- You are the owner of a travel agency. Write a list of some travel destinations you sell tickets for. A new customer comes in, and you ask where he wants to go. You check whether you offer that travel destination and reply accordingly.

3. **Coffee Order**:- The Konditorei coffee shop sells coffee at $10.50 a pound plus the cost of shipping. Each order ships for $0.86 per pound + $1.50 fixed cost for overhead. Write a program that calculates the cost of an order.

2. List I

2.1 Art Gallery Inventory Checker

You are the owner of an art gallery that sells several famous paintings. You maintain a list of paintings available in your gallery.

When a new customer visits, you ask them which painting they would like to buy.

Your program should then check whether the requested painting is available in your gallery's list and respond accordingly:

If the painting is available, print a message confirming that it is available for purchase. If not, inform the customer that the painting is currently unavailable.

Input Format

A predefined list of paintings (strings) in your gallery.

A single string input — the painting name the customer wants to buy.

Output Format

A message indicating whether the requested painting is available or not.

Sample Test Case 1

Input

Available paintings: ["Starry Night", "The Mona Lisa", "The Last Supper", "The Scream", "Girl with a Pearl Earring"]

Enter the painting you want to buy: The Mona Lisa

Output

Yes, we have "The Mona Lisa" available for purchase!

Sample Test Case 2

Input

Available paintings: ["Starry Night", "The Mona Lisa", "The Last Supper", "The Scream", "Girl with a Pearl Earring"]

Enter the painting you want to buy: The Persistence of Memory

Output

Sorry, we don't have "The Persistence of Memory" right now.

2.2 Shoe Store

You are the owner of a shoe store, and you need to place a new order for the upcoming summer season.

You go to the storage room and create a list of the remaining shoes — sneakers, boots, and ballerinas.

Since you know that in summer your customers will prefer sandals, you add them to your list.

However, customers are unlikely to buy boots, so you remove them from the list.

After restocking, a new customer walks in. You ask what type of shoe they would like to try, and the customer gives a response (for example, sandals). You then check your updated list and reply accordingly:

1. If the requested shoe type is available, display a message that it is available.

2. Otherwise, inform the customer that it is not available.

Input Format

The initial list of shoe types (comma-separated).

The shoe type to be added to the list.

The shoe type to be removed from the list.

The shoe type requested by the customer.

Output Format

Display:

The final list of available shoes after addition and removal.

A message indicating whether the requested shoe type is available or not.

Sample Test Case 1

Input

sneakers, boots, ballerinas

sandals

boots

sandals

Output

Final list of shoes: ['sneakers', 'ballerinas', 'sandals']

Yes, sandals are available in the store.

Sample Test Case 2

Input

sneakers, boots, ballerinas

sandals

boots

loafers

Output

Final list of shoes: ['sneakers', 'ballerinas', 'sandals']

Sorry, loafers are not available in the store.

2.3 Currency Exchange Office

You work at a currency exchange office. The available currencies are Euros, Canadian Dollars, and Yen, whereas the Swiss Franc is unavailable, so you will have to order it. Create a list of available currencies and a list of currencies to order. A new customer comes in; you ask what currency she wants. After she replies, you check in the list of available currencies. If the currency she wants is available, you tell her that you have it, remove the currency from the list of available currencies, and add the currency to the list of currencies to order. If the currency she wants is not available, you tell her that you do not have that currency, and add the currency to the list of currencies to order.

Input Format

List of available currencies (comma-separated).

List of currencies to order (comma-separated).

The currency requested by the customer.

Output Format

Display:

Whether the requested currency is available or not.

The updated list of available currencies.

The updated list of currencies to order.

Sample Test Case 1

Input

Euros, Canadian Dollars, Yen

Swiss Franc

Euros

Output

Yes, Euros are available.

Updated available currencies: ['Canadian Dollars', 'Yen']

Updated currencies to order: ['Swiss Franc', 'Euros']

Sample Test Case 2

Input

Euros, Canadian Dollars, Yen

Swiss Franc

Pounds

Output

Sorry, Pounds are not available.

Updated available currencies: ['Euros', 'Canadian Dollars', 'Yen']

Updated currencies to order: ['Swiss Franc', 'Pounds']

2.4 Getting a New Bike

You go to a bike store to buy your new bike. There you find a bike you like: it is blue, electric, and has gears. Write a list with these characteristics. You are happy with the bike being electric and having gears, but you would like to change its color.

To do so, you

1. look at the position of the blue color in the bike option list,

2. remove the blue color, and

3. add the color you want.

Input Format

The list of initial bike features (comma-separated).

The new color you want for your bike.

Output Format

Display:

The position (index) of the color "blue" in the list.

The updated list of bike features after replacing the color.

Sample Test Case 1

Input

blue, electric, gears

red

Output

Position of 'blue' in the list: 0

Updated bike features: ['red', 'electric', 'gears']

Sample Test Case 2

Input

blue, electric, gears

green

Output

Position of 'blue' in the list: 0

Updated bike features: ['green', 'electric', 'gears']

2.5 Ordering a T-shirt Online

Ordering a T-shirt online. You are ordering a new T-shirt online. You find a T-shirt you like, which is red,

with a round neck, and with a print add your text here. Write a list with these characteristics. Now you want to add your own text to the T-shirt.

To do so, you

1. look at the position of add your text here,

2. remove add your text here, and

3. add the text you want to be printed on your T-shirt.

After completing the exercise, can you think of an alternative way can you think of an alternative way

 to change the T-shirt print?

Input Format

The list of T-shirt characteristics (comma-separated).

The new text you want to print on the T-shirt.

Output Format

Display:

The position (index) of "add your text here" in the list.

The updated list of T-shirt characteristics after changing the print.

Sample Test Case 1

Input

red, round neck, add your text here

Keep Smiling

Output

Position of 'add your text here' in the list: 2

Updated T-shirt features: ['red', 'round neck', 'Keep Smiling']

Sample Test Case 2

Input

red, round neck, add your text here

Dream Big

Output

Position of 'add your text here' in the list: 2

Updated T-shirt features: ['red', 'round neck', 'Dream Big']

2.6 Alan Turing

Alan Turing's contributions during World War II had a profound impact on history. To explore this programmatically, you are given the following list:

alan_turing = ["Turing", "created", "an electromechanical machine", "to crack", "the Nazi Navy's", "Enigma Code"]

You must perform a series of list modifications to form meaningful sentences describing his contribution.

Use list slicing to perform the following tasks:

a. Replace "the Nazi Navy's" with "shortened the war".

b. Insert "by two years" in position 5 (i.e., as the sixth element).

c. Replace "an electromechanical machine" with "his contribution".

d. Add "saving millions of lives" to the end of the list.

e. Replace "created" with "that".

f. Remove "to crack".

g. Replace "Turing" with "It is estimated".

h. Remove the element in position 5 (sixth element).

After performing all of these operations using list slicing, redo the same operations using list methods (like .insert(), .append(), .remove(), etc.).

Input Format

No user input is required.

The list alan_turing is predefined in the program.

Output Format

Display:

The list after all operations using list slicing.

The list after performing the same operations using list methods.

Sample Test Case 1

Output

After performing operations using list slicing:

['It is estimated', 'that', 'his contribution', 'shortened the war', 'Enigma Code', 'saving millions of lives']

After performing operations using list methods:

['It is estimated', 'that', 'his contribution', 'shortened the war', 'Enigma Code', 'saving millions of lives']

2.7 Four Seasons

You are given a list of the four seasons:

seasons = ["spring", "summer", "fall", "winter"]

Perform the following tasks using list indexing, slicing, and conditional checks:

a. Print all seasons whose names are composed of at least 5 characters.

b. Print all seasons whose names are composed of a number of characters equal to or less than 4.

c. Print all seasons whose position (index) is less than 2.

d. Print all seasons whose position (index) is at least 2.

Input Format

No user input is required.

The list seasons is predefined in the program.

Output Format

Print the required results for each of the four conditions with descriptive labels.

Sample Test Case 1

Output

Seasons with at least 5 characters: ['spring', 'summer', 'winter']

Seasons with 4 or fewer characters: ['fall']

Seasons with position less than 2: ['spring', 'summer']

Seasons with position at least 2: ['fall', 'winter']

2.8 Word Search

You are working for a magazine and have just designed a new word search puzzle for your readers.

The hidden words in the puzzle are:

words = ["cards", "park", "pets", "football", "golf", "crosswords", "toys", "exercise", "hobbies", "riding", "biking", "games", "reading", "movies", "walking", "concerts"]

Perform the following tasks using Python:

a. Create a variable called title containing the number of words in the list and print it as

"Word search with X words."

b. Find and print all words composed of exactly 5 letters. Print a descriptive title along with the count.

c. Check whether there are words with fewer than 5 characters.

For each such word, print a sentence containing the word, its position (index) in the list, and its length.

d. Similarly, check whether there are words with more than 8 characters.

For each such word, print a sentence containing the word, its position, and its length.

e. From the second half of the list, print all words whose number of characters is different from 7.

Also display their position and length.

f. From the first fourth of the list, print all 4-letter words.

Display their position in the list.

Input Format

No user input is required.

The list of words is predefined in the program.

Output Format

Display the results of all the above operations with descriptive messages.

Sample Test Case 1

Output

Word search with 16 words

Words with 5 letters: ['cards', 'riding', 'biking', 'games']

Number of 5-letter words: 4

Words with less than 5 letters:

- 'park' (position 1) has 4 characters.

- 'pets' (position 2) has 4 characters.

- 'golf' (position 4) has 4 characters.

- 'toys' (position 7) has 4 characters.

Words with more than 8 characters:

- 'crosswords' (position 6) has 10 characters.

- 'exercise' (position 8) has 8 characters.

- 'hobbies' (position 9) has 7 characters. # not >8, excluded

- 'concerts' (position 15) has 8 characters. # not >8, excluded

Words in the second half (different from 7 characters):

- 'riding' (position 9) → 6 characters

- 'games' (position 11) → 5 characters

- 'walking' (position 14) → 7 characters (excluded)

- 'concerts' (position 15) → 8 characters

4-letter words in the first fourth of the list:

- 'park' (position 1)

- 'pets' (position 2)

- 'golf' (position 4)

2.9 Spelling Competition

You are preparing for a spelling competition, and the category for this round is the musculoskeletal (MSK) system.

The list of words you need to memorize is:

msk_words = ["ankle", "patella", "rib", "femur", "sternocleidomastoid", "tendon", "sternum", "abdominal external oblique", "muscle", "scapula", "radius", "bone", "vertebra", "ligament", "ulna", "skull", "clavicle"]

Perform the following tasks:

a. Find how many words you have to learn and print the total.

b. Print the length of each word (including spaces, if any).

c. Add all words with 6 or fewer characters to the list short = ["leg"] and print the updated list. Also, print how many words are in it.

d. Add all words with 7, 8, or 9 characters to the list intermediate = ["cartilage"]. Print the updated list and its count.

e. Add all the remaining words (10 or more characters) to the list long = ["pectoralis major"]. Print the updated list and its count.

Input Format

No user input is required.

The list msk_words is predefined in the program.

Output Format

Print descriptive messages showing:

Total number of words

Word lengths

Categorized lists (short, intermediate, long) with word counts

Sample Test Case 1

Output

Total number of words to learn: 17

Length of each word:

ankle: 5

patella: 7

rib: 3

femur: 5

sternocleidomastoid: 18

tendon: 6

sternum: 7

abdominal external oblique: 27

muscle: 6

scapula: 7

radius: 6

bone: 4

vertebra: 8

ligament: 8

ulna: 4

skull: 5

clavicle: 8

Short words (6 or fewer characters): ['leg', 'ankle', 'rib', 'femur', 'tendon', 'muscle', 'radius', 'bone', 'ulna', 'skull']

Number of short words: 10

Intermediate words (7–9 characters): ['cartilage', 'patella', 'sternum', 'scapula', 'vertebra', 'ligament', 'clavicle']

Number of intermediate words: 7

Long words (10+ characters): ['pectoralis major', 'sternocleidomastoid', 'abdominal external oblique']

Number of long words: 3

2.10 Bookstore

You are managing the inventory of a bookstore. You maintain a list of books that are currently available:

books = ["The Alchemist", "1984", "To Kill a Mockingbird", "The Great Gatsby", "Moby Dick"]

Perform the following tasks using list operations:

a. A customer buys "1984". Remove this book from the list and print the updated list.

b. A new shipment arrives with two new titles — "Pride and Prejudice" and "The Catcher in the Rye". Add them to your inventory and print the updated list.

c. Display the total number of books now in stock.

d. Print the first book and the last book in the list.

e. Sort the list alphabetically and display it.

f. Finally, check whether "Moby Dick" is still available in the store. Print a suitable message.

Input Format

No user input is required.

The list of books is predefined in the program.

Output Format

Display descriptive outputs after each operation.

Sample Test Case 1

Output

Original list of books: ['The Alchemist', '1984', 'To Kill a Mockingbird', 'The Great Gatsby', 'Moby Dick']

After selling '1984': ['The Alchemist', 'To Kill a Mockingbird', 'The Great Gatsby', 'Moby Dick']

After adding new books: ['The Alchemist', 'To Kill a Mockingbird', 'The Great Gatsby', 'Moby Dick', 'Pride and Prejudice', 'The Catcher in the Rye']

Total number of books: 6

First book: The Alchemist

Last book: The Catcher in the Rye

Books sorted alphabetically: ['Moby Dick', 'Pride and Prejudice', 'The Alchemist', 'The Catcher in the Rye', 'The Great Gatsby', 'To Kill a Mockingbird']

Yes, 'Moby Dick' is available in the store.

Try:

1. **Selling Electric Cars**: - You work at a famous car company, and you have to ship new electric cars that have just arrived. Your colleagues plated the cars destined to Spain and to Portugal, but they mixed them up:

e_cars = ["PT-754J", "ES-096L", "PT-536G", "ES-543H", "PT-653H"]

Separate the two groups of cars according to their destinations.

2. **Teaching English Verbs.** You are an English teacher for foreign students. Some of them have difficulties understanding when a present verb is conjugated in the third person singular (he/she/it), or in other persons (I/you/we/they). So you provide a list of verbs:

 english_verbs = ["eat", "drink", "eats", "sleep", "drinks", "sleeps"]

 and you help your students separate the verbs between third person and other persons.

3. List II

3.1 Two Sum

Given an array of integers nums and an integer target, return indices of the two numbers such that they add up to target. You may assume that each input would have exactly one solution, and you may not use the same element twice. You can return the answer in any order.

Input: nums = [2, 7, 11, 15], target = 9

Output: [0, 1]

Explanation: Because nums[0] + nums[1] == 9, so return [0, 1].

Input: nums = [3, 2, 4], target = 6

Output: [1, 2]

Input: nums = [3, 3], target = 6

Output: [0, 1]

3.2 Contains Duplicate

Given an integer array nums, return true if any value appears at least twice in the array, and return false if every element is distinct.

Input: nums = [1, 2, 3, 1]

Output: true

Input: nums = [1, 2, 3, 4]

Output: false

Input: nums = [1, 1, 1, 3, 3, 4, 3, 2, 4, 2]

Output: true

3.3 Roman to Integer

Roman numerals are represented by seven different symbols: I, V, X, L, C, D and M.

Symbol	Value
I	1
V	5
X	10
L	50
C	100
D	500
M	1000

For example, 2 is written as II in Roman numeral, just two ones added together. 12 is written as XII, which is simply X + II. The number 27 is written as XXVII, which is XX + V + II.

Roman numerals are usually written largest to smallest from left to right. However, the numeral for four is not IIII. Instead, the number four is written as IV. Because the one is before the five we subtract it making four. The same principle applies to the number nine, which is written as IX. There are six instances where

subtraction is used:

I can be placed before V (5) and X (10) to make 4 and 9.

X can be placed before L (50) and C (100) to make 40 and 90.

C can be placed before D (500) and M (1000) to make 400 and 900.

Given a roman numeral, convert it to an integer.

Input: s = "III"

Output: 3

Input: s = "LVIII"

Output: 58

3.4 Plus One

You are given a large integer represented as an integer array digits, where each digits[i] is the ith digit of the integer. The digits are ordered from most significant to least significant in left-to-right order. The large integer does not contain any leading 0's. Increment the large integer by one and return the resulting array of digits.

Input: digits = [1, 2, 3]

Output: [1, 2, 4]

Explanation: The array represents the integer 123.

Incrementing by one gives 123 + 1 = 124.

Thus, the result should be [1, 2, 4].

3.5 Majority Element

Given an array nums of size n, return the majority element. The majority element is the element that appears more than ⌊n / 2⌋ times. You may assume that the majority element always exists in the array.

Input: nums = [3, 2, 3]

Output: 3

Input: nums = [2, 2, 1, 1, 1, 2, 2]

Output: 2

3.6 Richest Customer Wealth

You are given an m x n integer grid accounts where accounts[i][j] is the amount of money the ith customer has in the jth bank. Return the wealth that the richest customer has. A customer's wealth is the amount of money they have in all their bank accounts. The richest customer is the customer that has the maximum wealth.

Input: accounts = [[1, 2, 3], [3,2,1]]

Output: 6

Explanation:

1st customer has wealth = 1 + 2 + 3 = 6

2nd customer has wealth = 3 + 2 + 1 = 6

Both customers are considered the richest with a wealth of 6 each, so return 6.

Input: accounts = [[1, 5], [7,3],[3,5]]

Output: 10

Explanation:

1st customer has wealth = 6

2nd customer has wealth = 10

3rd customer has wealth = 8

The 2nd customer is the richest with a wealth of 10.

Input: accounts = [[2,8,7],[7,1,3],[1,9,5]]

Output: 17

3.7 Fizz Buzz

Given an integer n, return a string array answer (1-indexed) where:

answer[i] == "FizzBuzz" if i is divisible by 3 and 5.

answer[i] == "Fizz" if i is divisible by 3.

answer[i] == "Buzz" if i is divisible by 5.

answer[i] == i (as a string) if none of the above conditions are true.

Input: n = 3

Output: ["1","2","Fizz"]

Input: n = 5

Output: ["1","2","Fizz","4","Buzz"]

Input: n = 15

Output: ["1","2","Fizz","4","Buzz","Fizz","7","8","Fizz","Buzz","11","Fizz","13","14","FizzBuzz"]

3.8 Number of Steps to Reduce a Number to Zero

Given an integer num, return the number of steps to reduce it to zero. In one step, if the current number is even, you have to divide it by 2, otherwise, you have to subtract 1 from it.

Input: num = 14

Output: 6

Explanation:

- 14 is even; divide by 2 and obtain 7.
- 7 is odd; subtract 1 and obtain 6.
- 6 is even; divide by 2 and obtain 3.
- 3 is odd; subtract 1 and obtain 2.
- 2 is even; divide by 2 and obtain 1.
- 1 is odd; subtract 1 and obtain 0.

Input: num = 8

Output: 4

Explanation:

- 8 is even; divide by 2 and obtain 4.
- 4 is even; divide by 2 and obtain 2.
- 2 is even; divide by 2 and obtain 1.
- 1 is odd; subtract 1 and obtain 0.

Input: num = 123

Output: 12

3.9 Running Sum of 1D Array

Given an array nums. We define a running sum of an array as runningSum[i] = sum (nums[0]...nums[i]).

Return the running sum of nums.

Input: nums = [1, 2, 3, 4]

Output: [1, 3, 6, 10]

Explanation: Running sum is obtained as follows: [1, 1+2, 1+2+3, 1+2+3+4].

Input: nums = [1, 1, 1, 1, 1]

Output: [1, 2, 3, 4, 5]

Explanation: Running sum is obtained as follows: [1, 1+1, 1+1+1, 1+1+1+1, 1+1+1+1+1].

Input: nums = [3, 1, 2, 10, 1]

Output: [3, 4, 6, 16, 17]

3.10 Remove Element

Given an integer array nums and an integer val, remove all occurrences of val in nums in-place. The order of the elements may be changed. Then return the number of elements in nums which are not equal to val. Consider the number of elements in nums which are not equal to val be k, to get accepted, you need to do the following things:

- Change the array nums such that the first k elements of nums contain the elements which are not equal to val. The remaining elements of nums are not important as well as the size of nums.
- Return k.

Input: nums = [3, 2, 2, 3], val = 3

Output: 2, nums = [2, 2, _, _]

Explanation: Your function should return k = 2, with the first two elements of nums being 2.

It does not matter what you leave beyond the returned k (hence they are underscores).

Input: nums = [0,1,2,2,3,0,4,2], val = 2

Output: 5, nums = [0,1,4,0,3,_,_,_]

Explanation: Your function should return k = 5, with the first five elements of nums containing 0, 0, 1, 3, and 4.

Note that the five elements can be returned in any order.

It does not matter what you leave beyond the returned k (hence they are underscores).

4. Tuple

4.1 Student Report Card

A school teacher wants to automate the process of calculating students' performance. For each student, the teacher maintains tuples in the form: (name, subject, marks)

For example,

("Alisha", "Math", 85) means Alisha scored 85 in Math.

The teacher wants to generate a summary report that shows:

The average marks of each student.

The student with the highest average marks (topper).

- Calculate the average marks per student.
- Identify the topper (student with the highest average).
- Return a tuple (topper_name, topper_average).

Input Format

The first line contains an integer n, the number of records.

The next n lines each contain:

Student name (string)

Subject name (string)

Marks (integer)

Output Format

The first line should display each student's name and average marks (sorted alphabetically).

The second line should display the topper's name and average marks.

Sample Test Case 1

Input

6

Alisha Math 85

Alisha Science 90

Bibek Math 75

Bibek Science 80

Charan Math 95

Charan Science 100

Output

Alisha: 87.5

Bibek: 77.5

Charan: 97.5

Topper: Charan with average 97.5

Sample Test Case 2

Input

5

John English 70

John Math 80

Mary English 85

Mary Math 95

Tom Science 88

Output

John: 75.0

Mary: 90.0

Tom: 88.0

Topper: Mary with average 90.0

4.2 Grocery Inventory Tracker

A store keeps its stock in tuples of the form (item_name, price_per_unit, quantity). When a customer buys an item, you must update the stock and calculate the bill.

For example,

("Rice", 60, 50) means the store has 50 kg of rice, each costing ₹60 per kg.

When a customer purchases certain quantities of items, the system must:

- Check if the requested quantity is available.
- Calculate the total bill based on the purchased quantities.
- Update the stock by reducing the sold quantities.

If the requested quantity exceeds available stock, the system should ignore that item and continue with others.

Input Format:

The first line contains an integer n, the number of items in the inventory.

The next n lines each contain:

item_name price_per_unit quantity_in_stock

The next line contains an integer m, the number of purchased items.

The following m lines each contain:

item_name quantity_purchased

Output Format:

First line: Total Bill

Then, display the Updated Inventory in the format:

item_name price_per_unit quantity_left

Sample Test Case 1

Input

4

Rice 60 50

Sugar 40 30

Oil 150 20

Salt 20 40

3

Rice 10

Oil 5

Salt 45

Output

Total Bill: 1350

Updated Inventory:

Rice 60 40

Sugar 40 30

Oil 150 15

Salt 20 40

Explanation:

Rice: 10 × 60 = 600

Oil: 5 × 150 = 750

Salt: requested 45 > 40 → ignored

Total Bill = 600 + 750 = ₹1350

Sample Test Case 2

Input

3

Apple 100 20

Banana 30 50

Mango 80 10

2

Apple 5

Mango 12

Output

Total Bill: 500

Updated Inventory:

Apple 100 15

Banana 30 50

Mango 80 10

4.3 Quiz Master Analyzer

A quiz competition system records each participant's answers as tuples of the form:

(question_id, correct_option, chosen_option)

For example:

(1, 'B', 'B') means Question 1 had the correct answer 'B', and the participant also chose 'B'.

The Quiz Master wants to evaluate the participant's performance by finding:

The total score — each correct answer gives 4 points, and wrong answers give 0 points.

The accuracy percentage, calculated as:

$$\text{Accuracy } (\%) = \frac{\text{Number of Correct Answers}}{\text{Total Questions}} \times 100$$

Input Format:

First line: integer n → number of questions

Next n lines: each contains

question_id correct_option chosen_option

Output Format:

First line: Total score (integer)

Second line: Accuracy percentage (float, rounded to 2 decimal places)

Sample Test Case 1

Input

5

1 A A

2 B C

3 D D

4 C C

5 A B

Output

Total Score: 12

Accuracy: 60.0%

Sample Test Case 2

Input

4

1 A B

2 C C

3 D A

4 B B

Output

Total Score: 8

Accuracy: 50.0%

4.4 Library Book Tracker

A library maintains its collection as tuples in the format: (title, author, year, copies_available)

The librarian wants to find all books published within a specific year range (both start and end inclusive).

You need to help by listing all such books that fall within the range. Write a program that takes a list of book records stored as tuples and a start and end year.

The program should return a list of all books (tuples) that were published between the given years (inclusive).

Input Format:

The first line contains an integer n — number of books.

The next n lines each contain details of a book in the form: title author year copies_available

The last line contains two integers: start_year and end_year.

Output Format:

Print all the book tuples that were published between start_year and end_year (inclusive).

If no books match, print "No books found in the given range."

Sample Test Case 1

Input

5

PythonCrashCourse EricMatthes 2016 10

CleanCode RobertMartin 2008 5

AutomateBoringStuff AlSweigart 2015 8

DeepLearning IanGoodfellow 2016 3

IntroToAlgorithms Cormen 2009 6

2010 2016

Output

('PythonCrashCourse', 'EricMatthes', 2016, 10)

('AutomateBoringStuff', 'AlSweigart', 2015, 8)

('DeepLearning', 'IanGoodfellow', 2016, 3)

Sample Test Case 2

Input

3

DataScienceFromScratch JoelGrus 2019 7

ArtificialIntelligence Russell 2003 4

ThinkPython AllenDowney 2012 9

2000 2010

Output

('ArtificialIntelligence', 'Russell', 2003, 4)

4.5 Banking Transaction Log

A bank maintains its customer transactions as tuples in the form: (account_number, transaction_type, amount). Each transaction can either be a credit (money added) or a debit (money subtracted). You need to calculate the final balance for each account based on all transactions.

Given a list of transaction records represented as tuples, write a program that computes the final balance of every account.

Each record has:

account_number — an integer

transaction_type — either "credit" or "debit"

amount — a positive number

The program should output a list of tuples in the format: (account_number, final_balance)

Input Format:

The first line contains an integer n — number of transactions.

The next n lines each contain:

account_number transaction_type amount

where transaction_type is either "credit" or "debit".

Output Format:

Print all account numbers with their final balances in tuple form: (account_number, final_balance)

If no transactions exist, print "No transactions found."

Sample Test Case 1

Input

6

101 credit 5000

102 credit 3000

101 debit 1000

103 credit 7000

102 debit 500

101 credit 2000

Output

(101, 6000)

(102, 2500)

(103, 7000)

Sample Test Case 2

Input

4

200 credit 1000

201 debit 500

200 credit 2000

201 credit 700

Output

(200, 3000.0)

(201, 200.0)

Try:

1. **Sports Tournament Analyzer**: A sports tournament keeps match results as tuples in the format:

(team_name, matches_played, matches_won, matches_lost, matches_drawn)

The organizer wants to calculate total points for each team.

Points are given as:

Win → 3 points

Draw → 1 point

Loss → 0 points

You must display a list of tuples showing each team's name and total points. Write a program that takes a list of tuples representing team records and calculates total points per team.

2. **Employee Salary Updater:** A company stores its employee details as tuples in the format: (employee_id, name, department, salary)

At the end of the year, every employee in a specific department gets a 10% salary hike. You must update and print the new salary records.

Write a program that takes a list of employee records and a department name, then prints updated tuples with incremented salaries for that department.

5. Dictionary

5.1 Student Information

You work in a school registrar's office, and you are required to manage and update a student's information stored in a Python dictionary.

Initially, the student's data is given as follows:

student = {

   "Firstname": "Rahul",

   "Lastname": "Sharma",

   "Sex": "Male",

   "Age": 21,

   "Course": "Literature",

"Hobby": "Swimming"

}

You need to perform the following operations:

- Print all the keys and their values.
- Print all the keys only.
- Print all the values only.
- Update the student's course from "Literature" to "Foreign Languages".
- Add two new pieces of information:
  - "Address" (using direct assignment syntax)
  - "Phone number" (using the .update() method)
- Remove "Sex" and "Hobby" from the dictionary due to new privacy policies.

Input Format

There is no user input; the data is predefined inside the program.

The program performs the above-listed operations on the student dictionary.

Output Format

The program should print:

- All keys and their corresponding values.
- All keys only.
- All values only.
- The updated dictionary after the course change.
- The dictionary after adding the new information.
- The final dictionary after removing sensitive data.

Sample Test Case 1

Input

student = {

    "Firstname": "Rahul",

    "Lastname": "Sharma",

    "Sex": "Male",

    "Age": 21,

    "Course": "Literature",

    "Hobby": "Swimming"

}

Output

a. Keys and Values:

Firstname : Rahul

Lastname : Sharma

Sex : Male

Age : 21

Course : Literature

Hobby : Swimming

b. Keys: dict_keys(['Firstname', 'Lastname', 'Sex', 'Age', 'Course', 'Hobby'])

c. Values: dict_values(['Rahul', 'Sharma', 'Male', 21, 'Literature', 'Swimming'])

d. After updating course: {'Firstname': 'Rahul', 'Lastname': 'Sharma', 'Sex': 'Male', 'Age': 21, 'Course': 'Foreign Languages', 'Hobby': 'Swimming'}

e. After adding Address and Phone number:

{'Firstname': 'Rahul', 'Lastname': 'Sharma', 'Sex': 'Male', 'Age': 21, 'Course': 'Foreign Languages', 'Hobby': 'Swimming', 'Address': 'New York', 'Phone number': '9876543210'}

f. After removing Sex and Hobby:

{'Firstname': 'Rahul', 'Lastname': 'Sharma', 'Age': 21, 'Course': 'Foreign Languages', 'Address': 'New York', 'Phone number': '9876543210'}

Sample Test Case 2

Input

student = {

   "Firstname": "Shruti",

   "Lastname": "Verma",

   "Sex": "Female",

   "Age": 19,

   "Course": "Computer Science",

   "Hobby": "Painting"

}

Output

a. Keys and Values:

Firstname : Shruti

Lastname : Verma

Sex : Female

Age : 19

Course : Computer Science

Hobby : Painting

b. Keys:

dict_keys(['Firstname', 'Lastname', 'Sex', 'Age', 'Course', 'Hobby'])

c. Values:

dict_values([' Shruti ', ' Verma ', 'Female', 19, 'Computer Science', 'Painting'])

d. After updating course:

{'Firstname': ' Shruti ', 'Lastname': ' Verma ', 'Sex': 'Female', 'Age': 19, 'Course': 'Foreign Languages', 'Hobby': 'Painting'}

e. After adding Address and Phone number:

{'Firstname': ' Shruti ', 'Lastname': ' Verma ', 'Sex': 'Female', 'Age': 19, 'Course': 'Foreign Languages', 'Hobby': 'Painting', 'Address': 'New York', 'Phone number': '9876543210'}

f. After removing Sex and Hobby:

{'Firstname': ' Shruti ', 'Lastname': ' Verma ', 'Age': 19, 'Course': 'Foreign Languages', 'Address': 'New York',

'Phone number': '9876543210'}

5.2 New T-shirts in the Store

You are the owner of a clothing store getting ready for the summer season. Your supplier has just delivered a new batch of trendy T-shirts. You need to manage their details using a Python dictionary and perform several updates.

Perform the following tasks:

1. Create a dictionary containing the initial characteristics of the new T-shirts:

"Color" = "Red"

"Size" = "M"

"Neck Type" = "Round"

2. Add more information about the new T-shirts:

"Quantity" = 25 (use direct assignment)

"Logo Color" = "Blue" (use the update () method)

3. Record sales data:

"Sold" = 20 (new item added)

4. Update remaining stock:

Calculate remaining quantity as Quantity - Sold, and update "Quantity" accordingly.

Input Format

- There is no user input; all data is defined inside the program.
- Operations are performed step-by-step on the dictionary representing the T-shirt stock.

Output Format

The program should display:

- The initial dictionary.
- The dictionary after adding more details.
- The dictionary after adding the number of sold T-shirts.
- The final dictionary after updating the remaining quantity.

Sample Test Case 1

Input

tshirt = {

   "Color": "Red",

   "Size": "M",

   "Neck Type": "Round"

}

Output

a. Initial T-shirt information:

{'Color': 'Red', 'Size': 'M', 'Neck Type': 'Round'}

b. After adding quantity and logo color:

{'Color': 'Red', 'Size': 'M', 'Neck Type': 'Round', 'Quantity': 25, 'Logo Color': 'Blue'}

c. After recording sales:

{'Color': 'Red', 'Size': 'M', 'Neck Type': 'Round', 'Quantity': 25, 'Logo Color': 'Blue', 'Sold': 20}

d. After updating remaining quantity:

{'Color': 'Red', 'Size': 'M', 'Neck Type': 'Round', 'Quantity': 5, 'Logo Color': 'Blue', 'Sold': 20}

Sample Test Case 2

Input

tshirt = {

   "Color": "Black",

   "Size": "L",

   "Neck Type": "V-Neck"

}

Output

a. Initial T-shirt information:

{'Color': 'Black', 'Size': 'L', 'Neck Type': 'V-Neck'}

b. After adding quantity and logo color:

{'Color': 'Black', 'Size': 'L', 'Neck Type': 'V-Neck', 'Quantity': 30, 'Logo Color': 'White'}

c. After recording sales:

{'Color': 'Black', 'Size': 'L', 'Neck Type': 'V-Neck', 'Quantity': 30, 'Logo Color': 'White', 'Sold': 12}

d. After updating remaining quantity:

{'Color': 'Black', 'Size': 'L', 'Neck Type': 'V-Neck', 'Quantity': 18, 'Logo Color': 'White', 'Sold': 12}

5.3 Colosseum

You are helping your neighbor's kid with a history assignment about the Colosseum. You visit the Colosseum's Wikipedia page to collect information and organize it using a Python dictionary.

Perform the following tasks step-by-step:

1. Create an initial dictionary with basic information from the Wikipedia page:

"Location" = "Rome"

"Construction Years" = "70–80 AD"

"Type" = "Amphitheater"

2. Update construction details based on new findings:

Construction began in 72 AD and was completed in 80 AD.

Remove the old key "Construction Years".

Add:

"Construction Start Year" = 72 (use direct assignment)

"Construction End Year" = 80 (use .update() method)

3. Calculate and display:

(a) How many years it took to build the Colosseum.
   → End Year - Start Year

(b) How many years have passed since its construction started (considering the current year).

Input Format

- There is no user input; all data is predefined in the program.
- The program performs dictionary manipulations and arithmetic calculations.

Output Format

The program should display:

- The initial dictionary.
- The dictionary after updating construction years.
- The number of years it took to build the Colosseum.
- The number of years passed since construction began.

Sample Test Case 1

Input

{

  "Location": "Rome",

  "Construction Years": "70–80 AD",

  "Type": "Amphitheater"

}

Output

a. Initial Colosseum information:

{'Location': 'Rome', 'Construction Years': '70–80 AD', 'Type': 'Amphitheater'}

b. After updating construction details:

{'Location': 'Rome', 'Type': 'Amphitheater', 'Construction Start Year': 72, 'Construction End Year': 80}

c. It took 8 years to build the Colosseum.

d. 1953 years have passed since its construction started.

Sample Test Case 2

Input

{

  "Location": "Rome",

  "Construction Years": "118–128 AD",

  "Type": "Temple"

}

Output

a. Initial structure information:

{'Location': 'Rome', 'Construction Years': '118–128 AD', 'Type': 'Temple'}

b. After updating construction details:

{'Location': 'Rome', 'Type': 'Temple', 'Construction Start Year': 118, 'Construction End Year': 128}

c. It took 10 years to build the Pantheon.

d. 1907 years have passed since its construction started.

5.4 At a Pet Clinic

You are a veterinarian managing a list of pets currently at your clinic. Each pet is represented as a dictionary containing the following details:

- "name" — the name of the pet

- "animal type" — type of animal (e.g., dog, cat, parrot)

- "age" — the pet's age in years

You start with the following list of pets:

pets = [

   {"name": "Toby", "animal type": "dog", "age": 2},

   {"name": "Kitty", "animal type": "cat", "age": 5},

   {"name": "Tiki", "animal type": "parrot", "age": 1}

]

Your tasks are:
a. Add a new patient, a 4-year-old horse named Sugar, to the list.
b. Print all the animal names twice:

- First, using a for loop through elements

- Then, using a for loop through indices
  c. Finally, add a new item indicating that all animals are currently in the clinic (choose an appropriate datatype to store this information).

Input Format

There is no user input for this problem.
All data is predefined within the program.

Output Format

The program should print:

1. The list of pets after adding the new patient.

2. The names of all pets printed twice —

    o   Once using a for loop through elements

    o   Once using a for loop through indices

3. The updated list of pets showing that all animals are currently in the clinic.

Sample Test Case 1

Input

pets = [{"name":"Toby", "animal type":"dog", "age":2},

      {"name":"Kitty", "animal type":"cat", "age":5},

      {"name":"Tiki", "animal type":"parrot", "age":1}]

Output

After adding new patient:

[{'name': 'Toby', 'animal type': 'dog', 'age': 2},

 {'name': 'Kitty', 'animal type': 'cat', 'age': 5},

 {'name': 'Tiki', 'animal type': 'parrot', 'age': 1},

 {'name': 'Sugar', 'animal type': 'horse', 'age': 4}]

Animal names (using elements):

Toby

Kitty

Tiki

Sugar

Animal names (using indices):

Toby

Kitty

Tiki

Sugar

After adding clinic status:

[{'name': 'Toby', 'animal type': 'dog', 'age': 2},

 {'name': 'Kitty', 'animal type': 'cat', 'age': 5},

 {'name': 'Tiki', 'animal type': 'parrot', 'age': 1},

 {'name': 'Sugar', 'animal type': 'horse', 'age': 4}]

Clinic Status: All animals are currently in the clinic.

Sample Test Case 2

Input

Initial Pets List

pets = [

   {"name": "Bruno", "animal type": "dog", "age": 3},

   {"name": "Misty", "animal type": "cat", "age": 2},

   {"name": "Coco", "animal type": "rabbit", "age": 1}

]

New Patient to Add

Name: Rocky

Animal Type: turtle

Age: 6

Output

After adding new patient:

[{'name': 'Bruno', 'animal type': 'dog', 'age': 3},

 {'name': 'Misty', 'animal type': 'cat', 'age': 2},

 {'name': 'Coco', 'animal type': 'rabbit', 'age': 1},

{'name': 'Rocky', 'animal type': 'turtle', 'age': 6}]

Animal names (using elements):

Bruno

Misty

Coco

Rocky

Animal names (using indices):

Bruno

Misty

Coco

Rocky

After adding clinic status:

[{'name': 'Bruno', 'animal type': 'dog', 'age': 3},

 {'name': 'Misty', 'animal type': 'cat', 'age': 2},

 {'name': 'Coco', 'animal type': 'rabbit', 'age': 1},

 {'name': 'Rocky', 'animal type': 'turtle', 'age': 6}]

Clinic Status: All animals are currently in the clinic.

5.5 Juices

You own a juice stand and want to manage your juice inventory and sales details efficiently. Your task is to perform the following steps:

1. Create a list of dictionaries, each representing a juice flavor with:

"flavor" — name of the juice (e.g., orange, lemon, pomegranate)

"price" — price of the juice

"color" — color of the juice

Example:

{"flavor": "orange", "price": 50, "color": "orange"}

2. Add a new key-value pair to each dictionary where the key is "in shop" and the value is a Boolean (True or False) indicating whether the juice is currently available in the shop.

3. Add a new juice order — "grape juice" — with its price and color, and mark it as available.

4. Calculate and print the average price of all juices in the shop.

Input Format

There is no user input for this program.
All data is defined inside the program.

Output Format

The program should print:

The list of juices after adding "in shop" details.

The updated list after adding the new "grape" juice.

The average price of all juices.

Sample Test Case 1

Output

Initial juice list with 'in shop' status:

[{'flavor': 'orange', 'price': 50, 'color': 'orange', 'in shop': True},

 {'flavor': 'lemon', 'price': 40, 'color': 'yellow', 'in shop': True},

 {'flavor': 'pomegranate', 'price': 70, 'color': 'red', 'in shop': True}]

After adding new juice (grape):

[{'flavor': 'orange', 'price': 50, 'color': 'orange', 'in shop': True},

 {'flavor': 'lemon', 'price': 40, 'color': 'yellow', 'in shop': True},

 {'flavor': 'pomegranate', 'price': 70, 'color': 'red', 'in shop': True},

 {'flavor': 'grape', 'price': 60, 'color': 'purple', 'in shop': True}]

Average price of juices: 55.0

Sample Test Case 2

If the initial prices differ:

Juices:

Orange — ₹80

Lemon — ₹60

Pomegranate — ₹100

New juice (grape) — ₹70

Output

Initial juice list with 'in shop' status:

[{'flavor': 'orange', 'price': 80, 'color': 'orange', 'in shop': True},

 {'flavor': 'lemon', 'price': 60, 'color': 'yellow', 'in shop': True},

 {'flavor': 'pomegranate', 'price': 100, 'color': 'red', 'in shop': True}]

After adding new juice (grape):

[{'flavor': 'orange', 'price': 80, 'color': 'orange', 'in shop': True},

 {'flavor': 'lemon', 'price': 60, 'color': 'yellow', 'in shop': True},

 {'flavor': 'pomegranate', 'price': 100, 'color': 'red', 'in shop': True},

 {'flavor': 'grape', 'price': 70, 'color': 'purple', 'in shop': True}]

Average price of juices: 77.5

5.6 Olympic Games

You are a sports journalist compiling information about sports performed at the Olympic Games. You want to organize the data into a Python dictionary where the keys represent the season ("Summer" and "Winter") and the values are lists of sports played in each season.

Perform the following tasks:

a. Create an empty dictionary named olympic_sports.

b. Add two summer sports and two winter sports.
c. The lists of sports look a bit short, so add two more summer sports and two more winter sports, each using a different method (like .append() or +=).
d. Print all items one by one in two different ways:

Using .items()

Using dictionary keys
e. Finally, print only the sports lists (values of the dictionary).

Input Format

There is no user input.
All data is predefined inside the program.

Output Format

The program should display:

The dictionary after adding all sports.

The items printed one by one in two different ways.

The sports lists only (dictionary values).

Sample Test Case 1

Output

Olympic Sports Dictionary:

{'Summer': ['Swimming', 'Athletics', 'Gymnastics', 'Cycling'],

 'Winter': ['Skiing', 'Ice Hockey', 'Snowboarding', 'Figure Skating']}

--- Printing items (method 1: using .items()) ---

Season: Summer -> Sports: ['Swimming', 'Athletics', 'Gymnastics', 'Cycling']

Season: Winter -> Sports: ['Skiing', 'Ice Hockey', 'Snowboarding', 'Figure Skating']

--- Printing items (method 2: using keys) ---

Season: Summer -> Sports: ['Swimming', 'Athletics', 'Gymnastics', 'Cycling']

Season: Winter -> Sports: ['Skiing', 'Ice Hockey', 'Snowboarding', 'Figure Skating']

--- Only sports lists ---

['Swimming', 'Athletics', 'Gymnastics', 'Cycling']

['Skiing', 'Ice Hockey', 'Snowboarding', 'Figure Skating']

Sample Test Case 2

Output

Olympic Sports Dictionary:

{'Summer': ['Boxing', 'Tennis', 'Basketball', 'Archery'],

 'Winter': ['Curling', 'Luge', 'Bobsleigh', 'Speed Skating']}

--- Printing items (method 1: using .items()) ---

Season: Summer -> Sports: ['Boxing', 'Tennis', 'Basketball', 'Archery']

Season: Winter -> Sports: ['Curling', 'Luge', 'Bobsleigh', 'Speed Skating']

--- Printing items (method 2: using keys) ---

Season: Summer -> Sports: ['Boxing', 'Tennis', 'Basketball', 'Archery']

Season: Winter -> Sports: ['Curling', 'Luge', 'Bobsleigh', 'Speed Skating']

--- Only sports lists ---

['Boxing', 'Tennis', 'Basketball', 'Archery']

['Curling', 'Luge', 'Bobsleigh', 'Speed Skating']

5.7 Teaching Python

You are teaching Python programming to a group of students. You want to keep track of which students are enrolled in which course — *Basic* or *Advanced*.

Perform the following tasks step by step:

a. Create an empty dictionary called students.
b. There are currently two students in the Basic course and three students in the Advanced course. Add their names to the dictionary.
c. You have received four new registrations — three for the Basic course and one for the Advanced course. Add them to the dictionary using four different methods (e.g., append(), +=, .extend(), and insert()).
d. After reviewing the backgrounds, you realize that one student from the Basic course actually belongs in the Advanced course. Move that student accordingly.
e. Print all the dictionary items one by one in two different ways:

Using .items()

Using dictionary keys
f. Finally, print only course names and only student lists separately.

Input Format

There is no user input — all data is predefined in the program.

Output Format

The program should print:

The updated dictionary after each modification.

Items printed one by one using both methods.

Course names (keys) printed separately.

Student names (values) printed separately.

Sample Test Case 1

Output

Initial dictionary:

{'Basic': ['Alice', 'Bob'], 'Advanced': ['Charlie', 'David', 'Eve']}

After adding new students:

{'Basic': ['Alice', 'Bob', 'Frank', 'Grace', 'Helen'],

 'Advanced': ['Charlie', 'David', 'Eve', 'Ivy']}

After moving 'Bob' from Basic to Advanced:

{'Basic': ['Alice', 'Frank', 'Grace', 'Helen'],

 'Advanced': ['Charlie', 'David', 'Eve', 'Ivy', 'Bob']}

--- Printing items (method 1: using .items()) ---

Course: Basic -> Students: ['Alice', 'Frank', 'Grace', 'Helen']

Course: Advanced -> Students: ['Charlie', 'David', 'Eve', 'Ivy', 'Bob']

--- Printing items (method 2: using keys) ---

Course: Basic -> Students: ['Alice', 'Frank', 'Grace', 'Helen']

Course: Advanced -> Students: ['Charlie', 'David', 'Eve', 'Ivy', 'Bob']

--- Course names ---

Basic

Advanced

--- Student lists ---

['Alice', 'Frank', 'Grace', 'Helen']

['Charlie', 'David', 'Eve', 'Ivy', 'Bob']

Sample Test Case 2

Output

Initial dictionary:

{'Basic': ['Raj', 'Kiran'], 'Advanced': ['Neha', 'Vikram', 'Rita']}

After adding new students:

{'Basic': ['Raj', 'Kiran', 'Asha', 'Ravi', 'Sita'],

 'Advanced': ['Neha', 'Vikram', 'Rita', 'Mohan']}

After moving 'Ravi' from Basic to Advanced:

{'Basic': ['Raj', 'Kiran', 'Asha', 'Sita'],

 'Advanced': ['Neha', 'Vikram', 'Rita', 'Mohan', 'Ravi']}

--- Printing items (method 1: using .items()) ---

Course: Basic -> Students: ['Raj', 'Kiran', 'Asha', 'Sita']

Course: Advanced -> Students: ['Neha', 'Vikram', 'Rita', 'Mohan', 'Ravi']

--- Printing items (method 2: using keys) ---

Course: Basic -> Students: ['Raj', 'Kiran', 'Asha', 'Sita']

Course: Advanced -> Students: ['Neha', 'Vikram', 'Rita', 'Mohan', 'Ravi']

--- Course names ---

Basic

Advanced

--- Student lists ---

['Raj', 'Kiran', 'Asha', 'Sita']

['Neha', 'Vikram', 'Rita', 'Mohan', 'Ravi']

5.8 Furniture Store

You are the manager of a furniture store, and you need to maintain an up-to-date record of the items in storage, their quantities, and prices.

Initially, you have the following inventory:

store = {

   "furniture": ["chair", "table", "sofa"],

   "amount": [24, 7, 6],

   "price": [200, 500, 1200]

}

- Perform the following operations step by step:
- A new customer buys 4 chairs. Update the stock count using an arithmetic operation.
- After a few days, new furniture items arrive:
  - 9 carpets worth 150 each
  - 4 lamps worth 180 each
    Add them to the dictionary using different syntaxes.
- A restaurant owner buys all the tables. Remove or update this entry using at least two different methods.
- Print the final dictionary, aligning keys to the right and values to the left for readability.
- Finally, calculate and print the total price of all furniture currently in storage.
- Input Format
- No direct input.
- The program internally initializes the dictionary and performs updates as described.

Output Format

Updated furniture dictionary after all operations.

Total value of the furniture in stock.

Data printed in an aligned format (keys right-aligned, values left-aligned).

Sample Test Case 1

Initial Data

store = {

   "furniture": ["chair", "table", "sofa"],

   "amount": [24, 7, 6],

   "price": [200, 500, 1200]

}

Output

Updated Furniture Store:

 furniture : ['chair', 'sofa', 'carpet', 'lamp']

 amount   : [20, 6, 9, 4]

 price   : [200, 1200, 150, 180]

Total price of all furniture in storage: ₹10440

Sample Test Case 2

Initial Data

store = {

    "furniture": ["chair", "table", "bed"],

    "amount": [10, 4, 3],

    "price": [250, 800, 2000]

}

Output

Updated Furniture Store:

 furniture : ['chair', 'bed', 'carpet', 'lamp']

 amount   : [6, 3, 5, 3]

 price   : [250, 2000, 300, 200]

Total price of all furniture in storage: ₹8650

5.9 Shifting List Elements

You are given the following dictionary:

dictionary = {"numbers": [2, 3, 4, 5, 6, 7, 8, 9, 10]}

Perform the following operations step by step:

1. Add a new key–value pair to the dictionary where:

Key = "even"

Value = A list containing True if the corresponding number is even, and False if it is odd.
(Expected result:)

{"numbers": [2, 3, 4, 5, 6, 7, 8, 9, 10],

 "even": [True, False, True, False, True, False, True, False, True]}

Subtract 1 from each number in the "numbers" list.
(So [2, 3, 4] becomes [1, 2, 3].)

2. Modify the Boolean list so that it corresponds to the new numbers by shifting it one position to the right.
The last element becomes the first, simulating a circular shift.

Input Format

No direct user input.

The program internally initializes the dictionary and performs the operations as described.

Output Format

Updated dictionary after:

Adding the "even" key,

Subtracting 1 from numbers, and

Shifting the Boolean list.

Each step's result should be printed for clarity.

Sample Test Case 1

Initial Dictionary

{"numbers": [2, 3, 4, 5, 6, 7, 8, 9, 10]}

Output

Step 1 - Added even list:

{'numbers': [2, 3, 4, 5, 6, 7, 8, 9, 10], 'even': [True, False, True, False, True, False, True, False, True]}

Step 2 - Subtracted 1 from numbers:

{'numbers': [1, 2, 3, 4, 5, 6, 7, 8, 9], 'even': [True, False, True, False, True, False, True, False, True]}

Step 3 - Shifted boolean list to match new numbers:

{'numbers': [1, 2, 3, 4, 5, 6, 7, 8, 9], 'even': [True, True, False, True, False, True, False, True, False]}

Sample Test Case 2

Initial Dictionary

{"numbers": [5, 6, 7, 8]}

Expected Output

Step 1 - Added even list:

{'numbers': [5, 6, 7, 8], 'even': [False, True, False, True]}

Step 2 - Subtracted 1 from numbers:

{'numbers': [4, 5, 6, 7], 'even': [False, True, False, True]}

Step 3 - Shifted boolean list to match new numbers:

{'numbers': [4, 5, 6, 7], 'even': [True, False, True, False]}

5.10 Numbers in a Triangle

You are creating a fun number game for a player.

1. Ask the player to enter an integer n.
2. Then, print a triangle pattern where each row contains:
3. A number from 1 to n, and
4. A list containing that number repeated as many times as its value.
5. Use a dictionary to store each number as a key and its repeated list as the value.
6. Allow the player to play multiple times — after each triangle, ask if they want to play again.

Example:

If the player enters 5, the output should look like:

1 [1]

2 [2, 2]

3 [3, 3, 3]

4 [4, 4, 4, 4]

5 [5, 5, 5, 5, 5]

Input Format

A single integer n entered by the user (number of rows in the triangle).

After printing the triangle, the player is asked if they want to play again (y/n).

Output Format

Prints each row in the format:

number [list of repeated numbers]

Continues until the player chooses to exit.

Sample Test Case 1

Input

Enter an integer: 5

Do you want to play again? (y/n): n

Output

1 [1]

2 [2, 2]

3 [3, 3, 3]

4 [4, 4, 4, 4]

5 [5, 5, 5, 5, 5]

Sample Test Case 2

Input

Enter an integer: 3

Do you want to play again? (y/n): y

Enter an integer: 4

Do you want to play again? (y/n): n

Output

1 [1]

2 [2, 2]

3 [3, 3, 3]

1 [1]

2 [2, 2]

3 [3, 3, 3]

4 [4, 4, 4, 4]

Try:

1. **Spices and herbs**: - You work in a grocery store selling spices and herbs. Here are the spices and herbs in the shop:

spices_herbs = ["basil","cinnamon","licorice","mint","rosemary","thyme", "cardamom","turmeric","cilantro","oregano","pepper","chili","dill", "cayennepepper","ginger","garlic","marjoram","nutmeg","sage","saffron", "staranise","bayleaves"]

a. You have to change the labels on the containers and give them a more modern look. The length of the new labels is proportional to the length of the word written on it. Create a dictionary where keys are word lengths and values are lists of words with that length.

b. You need to know how many labels you have to cut for each length. Create another dictionary where keys are word lengths in an ascending order, and values are the number of labels you have to cut for each length.

c. What is the most common label? How many letters does it correspond to? Compute it!

6. Set

6.1 Count the Number of Vowels

You are required to write a Python program that helps identify how many vowels are present in a given English word. A set named vowels containing the characters 'a', 'e', 'i', 'o', and 'u' should be declared. The program must:

1. Prompt the user to enter an English word (can include both uppercase and lowercase letters).
2. Convert the input word to lowercase to ensure case insensitivity.
3. Iterate through each character of the word and check whether it is a vowel using the vowels set.
4. Count the total number of vowels present in the word.
5. Display the count to the user in a clear message.

Input Format:

- The input consists of a single word entered by the user (string).

Output Format:

- The program should output the number of vowels present in the given word in a descriptive message.
- The word '<word>' contains <count> vowel(s).

Sample Test Cases 1

Input

Education

Output

The word 'Education' contains 5 vowel(s).

Sample Test Cases 2

Input

Rhythm

Output

The word 'Rhythm' contains 0 vowel(s).

Sample Test Cases 3

Input

APPLE

Output

The word 'APPLE' contains 2 vowel(s).

Sample Test Cases 4

Input

Beautiful

Output

The word 'Beautiful' contains 5 vowel(s).

6.2 Common Letters between Two English Words

You are required to write a Python program that identifies which letters two English words have in common**.**

The program must:

1. Prompt the user to enter two English words**.**
2. Convert both words to lowercase to make the comparison case-insensitive.
3. Use set operations to determine which letters are common to both words.
4. Display the set of common letters between the two words in a clear, user-friendly message.

The solution should efficiently use Python's set data structure, as sets provide fast operations for finding intersections between collections.

Input Format:

- The input consists of two English words, each entered separately by the user.
- word1
- word2

Output Format:

- The program should display the letters that are common between the two words in alphabetical order.
- If no letters are common, display an appropriate message.

Sample Test Cases 1

Input

Apple

Place

Output

The common letters between 'Apple' and 'Place' are: {'a', 'e', 'l', 'p'}

Sample Test Cases 2

Input

Tiger

Elephant

Output

The common letters between 'Tiger' and 'Elephant' are: {'e', 't'}

Sample Test Cases 3

Input

Sky

Cloud

Output

The words 'Sky' and 'Cloud' have no letters in common.

Sample Test Cases 4

Input

Notebook

Bookstore

Output

The common letters between 'Notebook' and 'Bookstore' are: {'b', 'e', 'k', 'o', 'r', 't'}

6.3 Missing Letters Finder

You are required to write a Python program that determines which letters of the English alphabet are not present in either of two given English words.

The program should:

1. Prompt the user to enter two English words.

2. Convert both words to lowercase to make the comparison case-insensitive.

3. Use Python sets to represent:

   o   All 26 letters of the English alphabet.

   o   The letters contained in each of the two input words.

4. Identify which letters are not present in either word, i.e., letters that are missing from both.

5. Display the missing letters in alphabetical order.

This exercise demonstrates how to use set operations like union and difference efficiently.

Input Format:

- The input consists of two English words, each entered separately by the user.

- word1

- word2

Output Format:

- The program should output the letters of the English alphabet that are not found in either of the two words, displayed in alphabetical order.

Sample Test Cases 1

Input

Apple

Place

Output

Letters not present in either 'Apple' or 'Place' are: ['b', 'd', 'f', 'g', 'h', 'i', 'j', 'k', 'm', 'n', 'o', 'q', 'r', 's', 't', 'u', 'v', 'w', 'x', 'y', 'z']

Sample Test Cases 2

Input

Computer

Science

Output

Letters not present in either 'Computer' or 'Science' are: ['a', 'b', 'd', 'f', 'g', 'h', 'j', 'k', 'l', 'q', 'v', 'w', 'x', 'y', 'z']

Sample Test Cases 3

Input

abcdefghijklmnopqrstuvwxyz

Python

Output

All letters of the alphabet are present in the given words.

Sample Test Cases 4

Input

Dog

Cat

Output

Letters not present in either 'Dog' or 'Cat' are: ['b', 'e', 'f', 'h', 'i', 'j', 'k', 'l', 'm', 'n', 'p', 'q', 'r', 's', 'u', 'v', 'w', 'x', 'y', 'z']

6.4 City Travel Tracker

Two friends, Person A and Person B, love to travel. Each has a list of cities they've visited. You are asked to write a Python program that uses sets to analyze their travel history and display:

1. The cities both have visited (common cities).

2. The cities only Person A has visited.

3. The cities only Person B has visited.

4. The list of all cities visited by either of them (union).

Input Format:

- The input consists of two lines:
    - First line: Cities visited by Person A (comma-separated).
    - Second line: Cities visited by Person B (comma-separated).

Output Format:

The program should display:

1. Cities visited by both persons**.**
2. Cities only Person A has visited.
3. Cities only Person B has visited.
4. All cities visited by either person.

Sample Test Cases 1

Input

Paris, London, New York, Delhi

London, Berlin, Delhi, Tokyo

Output

Cities visited by both: {'London', 'Delhi'}

Cities unique to Person A: {'Paris', 'New York'}

Cities unique to Person B: {'Berlin', 'Tokyo'}

All cities visited: {'Paris', 'London', 'New York', 'Delhi', 'Berlin', 'Tokyo'}

Sample Test Cases 2

Input

Mumbai, Chennai, Bangalore

Kolkata, Delhi, Chennai

Output

Cities visited by both: {'Chennai'}

Cities unique to Person A: {'Bangalore', 'Mumbai'}

Cities unique to Person B: {'Kolkata', 'Delhi'}

All cities visited: {'Mumbai', 'Chennai', 'Bangalore', 'Kolkata', 'Delhi'}

Sample Test Cases 3

Input

Sydney, Melbourne

Sydney, Melbourne

Output

Cities visited by both: {'Sydney', 'Melbourne'}

Cities unique to Person A: set()

Cities unique to Person B: set()

All cities visited: {'Sydney', 'Melbourne'}

Sample Test Cases 4

Input

Rome, Venice

Paris, Berlin

Output

Cities visited by both: set()

Cities unique to Person A: {'Rome', 'Venice'}

Cities unique to Person B: {'Paris', 'Berlin'}

All cities visited: {'Rome', 'Venice', 'Paris', 'Berlin'}

6.5 DNA Sequence Comparison

DNA is composed of four types of nucleotide bases represented by the letters: A (Adenine), T (Thymine), C (Cytosine), and G (Guanine).

You are required to write a Python program that compares two given DNA sequences using set operations.

Your program should determine:

1. The common nucleotides present in both DNA sequences.

2. The unique nucleotides found only in the first DNA sequence.

3. The unique nucleotides found only in the second DNA sequence.

4. The missing nucleotides (from {A, T, C, G}) that are not present in each DNA sequence.

Input Format:

- Two lines of input:

    o First line: DNA sequence 1 (a string containing only A, T, C, G)

    o Second line: DNA sequence 2 (a string containing only A, T, C, G)

Output Format:

The program should display:

1. Common nucleotides

2. Nucleotides unique to the first sequence

3. Nucleotides unique to the second sequence

4. Missing nucleotides from the first sequence

5. Missing nucleotides from the second sequence

Sample Test Cases 1

Input

AATGCC

TTGCAA

Output

Common nucleotides: {'A', 'C', 'G', 'T'}

Unique to first sequence: set()

Unique to second sequence: set()

Missing from first sequence: set()

Missing from second sequence: set()

Sample Test Cases 2

Input

AT

CG

Output

Common nucleotides: set()

Unique to first sequence: {'A', 'T'}

Unique to second sequence: {'C', 'G'}

Missing from first sequence: {'C', 'G'}

Missing from second sequence: {'A', 'T'}

Sample Test Cases 3

Input

AAATTT

AATTCCGG

Output

Common nucleotides: {'A', 'T'}

Unique to first sequence: set()

Unique to second sequence: {'C', 'G'}

Missing from first sequence: {'C', 'G'}

Missing from second sequence: set()

Sample Test Cases 4

Input

AGG

CCC

Output

Common nucleotides: set()

Unique to first sequence: {'A', 'G'}

Unique to second sequence: {'C'}

Missing from first sequence: {'C', 'T'}

Missing from second sequence: {'A', 'G', 'T'}

6.6 Panagram Detector

A pangram is a sentence that contains every letter of the English alphabet at least once. For example, "The quick brown fox jumps over the lazy dog" is a pangram because it uses all 26 letters from A–Z. Your task is to write a program that checks whether a given sentence is a pangram using set comparison.

The program should:

1. Accept a sentence from the user.

2. Ignore case (uppercase/lowercase) and any non-alphabetic characters.

3. Compare the set of letters in the sentence to the set of all 26 English letters.

4. Print whether the sentence is a pangram or not.

Input Format:

- A single line of input containing a sentence (string).

Output Format:

- If the sentence contains all 26 letters:
- The sentence is a pangram.
- Otherwise:
- The sentence is not a pangram.

Sample Test Cases 1

Input

The quick brown fox jumps over the lazy dog

Output

The sentence is a pangram.

Sample Test Cases 2

Input

Pack my box with five dozen liquor jugs

Output

The sentence is a pangram.

Sample Test Cases 3

Input

Hello world

Output

The sentence is not a pangram.

Sample Test Cases 4

Input

Crazy Fredrick bought many very exquisite opal jewels

Output

The sentence is a pangram.

Sample Test Cases 5

Input

Python is fun

Output

The sentence is not a pangram.

6.7 Shopping List Optimizer

You are maintaining two shopping lists — one for Home and another for the Office. Using Python sets, write a program to analyze these lists and find:

1. Items common to both lists (need to buy for both).

2. Items unique to the Home list.

3. Items unique to the Office list.

4. Combined unique list of all items (no duplicates).

This helps avoid buying duplicate items and ensures that all required items are tracked efficiently.

Input Format:

- Two lines of input:

  o First line: space-separated items in the Home shopping list.

  o Second line: space-separated items in the Office shopping list.

Output Format:

Display:

1. Items common to both.

2. Items unique to Home.

3. Items unique to Office.

4. Combined unique list (no duplicates).

Sample Test Cases 1

Input

milk bread eggs sugar

coffee milk paper pens

Output

Items to buy for both: {'milk'}

Items only for home: {'bread', 'eggs', 'sugar'}

Items only for office: {'coffee', 'paper', 'pens'}

All unique items: {'milk', 'bread', 'eggs', 'sugar', 'coffee', 'paper', 'pens'}

Sample Test Cases 2

Input

tea biscuits snacks

coffee water tea

Output

Items to buy for both: {'tea'}

Items only for home: {'biscuits', 'snacks'}

Items only for office: {'coffee', 'water'}

All unique items: {'tea', 'biscuits', 'snacks', 'coffee', 'water'}

Sample Test Cases 3

Input

fruits vegetables rice

stationery notebooks rice

Output

Items to buy for both: {'rice'}

Items only for home: {'fruits', 'vegetables'}

Items only for office: {'stationery', 'notebooks'}

All unique items: {'fruits', 'vegetables', 'rice', 'stationery', 'notebooks'}

6.8 Unique Words in Two Articles

You are given two paragraphs (representing two different articles). Your task is to analyze the text using Python sets and determine:

1. Words common to both articles

2. Words unique to the first article

3. Words unique to the second article

4. Total number of distinct word**s** across both articles

The comparison should be case-insensitive, and punctuation marks should be ignored.
This helps in comparing the vocabulary diversity and similarity between two written pieces.

Input Format:

- Two lines of input:

    o First line: Paragraph 1 (Article 1)

    o Second line: Paragraph 2 (Article 2)

Output Format:

Display:

1. Words common to both

2. Words unique to the first article

3. Words unique to the second article

4. Total distinct words in both articles

Sample Test Cases 1

Input

Python is a powerful programming language.

Many developers love Python for its simplicity and versatility.

Output

Common words: {'python'}

Unique to first: {'a', 'powerful', 'language', 'programming', 'is'}

Unique to second: {'and', 'simplicity', 'developers', 'love', 'for', 'many', 'its', 'versatility'}

Total distinct words: 14

Sample Test Cases 2

Input

Data science involves statistics and programming.

Machine learning uses programming and data analysis.

Output

Common words: {'and', 'programming', 'data'}

Unique to first: {'involves', 'science', 'statistics'}

Unique to second: {'uses', 'machine', 'learning', 'analysis'}

Total distinct words: 10

Sample Test Cases 3

Input

Artificial Intelligence is the future.

AI will transform industries and daily life.

Output

Common words: set()

Unique to first: {'intelligence', 'artificial', 'future', 'the', 'is'}

Unique to second: {'and', 'transform', 'industries', 'life', 'ai', 'will', 'daily'}

Total distinct words: 12

6.9 College Course Enrollment

In a college, students can enroll in multiple courses. You are given the lists of student names enrolled in three courses — Course A, Course B, and Course C.

Your task is to write a program using sets to determine:

1. Students enrolled in all three courses
2. Students enrolled in exactly two courses
3. Students enrolled in only one course

This helps the college administration analyze student participation patterns and identify overlaps between courses.

Input Format:

- Three lines of input:
    - First line → Space-separated names of students in Course A
    - Second line → Space-separated names of students in Course B
    - Third line → Space-separated names of students in Course C

Output Format:

Display:

1. Students enrolled in all three courses
2. Students enrolled in exactly two courses
3. Students enrolled in only one course

Sample Test Cases 1

Input

Alice Bob Charlie

Bob David Emily

Charlie David Frank

Output

Students in all three courses: set()

Students in exactly two courses: {'Bob', 'Charlie', 'David'}

Students in only one course: {'Alice', 'Emily', 'Frank'}

Sample Test Cases 2

Input

Amit Raj Neha

Raj Meena Neha

Neha Meena Amit

Output

Students in all three courses: {'Neha'}

Students in exactly two courses: {'Amit', 'Raj', 'Meena'}

Students in only one course: set()

Sample Test Cases 3

Input

John Mary Sam

Mary Sam Lisa

Sam Lisa Tom

Output

Students in all three courses: {'Sam'}

Students in exactly two courses: {'Mary', 'Lisa'}

Students in only one course: {'John', 'Tom'}

Sample Test Cases 4

Input

Ravi Sneha

Ravi Sneha

Ravi Sneha

Output

Students in all three courses: {'Sneha', 'Ravi'}

Students in exactly two courses: set()

Students in only one course: set()

6.10 Lucky Draw Participants

A company is organizing two promotional Lucky Draw events — Event A and Event B. Each event has a list of registered participants. You need to write a program using sets to determine:

1. Participants who registered for both events

2. Participants who registered for only one event

This helps the organizers identify loyal participants and those exclusive to each event.

Input Format:

- Two lines of input:
    - First line: space-separated names of participants in Event A
    - Second line: space-separated names of participants in Event B

Output Format:

Display:

1. Participants registered for both events
2. Participants registered for only one event

Sample Test Cases 1

Input

Alice Bob Charlie David

Charlie Eve Bob Frank

Output

Participants in both events: {'Bob', 'Charlie'}

Participants in only one event: {'Alice', 'David', 'Eve', 'Frank'}

Sample Test Cases 2

Input

Ravi Sneha Priya

Priya Manoj Sneha

Output

Participants in both events: {'Sneha', 'Priya'}

Participants in only one event: {'Ravi', 'Manoj'}

Sample Test Cases 3

Input

Amit Neha Raj

Pooja Kiran Rahul

Output

Participants in both events: set()

Participants in only one event: {'Amit', 'Neha', 'Raj', 'Pooja', 'Kiran', 'Rahul'}

Sample Test Cases 4

Input

John Mary Sam

John Mary Sam

Output

Participants in both events: {'John', 'Mary', 'Sam'}

Participants in only one event: set()

Try

1. **Conference Attendee Analyzer**: A global tech conference has three sessions — AI, Cloud, and Cybersecurity. Each attendee can join one or more sessions. Write a program using sets to determine:

- Attendees who attended all three sessions
- Attendees who attended at least two sessions
- Attendees who attended exactly one session
- Total unique attendees in the entire conference

2. **Library Borrowing System**: A college library tracks which students borrowed books in the Science, Arts, and Commerce sections. Using Python sets, determine:

- Students who borrowed from Science and Arts but not Commerce
- Students who borrowed from only one section
- Students who borrowed from at least two sections
- Total unique students who borrowed books

7. Functions I

7.1 Sum of Natural Numbers and Their Cubes

Define two functions sumN() and sumNCubes():

sumN(n) − returns the sum of the first *n* natural numbers.
Formula: Sum=1+2+3+…+n

sumNCubes(n) − returns the sum of the cubes of the first *n* natural numbers.
Formula: Sum of Cubes=1^3+2^3+3^3+…+n^3

The program should then prompt the user to enter a positive integer n and display:

- The sum of the first *n* natural numbers.
- The sum of the cubes of the first *n* natural numbers.

Input Format:

- A single integer n, representing how many natural numbers to consider.

Output Format:

- Print the sum of the first n natural numbers.
- Print the sum of the cubes of the first n natural numbers.

Each value should be printed on a new line with descriptive text.

Sample Test Case 1

Input

5

Output

Sum of first 5 natural numbers: 15

Sum of cubes of first 5 natural numbers: 225

Sample Test Case 2

Input

3

Output

Sum of first 3 natural numbers: 6

Sum of cubes of first 3 natural numbers: 36

7.2 Compute nth Fibonacci Number

The Fibonacci sequence is a series of numbers in which each number (after the first two) is the sum of the two preceding ones.
It starts as:

0,1,1,2,3,5,8,13,21,.....

Write a program that defines a function fibonacci(n) to compute the *nth* Fibonacci number.

- The first Fibonacci number is 0 (for n = 0).
- The second Fibonacci number is 1 (for n = 1).

The program should prompt the user to enter a non-negative integer n and then print the *nth* Fibonacci number.

Input Format:

- A single integer n representing the position in the Fibonacci sequence (0-indexed).

Output Format:

- Print the *nth* Fibonacci number.

Sample Test Case 1

Input

6

Output

8

Sample Test Case 2

Input

0

Output

0

Sample Test Case 3

Input

1

Output

1

7.3 Next Guess for Square Root Approximation

In numerical methods such as **Newton's Method**, we can approximate the square root of a number x using iterative improvement. The formula for improving a guess is:

$$nextGuess = \frac{guess + \frac{x}{guess}}{2}$$

Write a function nextGuess(guess, x) that takes:

- guess: the current guess for the square root of x
- x: the number whose square root we want to find

and returns the next improved guess using the above formula.

Then, in your main program, prompt the user to enter values for guess and x, and print the result of the next guess.

Input Format:

- The first line contains a floating-point number guess.
- The second line contains a floating-point number x.

Output Format:

- Print the next improved guess, rounded to two decimal places.

Sample Test Case 1

Input

3

10

Output

Next guess: 3.17

Sample Test Case 2

Input

2

9

Output

Next guess: 2.75

Sample Test Case 3

Input

4

16

Output

Next guess: 4.00

7.4 Letter Grade from Score

Define a function grade(score) that returns the letter grade corresponding to a numeric score based on the following grading scale:

Score Range	Letter Grade

90 – 100	A
80 – 89	B
70 – 79	C
60 – 69	D
Below 60	F

The program should prompt the user to enter a score (integer or float), call the grade(score) function, and print the corresponding letter grade.

If the score is outside the range 0–100, display "Invalid score".

Input Format:

- A single integer or float value representing the score.

Output Format:

- A single line displaying the letter grade (A, B, C, D, or F).
- If the score is invalid, print "Invalid score".

Sample Test Case 1

Input

95

Output

Grade: A

Sample Test Case 1

Input

82

Output

Grade: B

Sample Test Case 2

Input

68

Output

Grade: D

Sample Test Case 3

Input

45

Output

Grade: F

Sample Test Case 4

Input

110

Output

Invalid score

7.5 Convert List of Number Strings to Numeric Values

Write and test a function toNumbers(strList) that takes a list of strings — where each string represents a number — and modifies each entry in the list by converting it into a number (integer or float). After conversion, the list should contain only numeric values instead of strings.

Your program should:

1. Take a list of numeric strings as input.
2. Call the toNumbers(strList) function to convert all strings to numbers.
3. Print the modified list containing numeric values.

Input Format:

- The first line contains space-separated numeric values as strings.
  (Example: ["12", "3.5", "9", "42"] → entered as 12 3.5 9 42)

Output Format:

- A list containing the corresponding numeric values (integers or floats).

Sample Test Case 1

Input

12 3.5 9 42

Output

[12.0, 3.5, 9.0, 42.0]

Sample Test Case 2

Input

5 10 15 20

Output

[5.0, 10.0, 15.0, 20.0]

Sample Test Case 3

Input

7.7 8.8 9.9

Output

[7.7, 8.8, 9.9]

7.6 Guess the Number Game

Create a program that implements a simple number guessing game using functions. The computer randomly selects a number between 0 and 10, and the player must guess it.

After each guess:

- If the guess is too high, display "Too high! Try again."

- If the guess is too low, display "Too low! Try again."
- If the guess is correct, display "Congratulations! You guessed it!"

The game should continue until the player guesses the correct number.
At the end, display the total number of attempts it took to guess the number correctly.

Input Format:

- Repeated integer inputs (player guesses) until the correct number is guessed.

Output Format:

- Hint messages after each guess (Too high!, Too low!, or Correct!)
- At the end, print the total number of attempts.

Sample Test Case 1

Input / Output

I'm thinking of a number between 0 and 10...

Enter your guess: 5

Too low! Try again.

Enter your guess: 8

Too high! Try again.

Enter your guess: 7

Congratulations! You guessed it in 3 attempts!

Sample Test Case 2

Input / Output:

I'm thinking of a number between 0 and 10...

Enter your guess: 0

Too low! Try again.

Enter your guess: 10

Too high! Try again.

Enter your guess: 9

Congratulations! You guessed it in 3 attempts!

7.7 Playing with Numbers

You are given the following list of numbers:

numbers = [7, 9, 15, 19, 24, 30, 37, 45, 50]

Write a program using functions to perform the following tasks:

a. Print all numbers that are divisible by both 3 and 5.
b. Print all numbers that are divisible by 3 or 5.
c. Print all numbers that are divisible by 3 but not 5, in two different ways:

- Using the not operator.
- Without using not (by changing the logical condition).

Each task should be implemented in a separate function, and all results should be displayed clearly.

Input Format:

- No input is required from the user.
- Use the predefined list:
- numbers = [7, 9, 15, 19, 24, 30, 37, 45, 50]

Output Format:

- Print four lines of output showing:

    1. Numbers divisible by both 3 and 5
    2. Numbers divisible by 3 or 5
    3. Numbers divisible by 3 but not 5 (using not)
    4. Numbers divisible by 3 but not 5 (without using not)

Sample Output

Numbers divisible by both 3 and 5: [15, 30, 45]

Numbers divisible by 3 or 5: [9, 15, 24, 30, 45, 50]

Numbers divisible by 3 but not 5 (using not): [9, 24]

Numbers divisible by 3 but not 5 (without using not): [9, 24]

7.8 Flipping Coins – Counting Heads and Tails

When flipping a coin, there are two possible outcomes: heads and tails.

In this exercise, we will represent:

- Heads as True
- Tails as False

Write a Python program using functions to simulate coin flips and analyze the outcomes.

Your program should:

1. Flip a coin 8 times, store the results (True/False) in a list, and count how many heads and tails occurred.
2. Compute and display the ratio of heads to tails for 8 flips.
3. Flip a coin 1000 times, repeat the same counting process, and calculate the new ratio.
4. Compare and display how the ratios differ between 8 flips and 1000 flips.

Input Format:

- No user input is required.
- The number of flips (8 and 1000) is predefined in the program.

Output Format:

- Display:

    1. The list of outcomes (for 8 flips only).
    2. The count of heads and tails for both 8 flips and 1000 flips.
    3. The ratio of heads to tails for both experiments.
    4. A short comparison comment.

Sample Output

Flipping the coin 8 times...

Outcomes: [True, False, True, True, False, True, False, True]

Heads: 5 | Tails: 3

Ratio (Heads/Tails): 1.67

Flipping the coin 1000 times...

Heads: 498 | Tails: 502

Ratio (Heads/Tails): 0.99

Observation: As the number of flips increases, the ratio of heads to tails becomes closer to 1.

7.9 Comparator – Comparing Two Integers Using Boolean Operators

A comparator is a simple algorithm that compares two numbers using comparison operators instead of arithmetic ones.

Write a program using functions to:

1. Ask the user for two integers.
2. Print the result (True or False) of all possible comparison operations between the two numbers:
    o   > (greater than)
    o   < (less than)
    o   >= (greater than or equal to)
    o   <= (less than or equal to)
    o   == (equal to)
    o   != (not equal to)
3. Use Booleans wherever possible to represent comparison results.
4. Allow the user to continue comparing numbers until they choose to stop.

Finally, test your program with several pairs of integers and observe when you get True or False as output.

Input Format:

*   Two integers entered by the user on separate prompts.
*   After comparison, the program asks if the user wants to continue (yes or no).

Output Format:

*   The program prints all comparison results between the two integers, one per line, showing the Boolean (True or False) result.

Sample Test Case 1

Input

Enter first integer: 3

Enter second integer: 5

Do you want to compare another pair? (yes/no): no

Output

3 > 5 is False

3 < 5 is True

3 >= 5 is False

3 <= 5 is True

3 == 5 is False

3 != 5 is True

Sample Test Case 2

Input

Enter first integer: 7

Enter second integer: 7

Do you want to compare another pair? (yes/no): no

Output

7 > 7 is False

7 < 7 is False

7 >= 7 is True

7 <= 7 is True

7 == 7 is True

7 != 7 is False

7.10 Digit Power Sum

A number is said to be a Digit Power Sum Number if it can be expressed as the sum of its digits, raised to some power. For example the number 512, the sum of its digits is 5 + 1 + 2 = 8, and 8^3 = 512. Thus, 512 is a Digit Power Sum Number because it satisfies this condition.

Your task is to write a program that:

1. Takes an integer as input.
2. Calculates the sum of its digits.
3. Checks whether raising this sum to some integer power equals the original number.
4. Prints whether the number is a Digit Power Sum Number or not.

Use functions to modularize the solution.

Input Format

- A single integer n, the number to be checked.

Output Format

- Print a message indicating whether the number is a Digit Power Sum Number, and if true, display the sum of digits and the power.

Sample Test Case 1

Input

512

Output

Sum of digits = 8

8^3 = 512

512 is a Digit Power Sum Number.

Sample Test Case 2

Input

81

Output

Sum of digits = 9

9^2 = 81

81 is a Digit Power Sum Number.

Sample Test Case 3

Input

100

Output

Sum of digits = 1

No power of 1 equals 100.

100 is NOT a Digit Power Sum Number.

8. Functions II

8.1 Power and Energy Calculator

An electrical engineer named Arjun designs different electrical machines. To analyze their performance, he needs a Python tool that can calculate the power consumption and energy usage of any machine given its voltage, current, and operating time.

He wants a program that helps him:

1. Compute the power (P) of a machine using the formula: $P = V \times I$, where V is voltage (in volts) and I is current (in amperes).

2. Compute the energy consumed (E) by the machine using: $E = P \times t$, where t is time in hours and P is the power in watts.

Write a program that calculates the power and energy consumption of an electrical device based on given voltage, current, and time values.

Input Format

The first line of input contains two space-separated integers representing voltage (V) and current (I).

The second line contains a single integer representing time (t) in hours.

Output Format

Print the calculated power in watts as:

Power: <value> W

Print the calculated energy in watt-hours as:

Energy: <value> Wh

Sample Test Case 1

Input

230 5

3

Output

Power: 1150 W

Energy: 3450 Wh

Sample Test Case 2

Input

120 2

5

Output

Power: 240 W

Energy: 1200 Wh

8.2 Interest Analyzer

Meena is a banker who helps her clients understand how their investments grow over time. She often needs to calculate both Simple Interest (SI) and Compound Interest (CI) for various customers. Manually doing these calculations takes a lot of time, so Meena decides to build a Python program that can compute interest quickly and accurately.

She wants to enter:

The Principal amount (P) — the money invested or borrowed

The Rate of interest (R) — in percentage per year

The Time (T) — in years

and get the results for both Simple Interest and Compound Interest.

Write a program to calculate Simple Interest (SI) and Compound Interest (CI) using the given formulas:

Simple Interest (SI)

$$SI = \frac{P \times R \times T}{100}$$

Compound Interest (CI)

$$CI = P \times \left((1 + \frac{R}{100})^T - 1 \right)$$

Create two functions:

- simple_interest (p, r, t) → returns Simple Interest
- compound_interest (p, r, t) → returns Compound Interest

Your program should take inputs for P, R, and T, call both functions, and print the results.

Input Format

The first line contains the Principal amount (P) as an integer.

The second line contains the Rate of Interest (R) as a float or integer.

The third line contains the Time period (T) in years as an integer.

Output Format

Print the results in two lines:

Simple Interest: <value>

Compound Interest: <value>

Sample Test Case 1

Input

10000

5

2

Output

Simple Interest: 1000.0

Compound Interest: 1025.0

Sample Test Case 2

Input

15000

8

3

Output

Simple Interest: 3600.0

Compound Interest: 3880.7999999999993

8.3 Statistician's Data Analyzer

A statistician named Dr. Riya is studying the performance of students based on their test scores. To prepare her report, she needs to find the mean, median, and mode of the scores. Instead of performing the calculations manually every time, Dr. Riya decides to create a Python program that can analyze a list of scores and return these three important statistical values.

Write a program that computes the Mean, Median, and Mode of a given list of numbers using user-defined functions.

You need to implement the following functions:

1. mean(data): Returns the average (sum of all elements divided by the number of elements).

$$\text{Mean} = \frac{\sum data}{n}$$

2. median(data)

Returns the middle value when the list is sorted.

If the number of elements is odd, the median is the middle element.

If it's even, the median is the average of the two middle elements.

3. mode(data)

Returns the value that appears most frequently in the list.

Input Format

The first line contains an integer n, the number of data points.

The second line contains n space-separated integers, representing the data values (e.g., test scores).

Output Format

Print three lines showing:

Mean: <value>

Median: <value>

Mode: <value>

Sample Test Case 1

Input

5

10 20 20 30 40

Output

Mean: 24.0

Median: 20

Mode: 20

Explanation:

Mean = (10 + 20 + 20 + 30 + 40) / 5 = 120 / 5 = 24.0

Median = middle element in sorted list [10, 20, 20, 30, 40] = 20

Mode = value with highest frequency = 20

Sample Test Case 2

Input

6

15 10 20 25 10 30

Output

Mean: 18.333333333333332

Median: 17.5

Mode: 10

8.4 Astronomer's Orbit Calculator

An astronomer named Dr. Anika Sharma is studying the orbits of planets around a star. She needs to calculate two important parameters for her research:

The Orbital Circumference, which represents the total distance a planet travels in one complete orbit.

The Orbital Velocity, which indicates how fast the planet moves along its orbit.

Manually performing these calculations for each planet takes too long, so Dr. Anika decides to create a program that can compute these values accurately using simple formulas.

1. Orbital Circumference of a planet using the formula:

$$C = 2\pi r$$

where r = orbital radius (in kilometers).

2. Orbital Velocity of a planet using the formula:

$$V = \frac{2\pi r}{T}$$

where T = orbital period (in seconds).

Define and use the following functions:

orbit_length(r)

Returns the orbital circumference.

orbit_velocity(r, T)

Returns the orbital velocity.

Input Format

The first line contains the radius (r) of the orbit in kilometers.

The second line contains the time period (T) of the orbit in seconds.

Output Format

Print the Orbital Circumference in kilometers.

Print the Orbital Velocity in kilometers per second (km/s).

Both values should be displayed up to two decimal places.

Sample Test Case 1

Input

7000

90

Output

Orbital Circumference: 43982.30 km

Orbital Velocity: 488.69 km/s

Sample Test Case 2

Input

15000

120

Output

Orbital Circumference: 94247.78 km

Orbital Velocity: 785.40 km/s

8.5 Farmer's Field Division

A farmer named Ramesh owns a rectangular field. He plans to divide his land into equal-sized square plots for growing different crops like wheat, corn, and vegetables.

However, Ramesh wants to know:

1. How many square plots of a given side length can fit completely within his rectangular field.

2. How much unused land area will remain after the division.

To save time, he decides to write a program that performs these calculations efficiently.

The number of square plots that can be made from a rectangular field of given dimensions.

The remaining (unused) area of the land after dividing it into square plots.

Define and use the following functions:

number_of_plots(length, width, side)

Returns the total number of square plots that can fit within the field.

remaining_area(length, width, side)

Returns the remaining (unused) area of the field that cannot be divided into square plots.

Formulas Used

Let:

length = length of the rectangular field (in meters)

width = width of the rectangular field (in meters)

side = side of each square plot (in meters)

Then:

$$\text{Number of plots} = \left(\frac{\text{length}}{\text{side}}\right) \times \left(\frac{\text{width}}{\text{side}}\right)$$

$$\text{Remaining area} = (\text{total area}) - (\text{area covered by plots})$$

$$\text{Remaining area} = (length \times width) - (\text{number of plots} \times side^2)$$

Input Format

First line: Field length (in meters)

Second line: Field width (in meters)

Third line: Square plot side (in meters)

Output Format

First line: Number of plots

Second line: Remaining area in square meters (sq.m)

Sample Test Case 1

Input

20

15

4

Output

Number of plots: 18

Remaining area: 12 sq.m

Explanation:

Number of plots along length = 20 // 4 = 5

Number of plots along width = 15 // 4 = 3

Total plots = 5 × 3 = 15

Area covered = 15 × 4² = 240 sq.m

Total area = 20 × 15 = 300 sq.m

Remaining = 300 − 240 = 60 sq.m

Sample Test Case 2

Input

25

18

5

Output

Number of plots: 12

Remaining area: 75 sq.m

Explanation:

Plots along length = 25 // 5 = 5

Plots along width = 18 // 5 = 3

Total plots = 5 × 3 = 15

Covered area = 15 × 25 = 375 sq.m

Total area = 25 × 18 = 450 sq.m

Remaining = 450 − 375 = 75 sq.m

8.6 Banker's Loan Evaluator

A bank manager is developing a digital system to evaluate whether customers are eligible for a loan.

Each applicant provides their annual income, credit score, and existing loan amount.

The bank uses the following rules to decide:

- If the credit score ≥ 750 and annual income ≥ ₹500,000, the loan is approved immediately.
- If the credit score is between 650 and 749 (inclusive) and annual income ≥ ₹300,000, the loan is conditionally approved, but only if the existing loan amount ≤ ₹200,000.
- If the credit score < 650, the loan is rejected, regardless of income.
- In all other cases, the loan is rejected.

The system should also calculate the maximum eligible loan amount based on the applicant's income:

Max Eligible Loan = Annual Income × 0.5

Write a program that evaluates loan applications using a function evaluate_loan().

Input Format

First line: Annual income (integer)

Second line: Credit score (integer)

Third line: Existing loan amount (integer)

Output Format

First line: Loan evaluation status

Second line: Maximum eligible loan amount

Sample Test Case 1

Input

600000

780

150000

Output

Approved

300000.0

Sample Test Case 2

Input

400000

700

100000

Output

Conditionally Approved

200000.0

Sample Test Case 3

Input

250000

640

100000

Output

Rejected

125000.0

Try:

1. Treasure Weight Analyzer: A group of archaeologists has discovered an ancient chest containing gold coins of various weights.

They want to know:
- The total weight of all coins.
- The average weight.
- The heaviest coin found.

You must help them by writing a program that performs this analysis using functions.

2. The Fuel Efficiency Evaluator: An automobile company wants to evaluate the fuel efficiency of different car models.

For each car, they record:

Distance traveled (in km)

Fuel used (in liters)

They want a function that calculates mileage (km/l) and fuel category:

- If mileage ≥ 20 → "Excellent"
- If 15 ≤ mileage < 20 → "Good"
- If 10 ≤ mileage < 15 → "Average"
- Otherwise → "Poor"

9. Matrix Operations

9.1 Add Two Matrices

You are given two matrices X and Y of the same dimensions. The task is to compute the element-wise sum of the two matrices and print the resulting matrix. Each element in the resulting matrix should be the sum of the corresponding elements in X and Y.

Input Format:

- No user input is required.
- The matrices X and Y are predefined in the program.

Output Format:

Print the resulting matrix Result, where each element is the sum of the corresponding elements from X and Y.

Sample Test Case 1

Input

X = [[1, 2],

   [3, 4]]

Y = [[5, 6],

   [7, 8]]

Output

Result = [[6, 8],

     [10, 12]]

Sample Test Case 2

Input

X= [[1, 2, 3],

   [4, 5, 6],

   [7, 8, 9]]

Y = [[9, 8, 7],

   [6, 5, 4],

   [3, 2, 1]]

Output:

Result = [[10, 10, 10],

     [10, 10, 10],

     [10, 10, 10]]

9.2 Multiply Two Matrices

You are given two matrices X and Y. The task is to compute the matrix multiplication of these two matrices and print the resulting matrix.

In matrix multiplication, the element at position (i, j) in the result is obtained by multiplying elements of the ith row of X with the jth column of Y and then summing those products.

Input Format:

- No user input is required.
- The matrices X and Y are predefined in the program.

Output Format:

Print the resulting matrix Result, which is the product of matrices X and Y.

Sample Test Case 1

Input

X= [[1, 7, 3],

   [3, 5, 6],

   [6, 8, 9]]

Y = [[1, 1, 1, 2],

   [6, 7, 3, 0],

   [4, 5, 9, 1]]

 Output

Result = [[55, 65, 49, 5],

         [57, 68, 72, 12],

         [90, 107, 111, 21]]

Sample Test Case 2

Input

X = [[1, 2],

   [3, 4]]

Y = [[5, 6],

   [7, 8]]

Output

Result = [[19, 22],

       [43, 50]]

Sample Test Case 3

Input

X = [[2, 4, 1],

   [0, 1, 3]]

Y = [[1, 2],

[3, 4],
        [5, 6]]

Output

Result = [[19, 26],
            [18, 22]]

9.3 Transpose of a Matrix

A matrix can be represented in Python using a nested list, where each inner list represents a row of the matrix.

The task is to find the transpose of the given matrix using multiple methods. The transpose of a matrix is obtained by converting its rows into columns (or vice versa).

For example, if

$$A = \begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$$

then its transpose is

$$A^T = \begin{bmatrix} 1 & 3 & 5 \\ 2 & 4 & 6 \end{bmatrix}$$

Input Format:

- No user input is required.
- The matrix is predefined in the program as a list of lists.

Output Format:

Print the transposed matrix in list form.

Sample Test Case 1

Input

matrix = [[1, 2],
            [3, 4],
            [5, 6]]

Output

Transpose of the matrix: [[1, 3, 5], [2, 4, 6]]

Sample Test Case 2

Input

matrix = [[7, 8, 9],
            [10, 11, 12]]

Output

Transpose of the matrix: [[7, 10], [8, 11], [9, 12]]

9.4 Matrix Product

You are given a nested list (matrix) that contains several lists of integers. The task is to compute the product of all elements present across all the nested lists.

You need to use list comprehension as a concise way to calculate the product, instead of using traditional nested loops. At the end, the program should print the cumulative product of all elements.

Input Format:

- No user input is required.
- The matrix (nested list) is predefined in the program.

Output Format:

Print the total cumulative product of all elements across all inner lists.

Sample Test Case 1

Input

test_list = [[1, 4, 5], [7, 3], [4], [46, 7, 3]]

Output

The total element product in lists is: 1622880

Sample Test Case 2

Input

test_list = [[2, 2], [3, 3], [4, 1]]

Output

The total element product in lists is: 288

Sample Test Case 3

Input

test_list = [[1, 2, 3], [4, 5], [6]]

Output

The total element product in lists is: 720

9.5 Find Maximum Element in Each Row of a Matrix

You are given a matrix (a list of lists), where each inner list represents a row. Your task is to find the maximum element from each row and print the result as a list containing those maximum values.

You should solve this problem using list comprehension for concise and efficient implementation.

Input Format:

- No user input is required.
- The matrix is predefined in the program.

Output Format:

Print a list containing the maximum element from each row of the given matrix.

Sample Test Case 1

Input

matrix = [[3, 4, 1],

[7, 2, 9],

                                    [5, 8, 6]]

Output

Maximum elements in each row are: [4, 9, 8]

Sample Test Case 2

Input

matrix = [[10, 20],

                   [15, 5],

                   [7, 9]]

Output

Maximum elements in each row are: [20, 15, 9]

Sample Test Case 3

Input

matrix = [[1, 1, 1],

                   [2, 3, 4],

                   [9, 8, 7]]

Output

Maximum elements in each row are: [1, 4, 9]

Try:

1. **Sum of Each Row and Column in a Matrix:** You are given a 2D matrix (list of lists) containing integers.

Your task is to compute:

- The sum of each row, and
- The sum of each column of the matrix.

You must display the result with clear labels for each row and column.

2. **Check if a Matrix is Symmetric:** A square matrix is said to be symmetric if it is equal to its transpose.

In other words, a matrix A is symmetric if A[i][j] == A[j][i] for all valid indices i and j.

Your task is to write a Python program to check whether a given square matrix is symmetric or not.

If it is symmetric, print "The matrix is symmetric." Otherwise, print "The matrix is not symmetric."

10. Graph Representation

10.1 Build a graph

You are given two integers — V (number of vertices) and E (number of edges). Your task is to construct a simple undirected graph using these values and represent it using an adjacency list or adjacency matrix.

The program should also verify whether the given combination of V and E can form a valid simple graph, where:

- There are no self-loops, and

- There are no multiple edges between the same pair of vertices.

If the number of edges E exceeds the maximum possible number of edges in a simple graph (which is V × (V - 1) / 2), display an appropriate message indicating that the graph cannot be built.

Input Format:

- The first line contains two integers separated by a space: V E
- The next E lines each contain two integers u v, representing an edge between vertex u and vertex v. (Vertices are numbered from 1 to V.)

Output Format:

- If the graph is valid, display the adjacency list or adjacency matrix representation.
- Otherwise, print "Invalid graph: too many edges for the given number of vertices."

Sample Input:

4 3

1 2

2 3

3 4

Sample Output: *(Adjacency List)*

1: [2]

2: [1, 3]

3: [2, 4]

4: [3]

10.2 Number of Sink Nodes in a Directed Acyclic Graph (DAG)

You are given a Directed Acyclic Graph (DAG) with n nodes (numbered from 1 to n) and m directed edges.

Your task is to determine the number of sink nodes in the graph. A sink node is defined as a node that has no outgoing edges — i.e., no edge starts from it.

Input Format:

- The first line contains two integers, n and m, representing the number of nodes and edges.
- The next m lines each contain two integers u and v, representing a directed edge from node u to node v.

Output Format:

- Print a single integer — the number of sink nodes in the graph.

Sample Test Case 1

Input

4 2

2 3

4 3

Output

2

Explanation:

Edges: 2 → 3 and 4 → 3

- Node 2 and 4 have outgoing edges.
- Nodes 1 and 3 have no outgoing edges → 2 sink nodes.

Sample Test Case 2

Input

4 2

3 2

3 4

Output

3

Approach / Algorithm:

1. Create an array A[] of size n + 1, initialized with 0s.
   - Each index represents a node.
   - A[i] = 1 means that node i has at least one outgoing edge.
2. Traverse through all the given edges (u → v):
   - Mark the source node u as having an outgoing edge by setting A[u] = 1.
3. After processing all edges, the nodes that remain unmarked (A[i] = 0) are sink nodes.
4. Count and print the number of such sink nodes.

10.3 Represent a Graph using an Adjacency Matrix

A graph can be represented using an adjacency matrix, where each cell (i, j) in the matrix indicates whether there is an edge between vertex i and vertex j.

Write a program to create an adjacency matrix for an undirected graph based on the number of vertices and the list of edges. If an edge exists between vertices i and j, mark the matrix cell with 1, otherwise 0.

Input Format:

- Number of vertices n (predefined).
- List of edges (pairs of connected vertices).

Output Format:

Print the adjacency matrix representation of the graph.

Sample Test Case 1

Input

n = 3

edges = [(0, 1), (1, 2)]

Output

Adjacency Matrix:

[0, 1, 0]

[1, 0, 1]

[0, 1, 0]

10.4 Represent a Graph using an Adjacency List

A graph can also be represented using an adjacency list, where each vertex stores a list of its connected vertices. Write a program to represent an undirected graph using an adjacency list.

Input Format:

- Number of vertices n (predefined).
- List of edges (pairs of connected vertices).

Output Format:

Print the adjacency list representation of the graph.

Sample Test Case 1

Input

n = 3

edges = [(0, 1), (1, 2)]

Output

Adjacency List:

0: [1]

1: [0, 2]

2: [1]

10.5 Count the Number of Edges in an Undirected Graph

You are given an adjacency list representation of an undirected graph.

Write a program to count the total number of edges in the graph.

Input Format:

Adjacency list of the graph (predefined).

Output Format

Print the total number of edges in the graph.

Sample Test Case 1

Input

graph = {

   0: [1, 2],

   1: [0, 2],

   2: [0, 1, 3],

   3: [2]

}

Output:

Total number of edges: 4

Try:

1. **Find the Degree of Each Vertex in an Undirected Graph:** You are given an undirected graph represented as an adjacency list. The degree of a vertex is the number of edges connected to it.

Write a program to compute and print the degree of each vertex in the graph.

Input:

graph = {

   'A': ['B', 'C'],

   'B': ['A', 'C', 'D'],

   'C': ['A', 'B'],

   'D': ['B']

}

Output:

Degree of vertex A: 2

Degree of vertex B: 3

Degree of vertex C: 2

Degree of vertex D: 1

11. Graph Routing Algorithms

11.1 The Seven Bridges of Konigsberg

The city of Königsberg (now Kaliningrad) was set on both sides of the Pregel River, and it included two large islands connected to each other and the mainland by seven bridges. The challenge was simple to state:

Is it possible to walk through the city in such a way that you cross each bridge exactly once and return to the starting point?

Euler modeled the landmasses as nodes (vertices) and the bridges as edges, thereby introducing the concept of a graph.

Your task is to represent the Königsberg bridge network as a graph in Python and determine whether such a path (Eulerian circuit) exists.

Input Format

The graph can be represented as an adjacency list or edge list, where nodes represent landmasses and edges represent bridges.

Output Format

Print whether it is possible to traverse all bridges exactly once and return to the starting point.

Indicate if the graph contains an Eulerian Circuit or Eulerian Path.

Sample Test Case 1

Input

graph = {

      'A': ['B', 'C'],

      'B': ['A', 'C'],

      'C': ['A', 'B']

   }

Output

Degrees of vertices:

A: 2

B: 2

C: 2

Result: The graph has an Eulerian Circuit (can return to start).

Sample Test Case 2

Input

graph = {

   'A': ['B'],

   'B': ['A', 'C', 'D'],

   'C': ['B', 'D'],

   'D': ['B', 'C']

}

Output

Degrees of vertices:

A: 1

B: 3

C: 2

D: 2

Result: The graph has an Eulerian Path (cannot return to start).

11.2 Hamiltonian Cycle Detection in a Graph

A Hamiltonian Cycle in an undirected graph is a path that:

- Visits each vertex exactly once, and
- Returns to the starting vertex, forming a closed loop.

Given an undirected graph represented as an adjacency matrix or adjacency list, write a Python program to determine if the graph contains a Hamiltonian Cycle.

Input Format

The number of vertices n.

An n x n adjacency matrix graph, where:

graph[i][j] = 1 indicates an edge between vertex i and vertex j.

graph[i][j] = 0 indicates no edge.

Output Format

If a Hamiltonian Cycle exists: print one valid cycle (including the return to the start).

Otherwise, print a message indicating that no Hamiltonian Cycle exists.

Sample Test Case 1

Input

graph = [

   [0, 1, 0, 1, 0],

   [1, 0, 1, 1, 1],

   [0, 1, 0, 0, 1],

   [1, 1, 0, 0, 1],

   [0, 1, 1, 1, 0]

]

Output

Hamiltonian Cycle exists: [0, 1, 2, 4, 3, 0]

Sample Test Case 2

Input

graph = [

   [0, 1, 0, 1, 0],

   [1, 0, 1, 1, 1],

   [0, 1, 0, 0, 0],

   [1, 1, 0, 0, 1],

   [0, 1, 0, 1, 0]

]

Output

No Hamiltonian Cycle exists.

11.3 Count the Number of Hamiltonian Cycles in a Graph

A Hamiltonian Cycle in an undirected graph is a path that visits each vertex exactly once and returns to the starting vertex, forming a closed loop.

Given an undirected graph represented as an adjacency matrix, your task is to count all possible Hamiltonian Cycles in the graph.

Input Format

An integer n representing the number of vertices.

An n x n adjacency matrix graph, where:

graph[i][j] = 1 means there is an edge between vertex i and vertex j.

graph[i][j] = 0 means there is no edge.

Output Format

Print the total number of distinct Hamiltonian Cycles in the graph.

Sample Test Case 1

Input

graph = [

   [0, 1, 1, 1],

   [1, 0, 1, 0],

   [1, 1, 0, 1],

   [1, 0, 1, 0]

]

Output

Number of Hamiltonian Cycles: 2

Sample Test Case 2

Input

graph = [

   [0, 1, 1],

   [1, 0, 1],

   [1, 1, 0]

]

Output

Number of Hamiltonian Cycles: 1

12. Shortest Path Algorithms

12.1 Travelling Salesman Problem

The Travelling Salesman Problem (TSP) is a classic graph optimization problem. A salesman must visit every city exactly once and return to the starting city, with the goal of minimizing the total travel cost.

You are given a weighted graph represented as a cost matrix. Your task is to compute the minimum possible cost of completing the tour and print the minimum-cost Hamiltonian Cycle.

Input Format

An integer n representing the number of cities (vertices).

A 2D list graph[n][n], where:

graph[i][j] represents the cost to travel from city i to city j.

graph[i][i] = 0 (no self-loop).

Output Format

Print the minimum cost of the tour.

Print one minimum-cost path (cycle) starting and ending at the same city.

Sample Test Case 1

Input

graph = [

   [0, 10, 15, 20],

   [10, 0, 35, 25],

   [15, 35, 0, 30],

   [20, 25, 30, 0]

]

Output

Minimum tour cost: 80

Optimal path: [0, 1, 3, 2, 0]

Sample Test Case 2

Input

graph = [

   [0, 29, 20, 21],

   [29, 0, 15, 17],

   [20, 15, 0, 28],

   [21, 17, 28, 0]

]

Output

Minimum tour cost: 73

Optimal path: [0, 2, 1, 3, 0]

12.2 Shortest Paths from Source to all Vertices (Dijkstra's Algorithm)

Given a weighted, connected graph with non-negative edge weights, find the shortest distance from a given source vertex to all other vertices using Dijkstra's Algorithm.

This algorithm is widely used in real-world applications such as Google Maps, network routing, and transportation systems to find the shortest path efficiently.

Input Format

- An integer V representing the number of vertices in the graph.

- A list of adjacency lists graph, where each element graph[u] contains pairs (v, w) — meaning there is an edge from vertex u to vertex v with weight w.

- An integer src representing the source vertex.

x

Output Format

Print the shortest distances from the source vertex to all other vertices.

Sample Test Case 1

Input

V = 5

graph = {

   0: [(1, 9), (2, 6), (3, 5), (4, 3)],

   1: [(0, 9), (2, 2), (4, 4)],

   2: [(0, 6), (1, 2), (3, 4)],

   3: [(0, 5), (2, 4)],

   4: [(0, 3), (1, 4)]

}

src = 0

Output

Vertex	Distance from Source
0	0
1	7
2	6
3	5
4	3

Sample Test Case 2

Input

V = 6

graph = {

   0: [(1, 2), (2, 4)],

   1: [(2, 1), (3, 7)],

   2: [(4, 3)],

   3: [(5, 1)],

   4: [(3, 2), (5, 5)],

   5: []

}

src = 0

Output

Vertex	Distance from Source
0	0
1	2
2	3
3	8
4	6

5   9

12.3 Shortest Cycle in an Undirected Unweighted Graph

Given an undirected unweighted graph. The task is to find the length of the shortest cycle in the given graph. If no cycle exists print -1.

Input: Consider the graph given below
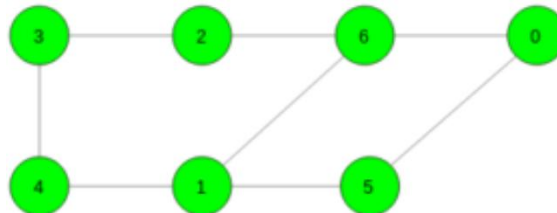
Output: 4

Cycle 6 -> 1 -> 5 -> 0 -> 6

Input: Consider the graph given below
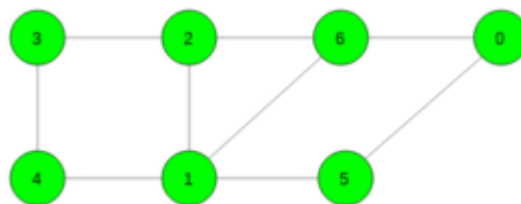
Output: 3

Cycle 6 -> 1 -> 2 -> 6

12.4 Count Unique and all Possible Paths in a M x N Matrix

Count unique paths: The problem is to count all unique possible paths from the top left to the bottom right of a M X N matrix with the constraints that from each cell you can either move only to the right or down.

Input: M = 2, N = 2
Output: 2
Explanation: There are two paths
(0, 0) -> (0, 1) -> (1, 1)
(0, 0) -> (1, 0) -> (1, 1)

Input: M = 2, N = 3
Output: 3
Explanation: There are three paths
(0, 0) -> (0, 1) -> (0, 2) -> (1, 2)
(0, 0) -> (0, 1) -> (1, 1) -> (1, 2)
(0, 0) -> (1, 0) -> (1, 1) -> (1, 2)

Count all possible paths: We can recursively move to right and down from the start until we reach the destination and then add up all valid paths to get the answer.

Procedure:

- Create a recursive function with parameters as row and column index
- Call this recursive function for N-1 and M-1
- In the recursive function
    - If N == 1 or M == 1 then return 1
    - else call the recursive function with (N-1, M) and (N, M-1) and return the sum of this
- Print the answer

12.5 All-Pairs Shortest Paths (Floyd-Warshall Algorithm)

Given a directed weighted graph represented using an adjacency matrix, the task is to find the shortest distances between every pair of vertices using the Floyd–Warshall Algorithm.

This algorithm is particularly useful for dense graphs and can handle negative edge weights (but no negative cycles). It is used in network routing, transit maps, and dependency analysis in compilers.

Input Format

An integer V — number of vertices.

A 2D list graph of size V x V, where graph[i][j] represents the weight of the edge from vertex i to vertex j.

If there is no edge, use a large value like INF = 99999.

Output Format

Print the matrix representing the shortest distance between every pair of vertices.

Sample Test Case 1

Input

V = 4

graph = [

   [0,　5,　99999, 10],

   [99999, 0,　3,　99999],

   [99999, 99999, 0,　1],

   [99999, 99999, 99999, 0]]

Output

Shortest distances between every pair of vertices:

[0, 5, 8, 9]

[99999, 0, 3, 4]

[99999, 99999, 0, 1]

[99999, 99999, 99999, 0]

Sample Test Case 2

Input

V = 3

graph = [

[0, 4, 11],

        [6, 0, 2],

        [3, 99999, 0]

]

Output

Shortest distances between every pair of vertices:

[0, 4, 6]

[5, 0, 2]

[3, 7, 0]

13. Graph Coloring

13.1 Graph Coloring using Greedy Algorithm

You are given an undirected graph, and your task is to assign colors to all vertices such that no two adjacent vertices share the same color.

Use a greedy algorithm to assign colors in a way that minimizes the total number of colors used.

The greedy algorithm assigns the first available color that has not been used by its adjacent vertices.

This problem has practical applications in register allocation, map coloring, timetable scheduling, and frequency assignment in wireless networks.

Input Format

An integer V — number of vertices in the graph.

A dictionary graph representing the adjacency list,

where each key represents a vertex, and the values are lists of vertices adjacent to it.

Output Format

Print the color assigned to each vertex.

Print the total number of colors used.

Sample Test Case 1

Input

V = 5

graph = {

    0: [1, 2],

    1: [0, 2, 3],

    2: [0, 1, 3, 4],

    3: [1, 2, 4],

    4: [2, 3]

}

Output

Vertex   Assigned Color

0   0

1   1

2   2

3   0

4   1

Total Colors Used: 3

Explanation:

Vertex 0 → Color 0

Vertex 1 → Adjacent to 0 → Color 1

Vertex 2 → Adjacent to 0 and 1 → Color 2

Vertex 3 → Adjacent to 1 and 2 → Color 0

Vertex 4 → Adjacent to 2 and 3 → Color 1

Sample Test Case 2

Input

V = 4

graph = {

   0: [1, 2, 3],

   1: [0, 2],

   2: [0, 1, 3],

   3: [0, 2]

}

Output

Vertex   Assigned Color

0   0

1   1

2   2

3   1

Total Colors Used: 3

Explanation:

Vertex 0 → Color 0

Vertex 1 → Adjacent to 0 → Color 1

Vertex 2 → Adjacent to 0 and 1 → Color 2

Vertex 3 → Adjacent to 0 and 2 → Color 1

13.2 Coloring a Cycle Graph

Given the number of vertices in a Cyclic Graph. The task is to determine the Number of colors required to color the graph so that no two adjacent vertices have the same color.

Approach:

- If the no. of vertices is Even then it is Even Cycle and to color such graph we require 2 colors.
- If the no. of vertices is Odd then it is Odd Cycle and to color such graph we require 3 colors.

Input: Vertices = 3

Output: No. of colors require is: 3

Input: vertices = 4

Output: No. of colors require is: 2

Example 1: Even Cycle: Number of vertices = 4
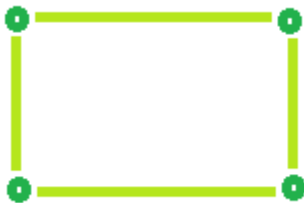
Color required = 2
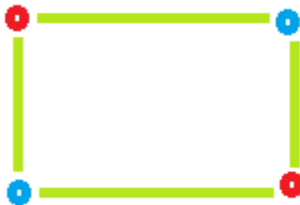
Example 2: Odd Cycle: Number of vertices = 5
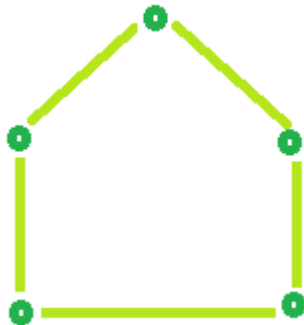
Color required = 3
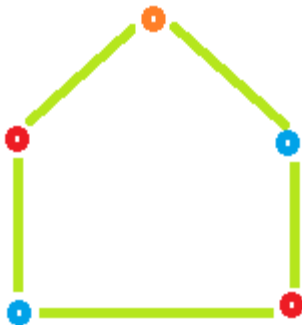
13.3 M-Coloring Problem

Given an undirected graph and a number m, determine if the graph can be colored with at most m colors such that no two adjacent vertices of the graph are colored with the same color.

Note: Here coloring of a graph means the assignment of colors to all vertices

Following is an example of a graph that can be colored with 3 different colors:
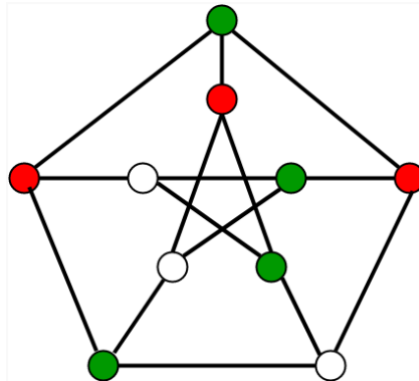
Input: graph = {0, 1, 1, 1},
{1, 0, 1, 0},
{1, 1, 0, 1},
{1, 0, 1, 0}
Output: Solution Exists: Following are the assigned colors: 1 2 3 2
Explanation: By coloring the vertices with following colors, adjacent vertices does not have same colors

Input: graph = {1, 1, 1, 1},
{1, 1, 1, 1},
{1, 1, 1, 1},
{1, 1, 1, 1}

Output: Solution does not exist
Explanation: No solution exits

Generate all possible configurations of colors. Since each node can be colored using any of the m available colors, the total number of color configurations possible is mV. After generating a configuration of color, check if the adjacent vertices have the same color or not. If the conditions are met, print the combination and break the loop

Follow the given steps to solve the problem:

● Create a recursive function that takes the current index, number of vertices and output color array

● If the current index is equal to number of vertices. Check if the output color configuration is safe, i.e check if the adjacent vertices do not have same color. If the conditions are met, print the configuration and break

● Assign a color to a vertex (1 to m)

● For every assigned color recursively call the function with next index and number of vertices

● If any recursive function returns true break the loop and returns true.

13.4 Edge Coloring of a Graph

Edge coloring of a graph is an assignment of "colors" to the edges of the graph so that no two

adjacent edges have the same color with an optimal number of colors. Two edges are said to be adjacent if they are connected to the same vertex. There is no known polynomial time algorithm for edge-coloring every graph with an optimal number of colors.

Input: u1 = 1, v1 = 4

u2 = 1, v2 = 2

u3 = 2, v3 = 3

u4 = 3, v4 = 4

Output: Edge 1 is of color 1

Edge 2 is of color 2

Edge 3 is of color 1

Edge 4 is of color 2

The above input shows the pair of vertices (u_i, v_i) who have an edge between them. The output shows the color assigned to the respective edges.
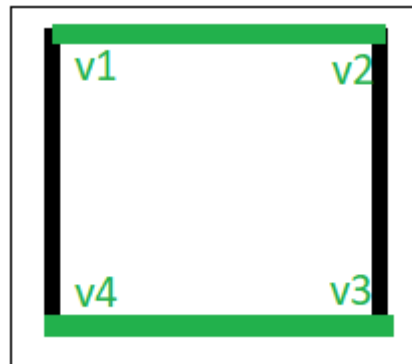
Edge colorings are one of several different types of graph coloring problems. The above figure of a Graph shows an edge coloring of a graph by the colors green and black, in which no adjacent edge have the same color.

Algorithm:

1. Use BFS traversal to start traversing the graph.

2. Pick any vertex and give different colors to all of the edges connected to it, and mark those edges as colored.

3. Traverse one of its edges.

4. Repeat step to with a new vertex until all edges are colored.

14. Final Notes

The only way to learn programming is program, program and program on challenging problems. The problems in this tutorial are certainly NOT challenging. There are tens of thousands of challenging problems available – used in training for various programming contests (such as International Collegiate Programming Contest (ICPC), International Olympiad in Informatics (IOI)). Check out these sites:

- The ACM - ICPC International collegiate programming contest (https://icpc.global/)
- The Topcoder Open (TCO) annual programming and design contest (https://www.topcoder.com/)
- Universidad de Valladolid's online judge (https://uva.onlinejudge.org/).
- Peking University's online judge (http://poj.org/).

- USA Computing Olympiad (USACO) Training Program @ http://train.usaco.org/usacogate.
- Google's coding competitions (https://codingcompetitions.withgoogle.com/codejam, https://codingcompetitions.withgoogle.com/hashcode)
- The ICFP programming contest (https://www.icfpconference.org/)
- BME International 24-hours programming contest (https://www.challenge24.org/)
- The International Obfuscated C Code Contest (https://www0.us.ioccc.org/main.html)
- Internet Problem Solving Contest (https://ipsc.ksp.sk/)
- Microsoft Imagine Cup (https://imaginecup.microsoft.com/en-us)
- Hewlett Packard Enterprise (HPE) Codewars (https://hpecodewars.org/)
- OpenChallenge (https://www.openchallenge.org/)

Coding Contests Scores

Students must solve problems and attain scores in the following coding contests:

Name of the contest	Minimum number of problems to solve	Required score
CodeChef	20	200
Leetcode	20	200
GeeksforGeeks	20	200
SPOJ	5	50
InterviewBit	10	1000
Hackerrank	25	250
Codeforces	10	100
BuildIT	50	500
Total score need to obtain		2500

Student must have any one of the following certification:

1. HackerRank - Problem Solving Skills Certification (Basic and Intermediate)
2. GeeksforGeeks – Data Structures and Algorithms Certification
3. CodeChef - Learn Data Structures and Algorithms Certification
4. Interviewbit – DSA pro / Python pro
5. Edx – Data Structures and Algorithms
5. NPTEL – Programming, Data Structures and Algorithms
6. NPTEL – Introduction to Data Structures and Algorithms
7. NPTEL – Data Structures and Algorithms
8. NPTEL – Programming and Data Structure

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- Universidad de Valladolid's online judge (https://uva.onlinejudge.org/).
- Peking University's online judge (http://poj.org/).
- USA Computing Olympiad (USACO) Training Program @ http://train.usaco.org/usacogate.
- Google's coding competitions (https://codingcompetitions.withgoogle.com/codejam, https://codingcompetitions.withgoogle.com/hashcode)

- The ICFP programming contest (https://www.icfpconference.org/)
- BME International 24-hours programming contest (https://www.challenge24.org/)
- The International Obfuscated C Code Contest (https://www0.us.ioccc.org/main.html)
- Internet Problem Solving Contest (https://ipsc.ksp.sk/)
- Microsoft Imagine Cup (https://imaginecup.microsoft.com/en-us)
- Hewlett Packard Enterprise (HPE) Codewars (https://hpecodewars.org/)
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5. Edx – Data Structures and Algorithms
5. NPTEL – Programming, Data Structures and Algorithms
6. NPTEL – Introduction to Data Structures and Algorithms
7. NPTEL – Data Structures and Algorithms
8. NPTEL – Programming and Data Structure

V. TEXT BOOKS:
1. Eric Matthes, "Python Crash Course: A Hands-On, Project-based Introduction to Programming", No Starch Press, 3rd Edition, 2023.
2. John M Zelle, "Python Programming: An Introduction to Computer Science", Ingram short title, 3rd Edition, 2016.

VI. REFERENCE BOOKS:
1. Yashavant Kanetkar, Aditya Kanetkar, "Let Us Python", BPB Publications, 2nd Edition, 2019.
2. Martin C. Brown, "Python: The Complete Reference", Mc. Graw Hill, Indian Edition, 2018.
3. Paul Barry, "Head First Python: A Brain-Friendly Guide", O'Reilly, 2nd Edition, 2016
4. Taneja Sheetal, Kumar Naveen, "Python Programming – A Modular Approach", Pearson, 1st Edition, 2017.
5. R Nageswar Rao, "Core Python Programming", Dreamtech Press, 2018.

VII. ELECTRONICS RESOURCES
8. https://realPython.com/Python3-object-oriented-programming/
9. https://Python.swaroopch.com/oop.html
10. https://Python-textbok.readthedocs.io/en/1.0/Object_Oriented_Programming.html
11. https://www.programiz.com/Python-programming/

12. https://www.geeksforgeeks.org/python-programming-language/

VIII. MATERIALS ONLINE
1. Course template
2. Lab Manual

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

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<tr><td colspan="9" align="center">COMPUTER AIDED ENGINEERING GRAPHICS</td></tr>
<tr><td colspan="9">I Semester: CSE / IT
II Semester: CSE (AI&ML) / CSE(DS) / ECE / EEE / AERO / MECH / CE</td></tr>
<tr><td align="center">Course Code</td><td align="center">Category</td><td colspan="3" align="center">Hours / Week</td><td align="center">Credits</td><td colspan="3" align="center">Maximum Marks</td></tr>
<tr><td rowspan="2" align="center">AMEE03</td><td rowspan="2" align="center">Foundation</td><td align="center">L</td><td align="center">T</td><td align="center">P</td><td align="center">C</td><td align="center">CIA</td><td align="center">SEE</td><td align="center">Total</td></tr>
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<tr><td align="center">Contact Classes: 15</td><td align="center">Tutorial Classes: Nil</td><td colspan="4" align="center">Practical Classes: 30</td><td colspan="3" align="center">Total Classes: 45</td></tr>
<tr><td colspan="9">Prerequisite: There is no prerequisite required to this course</td></tr>
</table>

I. COURSE OVERVIEW:

Engineering Drawing is the technique that develops the ability to visualize any object with all physical and dimensional configurations. The AutoCAD software assists in preparation of drawings to carry out sophisticated design and analysis of machine components and structures. This is the foundation course for civil engineering, mechanical engineering and aeronautical engineering that are improving their technologies in the era of digital manufacturing and construction.

II. COURSE OBJECTIVES:
The students will try to learn:
I. The illustration of different objects using technical drawings using concepts of engineering drawing.
II. The standard principles of orthographic projection of objects for making technical drawings.
III. The representation of draw sectional views and pictorial views of solids.
IV. The computer aided drafting skills for producing the 2D and 3D drawings.

III. COURSE OUTCOMES:
At the end of the course students should be able to:

CO1 Demonstrate the use of draw, modify and dimension commands of AutoCAD for development of drawings used in design and analysis of structures.

CO2 Explain the constructional procedure of scales, conic sections and special curves used in engineering practices.

CO3 Utilize the principles of orthographic projection for projections of points, lines, planes and regular solids using first angle projections.

CO4 Interpret the sectional views and true shape of the section for revealing interior features of an object veal interior features of an object

CO5 Illustrate the development of surfaces for construction of storage vessels, chemical vessels, boilers, and chimneys in industrial applications

CO6 Make use of the concept of orthographic and isometric projections for converting isometric view to orthographic views and Vice-versa for engineering applications.

MODULE – I: Introduction to engineering graphics

Principles of engineering graphics and their significance, scales, plain & diagonal, conic sections including the rectangular hyperbola, general method, cycloid, epicycloid and hypocycloid, introduction to computer aided drafting, views, commands.

MODULE – II: Orthographic projections

Principles of orthographic projections, conventions, projections of points and lines, projections of plane regular geometric figures. Computer aided orthographic projections, points, lines and planes.

MODULE – III: Projections of regular solids

Projections of regular solids, auxiliary views, sections or sectional views of right regular solids, prism. Cylinder, pyramid, cone, computer aided projections of solids, sectional views.

MODULE – IV: Development of surfaces

Development of surfaces of right regular solids, prism, cylinder, pyramid and cone, development of surfaces using computer aided drafting.

MODULE – V: Isometric projections

principles of isometric projection, isometric scale, isometric views, conventions, isometric views of lines, plane figures, simple and compound solids, isometric projection of objects having non-isometric lines. Isometric projection of spherical parts, conversion of isometric views to orthographic views and vice-versa, conventions, conversion of orthographic projection into isometric view using computer aided drafting.

V.TEXT BOOKS:
1. N.D. Bhatt; *Engineering Drawing* Charotar Publishing House PVT Ltd, 15th edition 2011.
2. K. Venugoplal; *Engineering Drawing and graphics Using AutoCAD*, 3rd edition 2007.

VI.REFERENCE BOOKS:
1. Basant Agrawal and C M Agrawal; *Engineering Drawing*, McGraw Hill, 3rd Edition 2011.
2. K L Narayana, P Kannaiah; *Engineering Drawing*, New age international (P) limited, 3rd edition, 2022.
3. M. B. Shah, B.C. Rane; Engineering *Drawing*, Pearson publications.

VII. ELECTRONIC RESOURCES:
1. https://archieve.nptel.ac.in/cources/112/103/112103019.
2. https://archieve.nptel.ac.in/cources/112/105/112105294.

VIII. MATERIALS ONLINE:
1. Course Template
2. Laboratory manual

COMPUTER AIDED ENGINEERING GRAPHICS

Note: Students are encouraged to bring their own laptops for laboratory practice sessions.

1. Getting Started Exercises
1.1 Introduction to AUTOCAD

AutoCAD is a widely-used computer-aided design (CAD) software application developed by Autodesk. It has been an industry standard for drafting and designing since its inception in the early 1980s. AutoCAD provides a versatile platform for creating and editing 2D and 3D drawings and models, making it an essential tool in various fields such as architecture, engineering, construction, manufacturing, and more.

   i.   Install AUTO CAD
  ii.   Purpose and Application
 iii.   Interface and Tools
 iv.   Precision and Accuracy
  v.   2D and 3D Modeling
 vi.   Collaboration and Sharing
vii.   Customization
viii.   Industry Usage
 ix.   Versions and Licensing

1.1 Commands

The main purpose of using commands and shortcuts in AutoCAD boils down to increased productivity. They allow you to execute functions more quickly, as you don't need to search through the entire AutoCAD interface for the right tool. You can just type the command, and the function window appears.

   i. Basic Drawing Commands
  ii. Editing Commands
 iii. Dimensioning Commands
 iv. Advanced and Miscellaneous Commands

Basic Drawing Commands:
- Line (LINE): Draws straight line segments between two points.
- Circle (CIRCLE): Creates circles by specifying a center point and radius.
- Rectangle (RECTANGLE): Constructs rectangles by defining two opposing corners.
- Arc (ARC): Draws arcs based on different methods, such as specifying start, end, and radius or center, start, and angle.

Editing Commands:
- Erase (ERASE): Deletes selected objects from the drawing.
- Copy (COPY): Copies objects to a specified location.
- Move (MOVE): Relocates selected objects to a different position.
- Trim (TRIM): Cuts selected objects at the cutting edges defined by other objects.
- Extend (EXTEND): Extends objects to meet the boundaries of other objects.

Dimensioning Commands:
- Line Dimension (DIMLINEAR): Adds linear dimensions to objects.
- Aligned Dimension (DIMALIGNED): Creates dimensions aligned with an angle of

the object.
- o Radial Dimension (DIMRADIUS): Add radius dimensions to arcs and circles.
- o Diameter Dimension (DIMDIAMETER): Creates diameter dimensions for circles.

Advanced and Miscellaneous Commands:
- o Hatch (HATCH): Fills enclosed areas with a pattern or gradient.
- o Offset (OFFSET): Creates parallel copies of objects at a specified distance.
- o Block (BLOCK): Defines reusable blocks (collections of objects) in the drawing.
- o Insert (INSERT): Inserts predefined blocks into the drawing.
- o Viewport (VPORTS): Manages viewports for layout and plotting in paper space.
- o Layer (LAYER): Manages layers for organizing and controlling object visibility.

TRY: Observe Exercise 1.1 in Solid works and in Creo software.

2. Introduction to Engineering Drawing

Engineering drawing, often referred to as technical drawing or drafting, is a graphical representation of an object, system, or structure used in various fields of engineering, manufacturing, and architecture. These drawings serve as a universal language that communicates design ideas, specifications, and instructions in a precise and standardized manner.

2.1 Basic Exercises

To be proficient in engineering drawing, basic exercises are required.
- i. Identify the basic tools used for drafting
- ii. Types of lines
- iii. Arcs
- iv. Circles

2.2 Practicing the standard lettering and numbering

Practicing standard lettering and numbering in engineering drawing is crucial for creating clear, professional, and easily understandable technical drawings. Proper lettering and numbering enhance communication and ensure that your drawings convey information accurately.

The following exercises are to be practiced to become proficient in lettering and numbering.
1. Use the correct fonts
2. Maintain uniformity
3. Lettering style
4. Height and spacing

Try: The following questions are to be answered in Solid works
1. How to use correct fonts in Solid Works
2. What are the commands are used to maintain uniformity of lettering and numbering.

3. Dimensioning

Dimensioning in engineering drawing is a crucial aspect that involves adding measurements and annotations to convey the size, location, and tolerances of objects, features, and components accurately. Proper dimensioning is essential for manufacturing, construction, and other engineering processes.

3.1 Exercises on Dimensioning

1. Understanding and use of the conventional dimensioning techniques.
2. Placing the dimension lines
3. Extension lines
4. Dimensions on angles

Hint: 1. The following Fig.3.1 shows the type of dimensioning on 2D drawing.
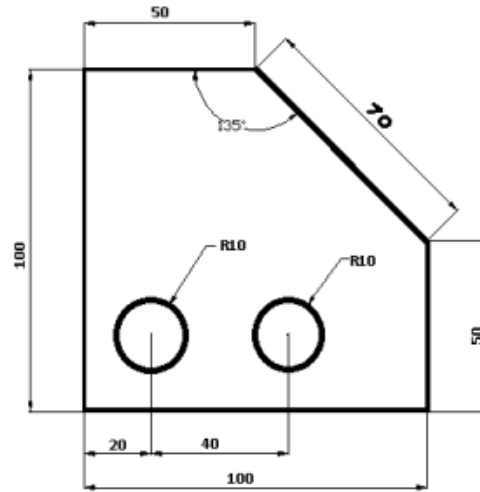
Fig.3.1 Dimensioning on 2D drawing

Hint: 2. The following Fig.3.2 shows the type of dimensioning on concentric circles.
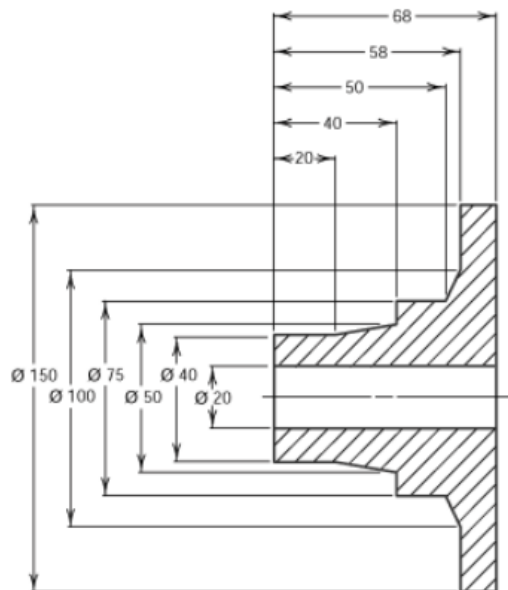
Fig.3.2 Dimensioning on Concentric circle

Try: Demonstrate the exercise 3 in Solid Works and CREO software.

4. Geometrical Constructions

Geometric construction is useful for learning how to use geometric tools like a ruler, compass, and straightedge to draw various angles, line segments, bisectors, and other forms of polygons, arcs, circles, and other geometric figures. Fig.4.1 shows the various geometric shapes to draw orthographic projections of lines, planes and solids.
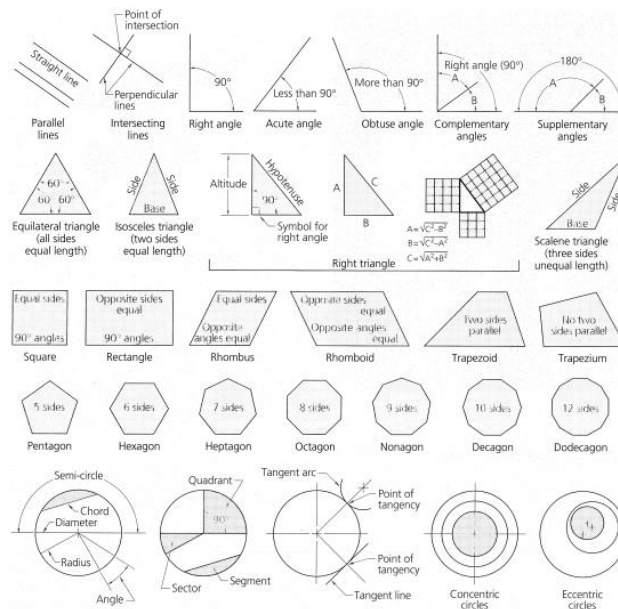
Fig.4.1 Geometric shapes

4.1. Exercises on Geometrical Constructions

To become proficient in engineering graphics geometrical constructions are required: Drawing lines, angles, triangle, square, pentagon, hexagon, octagon. Dividing line into equal or proportional parts. Drawing lines and arcs tangent to each other.

1. Divide a 16 cm straight line into a given number of equal parts say 5.
2. Divide a 8 cm line into 9 number of parts.
3. Bisect a given 45 degree sector.
4. Bisect a given straight line.
5. To draw a perpendicular to a given line from a point within it.
6. Construct a regular polygon, given the length of its side.

Hint: Dividing a line into equal number of parts

| Given | Step 1 | Step 2 | Step 3 | Step 4 |
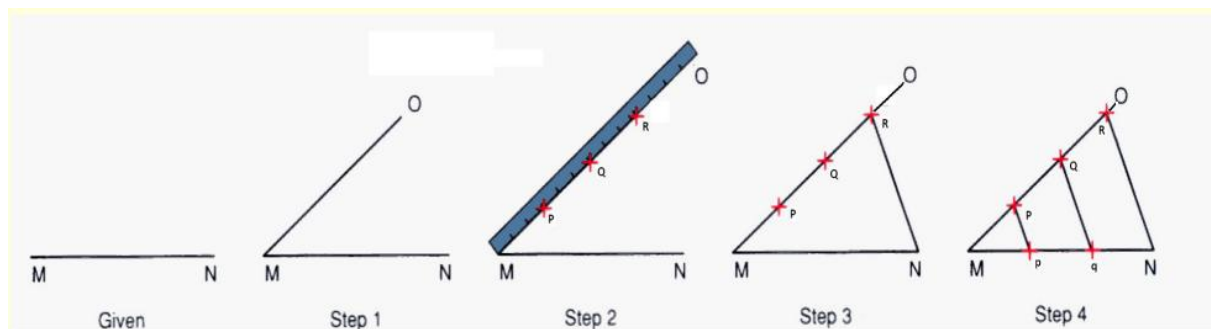
Try: The exercise 4 in Solid Works and CREO software.

5. Conic Sections

A conic section, conic or a quadratic curve is a curve obtained from a cone's surface intersecting a plane. The three types of conic section are the hyperbola, the parabola, and the ellipse.

5.1. Exercises on Conic Sections

1. Draw an ellipse with the distance of the focus from the directrix at 50mm and eccentricity = 2/3 (Eccentricity method)
2. Draw an ellipse with the distance of the focus from the directrix at 60mm and eccentricity = 2/3 (Eccentricity method)
3. Draw an ellipse with the distance of the focus from the directrix at 80mm and eccentricity = 2/3 (Eccentricity method)
4. Draw a parabola with the distance of the focus from the directrix at 50 mm (Eccentricity method).
5. Draw a parabola with the distance of the focus from the directrix at 40mm (Eccentricity method).
6. A vertex of a hyperbola is 60 mm from its focus. Draw two parts of the hyperbola; if the eccentricity is 3/2.
7. A vertex of a hyperbola is 50 mm from its focus. Draw two parts of the hyperbola; if the eccentricity is 1.5.

Try: The exercise 5 in Solid Works and CREO software.

6. Technical Sketching and Shape Description

6.1. Projections of planes and regular solids

1. Draw the projections of a regular pentagon of 30 mm side, having its surface inclined at 30° to the H.P. and a side parallel to the H.P. and inclined at an angle of 60° to the V.P.
2. Draw the projections of a regular hexagon of 40 mm side, having one of its sides in the H.P. and inclined at 60° to the V.P., and its surface making an angle of 45° with the H.P.
3. Draw the projections of a regular hexagon of 35 mm side, having one of its sides in the H.P. and inclined at 50° to the V.P., and its surface making an angle of 45° with the H.P.
4. Draw the projections of a regular pentagon of 40 mm side, having one of its sides in the H.P. and inclined at 30° to the V.P., and its surface making an angle of 45° with the H.P.

Try: The exercise 6.3 in Solid Works and CREO software.

7. Sectional views

A sectional view represents the part of an object remaining after a portion is assumed to have been cut and removed. The exposed cut surface is then indicated by section lines. Hidden features behind the cutting plane are omitted, unless required for dimensioning or for definition of the part.

7.1. Exercise on Sectional views of right regular solids, prism, cylinder, pyramid, cone.

1. A pentagonal pyramid, base 40 mm side and axis 60 mm long has its base horizontal and an edge of the base parallel to the V.P. A horizontal section plane cuts it at a distance of 20 mm above the base. Draw its front view and sectional top view.
2. A hexagonal prism, side of base 40 mm and height 70 mm is resting on one of its corners on the H.P. with a longer edge containing that corner inclined at 40° to the H.P. and a rectangular face parallel to the V.P. Draw the front view and sectional top view of the cut prism when a horizontal section plane cuts the prism in two equal halves. Draw the front view and sectional top view of the cut prism.
3. A pentagonal pyramid, base 40 mm side and axis 70 mm long has one of its triangular faces in the V.P. and the edge of the base contained by that face makes an angle of 40° with the H.P. Draw its projections.
4. Draw the projections of a cone, base 50 mm diameter and axis 75 mm long, lying on a generator on the ground with the top view of the axis making an angle of 45° with the V.P.

   Try: The exercise 7.1 and 7.2 in Solid Works and CREO software.

8. Development of surfaces

Knowledge of development is very useful in sheet metal work, construction of storage vessels, chemical vessels, boilers, and chimneys. Such vessels are manufactured from plates that are cut according to these developments and then properly bend into desired shaped.

8.1. Exercise on Basics of development of surfaces

1. Draw the development of the lateral surfaces of a right square prism of edge of base 30 mm and axis 50 mm long.
2. Draw the development of the complete surface of a cylindrical drum. Diameter is 40 mm and height 60 mm.

8.2. Exercise on Development of surfaces of Prisms

1. A hexagonal prism of base side 20 mm and height 45 mm is resting on one of its ends on the HP with two of its lateral faces parallel to the VP. It is cut by a plane perpendicular to the VP and inclined at 30° to the HP. The plane meets the axis at a distance of 20 mm above the base. Draw the development of the lateral surfaces of the lower portion of the prism.
2. A hexagonal prism, edge of base 20 mm and axis 50 mm long, rests with its base on HP such that one of its rectangular faces is parallel to VP. It is cut by a plane perpendicular to VP, inclined at 45° to HP and passing through the right corner of the top face of the prism. (i) Draw the sectional top view. (ii)Develop the lateral surfaces of the truncated prism.
3. A pentagonal prism, side of base 25 mm and altitude 50 mm, rests on its base on the HP such that an edge of the base is parallel to VP and nearer to the observer. It is cut by a plane inclined at 45° to HP, perpendicular to VP and passing through the center of the axis. (i) Draw the development of the complete surfaces of the truncated prism.

4. A pentagonal prism of side of base 30 mm and altitude 60 mm stands on its base on HP such that a vertical face is parallel to VP and away from observer. It is cut by a plane perpendicular to VP, inclined at an angle of 50° to HP and passing through the axis 35 mm above the base. Draw the development of the lower portion of the prism.

Try : The exercise 8.1 and 8.2 in Solid Works and CREO software.

9. Exercise on Development of surfaces-2

9.1. Exercise on Development of surfaces of cylinder and cone

1. Draw the development of the lateral surface of the lower portion of a cylinder of diameter 50 mm and axis 70 mm when sectioned by a plane inclined at 40° to HP and perpendicular to VP and bisecting axis.
2. A Cone of base diameter 60 mm and height 70 mm is resting on its base on HP. It is cut by a plane perpendicular to VP and inclined at 30° to HP. The plane bisects the axis of the cone. Draw the development of its lateral surface.

9.2. Exercise on Development of surfaces of pyramid

1. Draw the development of the lateral surfaces of a square pyramid, side of base 25 mm and height 50 mm, resting with its base on HP and an edge of the base parallel to VP.
2. A square pyramid of base side 25 mm and altitude 50 mm rests on it base on the HP with two sides of the base parallel to the VP. It is cut by a plane bisecting the axis and inclined a 30° to the base. Draw the development of the lateral surfaces of the lower part of the cut pyramid.
3. A pentagonal pyramid side of base 30 mm and height 52 mm stands with its base on HP and an edge of the base is parallel to VP and nearer to it. It is cut by a plane perpendicular to VP, inclined at 40° to HP and passing through a point on the axis 32 mm above the base. Draw the sectional top view. Develop the lateral surface of the truncated pyramid.

Try: The exercise 9.1 and 9.2 in Solid Works and CREO software.

10. Orthographic views

Orthographic views are two-dimensional views of three-dimensional objects. Orthographic views are created by projecting a view of an object onto a plane which is usually positioned so that it is parallel to one of the planes of the object.

10.1. Exercise on Conversion of isometric view to orthographic projections using CAD

1. Draw the front view, side view and top view for the below Fig.10.1
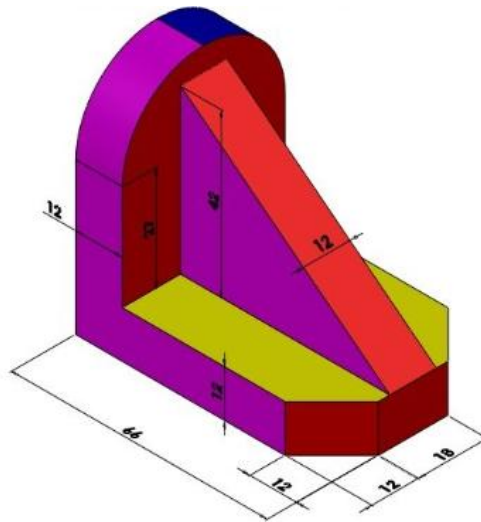
Fig.10.1

2. Draw the front view, side view and top view for the below Fig.10.2.
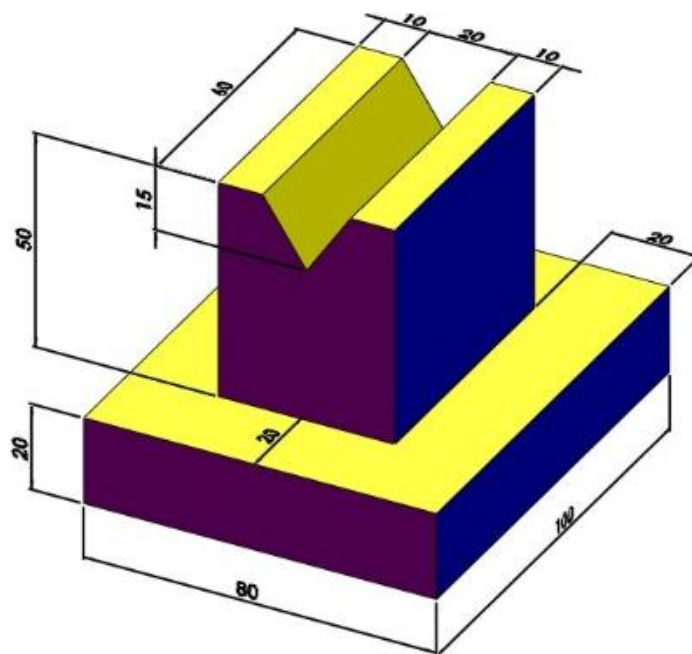
Fig.10.2

3. Draw the front view, side view and top view for the below Fig.10.3.
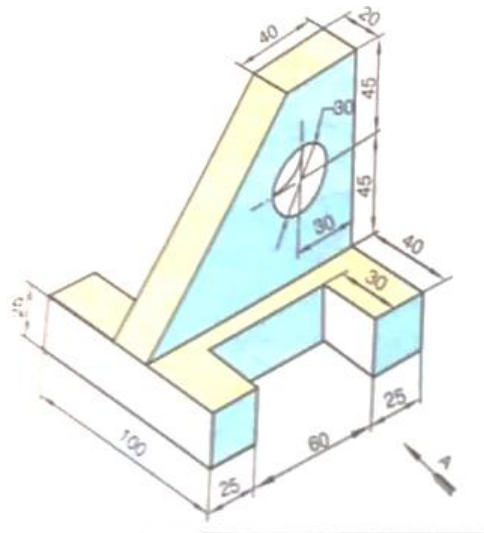
Fig.10.3

4. Draw the front view, side view and top view for the below Fig.10.4.
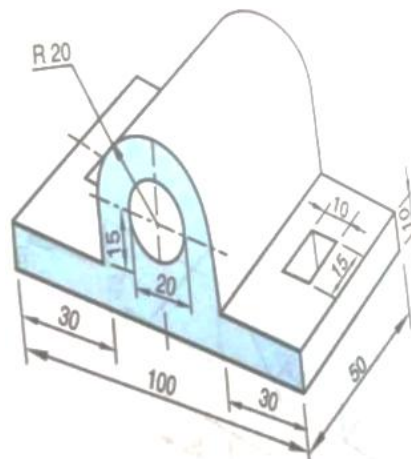
Fig.10.4

Try: Practice Exercise 10 in Solid Works

11. Isometric projection of planes

Isometric projection is a method for visually representing three-dimensional objects in two dimensions in technical and engineering drawings. It is an axonometric projection in which the three coordinate axes appear equally foreshortened and the angle between any two of them is 120 degrees.

11.1. Isometric scale

In engineering and technical drawing, an isometric scale is a method used to create an isometric projection of a three-dimensional object onto a two-dimensional surface, such as a drawing sheet or a computer screen. Isometric projection is a type of pictorial representation that shows an object in a three-dimensional view with all three principal axes (x, y, and z) at equal angles to the picture plane. An isometric scale is used to ensure that the dimensions and proportions of objects in the isometric drawing are accurate and maintain the proper relationships.

11.2. Exercise on Isometric projections of circle, square and rectangle and solids

1. Draw the isometric view of a circle of 60 mm diameter whose surface is parallel to the V.P.
2. Draw the isometric view of a square of side 60 mm whose surface is parallel to the H.P.
3. Draw the isometric view of a circle of 40 mm radius whose surface is parallel to the H.P.
4. Draw the isometric view of a square prism, side of the base 20 mm long and the axis 40 mm long, when its axis is i) Veritcal and ii) Horizontal.
5. Draw the isometric view of the semi-circle whose front view of its surface is parallel to the V.P.. The diameter of semi-circle is 60 mm.

Try : The exercise 11.2 in Solid Works and CREO software.

1.   Isometric projections of solids

12.1. Exercise on conversion of orthographic view to isometric view using CAD

1. Draw the isometric view for the given orthographic views Fig.12.1
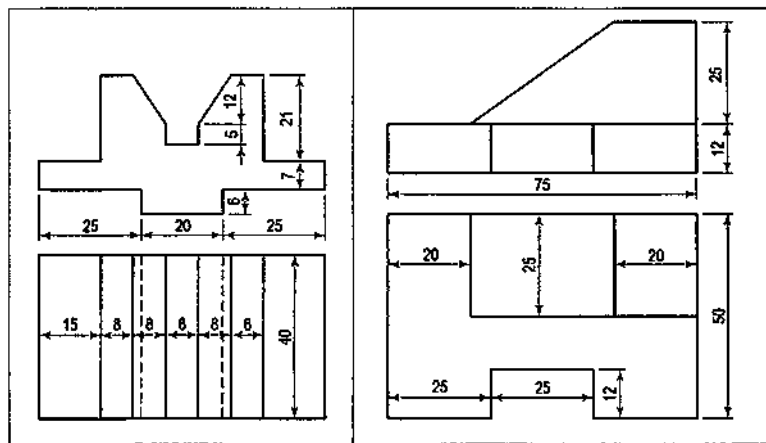
Fig.12.1

2. Draw the isometric view for the given orthographic views for Fig.12.2
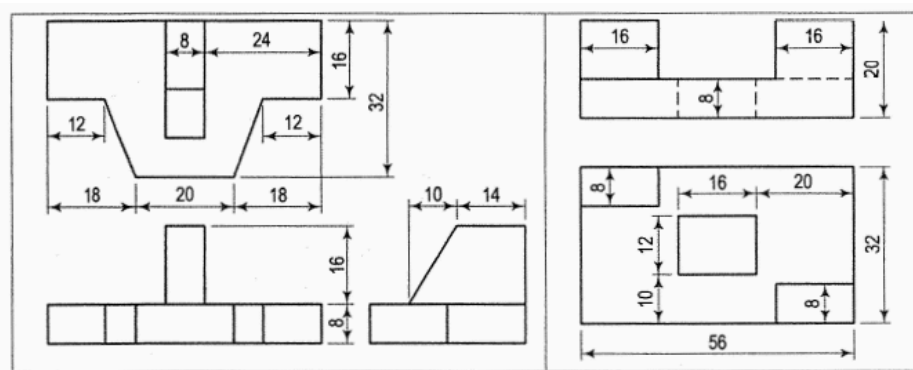
Fig.12.2

3.Draw the isometric view for the given orthographic views by assuming the dimensions for Fig.12.3
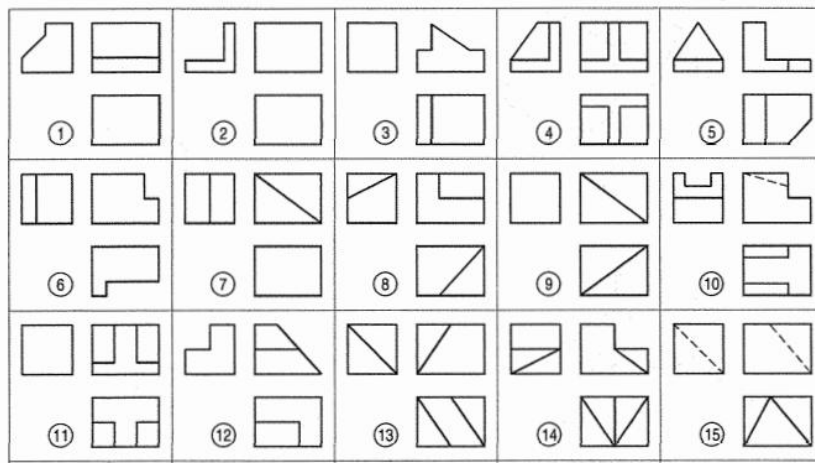
Fig.12.3

Try : The exercise 12 in Solid Works and CREO software.

13.Demonstration of SOLID WORKS Software

1. Introduction to SOLID WORKS
2. Demonstration of commands
3. 2D drawings
3. 3D drawings

V. TEXT BOOKS:

1. Frederick E Giesecke, Alva Mitchell, Henry C Spencer, Ivan L Hill, John T Dygdon, James E. Novak, R. O. Loving, Shawna Lockhart, Cindy Johnson, *Technical Drawing with Engineering Graphics*, Pearson Education, 15th Edition, 2016.
2. Kulkarni D.M, Rastogi A.P. and Sarkar A.K., *Engineering Graphics with Auto CAD*. (Revised Edition), Prentice Hall India, New Delhi, 2011.
3. Donald Hearn, "*Computer Graphics*", 12th Edition, Pearson, 2021.

VI. REFERENCE BOOKS:

1. Basant Agrawal and C M Agrawal, *Engineering Drawing*, McGraw Hill, 3rd Edition, 2018.
2. James M. Leake, Molly Hathaway Goldstein, Jacob L. Borgerson, *Engineering Design Graphics, Modelling and Visualization*, Wiley, 3rd Edition, 2020.

VII. ELECTRONICS RESOURCES:

4. https://archive.nptel.ac.in/courses/112/103/112103019.
5. https://archive.nptel.ac.in/courses/112/105/112105294.

VIII. MATERIALS ONLINE:

3. Course Template
4. Laboratory manual

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

DATA STRUCTURES LABORATORY								
II Semester: AE / ME / CE / ECE / EEE / CSE / IT / CSE (AI&ML) / CSE (DS)								
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
ACSE08	**Foundation**	L	T	P	C	CIA	SEE	Total
		-	-	2	1	40	60	100
Contact Classes: Nil	**Tutorial Classes: Nil**	**Practical Classes: 45**				**Total Classes: 45**		
Prerequisite: Essentials of Problem Solving								

I. COURSE OVERVIEW:

The course covers some of the general-purpose data structures and algorithms, and software development. Topics covered include managing complexity, analysis, static data structures, dynamic data structures and hashing mechanisms. The main objective of the course is to teach the students how to select and design data structures and algorithms that are appropriate for problems that they might encounter in real life. This course reaches to student by power point presentations, lecture notes, and lab which involve the problem solving in mathematical and engineering areas.

II. COURSES OBJECTIVES:

The students will try to learn

I. To provide students with skills needed to understand and analyze performance trade-offs of different algorithms / implementations and asymptotic analysis of their running time and memory usage.
II. To provide knowledge of basic abstract data types (ADT) and associated algorithms: stacks, queues, lists, tree, graphs, hashing and sorting, selection and searching.
III. The fundamentals of how to store, retrieve, and process data efficiently.
IV. To provide practice by specifying and implementing these data structures and algorithms in Python.
V. Understand essential for future programming and software engineering courses.

III. COURSE OUTCOMES:

At the end of the course students should be able to:

CO 1 Interpret the complexity of algorithm using the asymptotic notations.

CO 2 Select appropriate searching and sorting technique for a given problem.

CO 3 Construct programs on performing operations on linear and nonlinear data structures for organization of a data.

CO 4 Make use of linear data structures and nonlinear data structures solving real time applications.

CO 5 Describe hashing techniques and collision resolution methods for efficiently accessing data with respect to performance.

CO 6 Compare various types of data structures; in terms of implementation, operations and performance.

INSTITUTE OF AERONAUTICAL ENGINEERING
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Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
ACSE08	**Foundation**	**L**	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
		-	-	2	1	40	60	100
Contact Classes: Nil	**Tutorial Classes: Nil**	**Practical Classes: 45**				**Total Classes: 45**		
Prerequisite: Essentials of Problem Solving								

IV. COURSE OVERVIEW:

The course covers some of the general-purpose data structures and algorithms, and software development. Topics covered include managing complexity, analysis, static data structures, dynamic data structures and hashing mechanisms. The main objective of the course is to teach the students how to select and design data structures and algorithms that are appropriate for problems that they might encounter in real life. This course reaches to student by power point presentations, lecture notes, and lab which involve the problem solving in mathematical and engineering areas.

V. COURSES OBJECTIVES:

The students will try to learn

VI. To provide students with skills needed to understand and analyze performance trade-offs of different algorithms / implementations and asymptotic analysis of their running time and memory usage.

VII. To provide knowledge of basic abstract data types (ADT) and associated algorithms: stacks, queues, lists, tree, graphs, hashing and sorting, selection and searching.

VIII. The fundamentals of how to store, retrieve, and process data efficiently.

IX. To provide practice by specifying and implementing these data structures and algorithms in Python.

X. Understand essential for future programming and software engineering courses.

VI. COURSE OUTCOMES:

At the end of the course students should be able to:

CO 1 Interpret the complexity of algorithm using the asymptotic notations.

CO 2 Select appropriate searching and sorting technique for a given problem.

CO 3 Construct programs on performing operations on linear and nonlinear data structures for organization of a data.

CO 4 Make use of linear data structures and nonlinear data structures solving real time applications.

CO 5 Describe hashing techniques and collision resolution methods for efficiently accessing data with respect to performance.

CO 6 Compare various types of data structures; in terms of implementation, operations and performance.

DATA STRUCTURES LABORATORY (ACSE08)
CONTENTS

EXERCISES FOR DATA STRUCTURES LABORATORY

Note: Students are encouraged to bring their own laptops for laboratory practice sessions.

1. Getting Started Exercises

1.1 Sum of last digits of two given numbers

Rohit wants to add the last digits of two given numbers. For example, If the given numbers are 267 and 154, the output should be 11.
Below is the explanation -
Last digit of the 267 is 7
Last digit of the 154 is 4
Sum of 7 and 4 = 11
Write a program to help Rohit achieve this for any given two numbers.
The prototype of the method should be -
int addLastDigits(int input1, int input2);
where input1 and input2 denote the two numbers whose last digits are to be added.
Note: The sign of the input numbers should be ignored.
if the input numbers are 267 and 154, the sum of last two digits should be 11
if the input numbers are 267 and -154, the sum of last two digits should be 11
if the input numbers are -267 and 154, the sum of last two digits should be 11
if the input numbers are -267 and -154, the sum of last two digits should be 11
Input: 267 154
Output: 11
Input: 267 -154
Output: 11
Input: -267 154
Output: 11
Input: -267 -154
Output: 11

1.2 Is N an exact multiple of M?

Write a function that accepts two parameters and finds whether the first parameter is an exact multiple of the second parameter. If the first parameter is an exact multiple of the second parameter, the function should return 2 else it should return 1.
If either of the parameters are zero, the function should return 3.
Assumption: Within the scope of this question, assume that - the first parameter can be positive, negative or zero the second parameter will always be >=0
Input: num1 = 10, num2 = 5
Output: 2
Input: num1 = -10, num2 = 5
Output: 2
Input: num1 = 0, num2 = 5
Output: 3
Input: num1 = 10, num2 = 3
Output: 1

1.3 Combine Strings

Given 2 strings, a and b, return a new string of the form short+long+short, with the shorter string on the outside and the longer string in the inside. The strings will not be the same length, but they may be empty (length 0).

If input is "hi" and "hello", then output will be "hihellohi"

Input: Enter the first string: "hi"

Enter the second string: "hello"

Output: "hihellohi"

Input: Enter the first string: "iare"

Enter the second string: "college"

Output: "iarecollegeiare"

1.4 Even or Odd

Write a function that accepts 6 input parameters. The first 5 input parameters are of type int. The sixth input parameter is of type string. If the sixth parameter contains the value "even", the function is supposed to return the count of how many of the first five input parameters are even. If the sixth parameter contains the value "odd", the function is supposed to return the count of how many of the first five input parameters are odd.

Example:

If the five input parameters are 12, 17, 19, 14, and 115, and the sixth parameter is "odd", the function must return 3, because there are three odd numbers 17, 19 and 115.

If the five input parameters are 12, 17, 19, 14, and 115, and the sixth parameter is "even", the function must return 2, because there are two even numbers 12 and 14.

Note that zero is considered an even number.

Input: num1 = 12;

num2 = 17;

num3 = 19;

num4 = 14;

num5 = 115;

type = "odd"

Output: 3

Input: num1 = 12;

num2 = 17;

num3 = 19;

num4 = 14;

num5 = 115;

type = "even"

Output: 2

1.5 Second last digit of a given number

Write a function that returns the second last digit of the given number. Second last digit is being referred to the digit in the tens place in the given number.

Example: if the given number is 197, the second last digit is 9.

Note 1: The second last digit should be returned as a positive number. i.e. if the given number is -197, the second last digit is 9.

Note 2: If the given number is a single digit number, then the second last digit does not exist. In such cases, the function should return -1. i.e. if the given number is 5, the second last digit should be returned as -1.

Input: 197
Output: 9
Input: 5
Output: -1
Input: -197
Output: 9

1.6 Alternate String Combiner

Given two strings, a and b, print a new string which is made of the following combination-first character of a, the first character of b, second character of a, second character of b and so on.
Any characters left, will go to the end of the result.
Hello,World
HWeolrllod
Input: "Hello,World"
Output: "HWeolrllod"
Input: "Iare,College"
Output: "ICaorlelege"

1.7 Padovan Sequence

The Padovan sequence is a sequence of numbers named after Richard Padovan, who attributed its discovery to Dutch architect Hans van der Laan. The sequence was described by Ian Stewart in his Scientific American column Mathematical Recreations in June 1996. The Padovan sequence is defined by the following recurrence relation:
P(n) = P(n-2) + P(n-3)
with the initial conditions P(0) = P(1) = P(2) = 1.
In this sequence, each term is the sum of the two preceding terms, similar to the Fibonacci sequence. However, the Padovan sequence has different initial conditions and exhibits different growth patterns.
The first few terms of the Padovan sequence are: 1, 1, 1, 2, 2, 3, 4, 5, 7, 9, 12, ...
Input: num = 10
Output: Padovan Sequence up to 10:
　　　　1 1 1 2 2 3 4 5 7 9 12
Input: num = 20
Output: Padovan Sequence up to 20:
　　　　1 1 1 2 2 3 4 5 7 9 12 16 21 28 37 49 65 86 114 151 200

1.8 Leaders in an array

Given an array arr of n positive integers, your task is to find all the leaders in the array. An element of the array is considered a leader if it is greater than all the elements on its right side or if it is equal to the maximum element on its right side. The rightmost element is always a leader.
Input: n = 6, arr[] = (16, 17, 4, 3, 5, 2}
Output: 17 5 2
Input: n = 5, arr[] = {10, 4, 2, 4, 1}
Output: 10 4 4 1
Input: n = 4, arr[] = {5, 10, 20, 40}
Output: 40

Input: n = 4, arr[] = {30, 10, 10, 5}
Output: 30 10 10 5

1.9 Find the Value of a Number Raised to its Reverse

Given a number N and its reverse R. The task is to find the number obtained when the number is raised to the power of its own reverse
Input : N = 2, R = 2
Output: 4
Explanation: Number 2 raised to the power of its reverse 2 gives 4 which gives 4 as a result after performing modulo 10^9+7

Input: N = 57, R = 75
Output: 262042770
Explanation: 57^{75} modulo 10^9+7 gives us the result as 262042770

1.10 Mean of Array using Recursion

Find the mean of the elements of the array.
Mean = (Sum of elements of the Array) / (Total no of elements in Array)
Input: 1 2 3 4 5
Output: 3.0
Input: 1 2 3
Output: 2.0
To find the mean using recursion assume that the problem is already solved for N-1 i.e. you have to find for n
Sum of first N-1 elements = (Mean of N-1 elements) * (N-1)
Mean of N elements = (Sum of first N-1 elements + N-th elements) / (N)

Try:

1. **Kth Smallest Element:** Given an array arr[] and an integer k where k is smaller than the size of the array, the task is to find the kth smallest element in the given array. It is given that all array elements are distinct.
Note: l and r denotes the starting and ending index of the array.
Input: n = 6, arr[] = {7, 10, 4, 3, 20, 15}, k = 3, l = 0, r = 5
Output: 7
Explanation: 3rd smallest element in the given array is 7.
Input: n = 5, arr[] = {7, 10, 4, 20, 15}, k = 4, l=0 r=4
Output: 15
Explanation: 4th smallest element in the given array is 15.
Your task is to complete the function **kthSmallest()** which takes the array arr[], integers l and r denoting the starting and ending index of the array and an integer k as input and returns the kth smallest element.

2. **Count pairs with given sum:** Given an array of N integers, and an integer K, find the number of pairs of elements in the array whose sum is equal to K. Your task is to complete the function **getPairsCount()** which takes arr[], n and k as input parameters and returns the number of pairs that have sum K.
Input: N = 4, K = 6, arr[] = {1, 5, 7, 1}
Output: 2
Explanation: arr[0] + arr[1] = 1 + 5 = 6 and arr[1] + arr[3] = 5 + 1 = 6.
Input: N = 4, K = 2, arr[] = {1, 1, 1, 1}
Output: 6
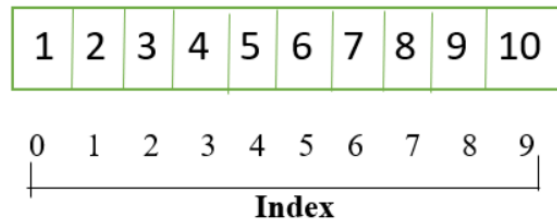
2. Searching

2.1 Linear / Sequential Search

Linear search is defined as the searching algorithm where the list or data set is traversed from one end to find the desired value. Given an array arr[] of n elements, write a recursive function to search a given element x in arr[].

Find '6'

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

0 1 2 3 4 5 6 7 8 9
Index

Note : We find '6' at index '5' through linear search

Linear search procedure:
1. Start from the leftmost element of arr[] and one by one compare x with each element of arr[]
2. If x matches with an element, return the index.
3. If x doesn't match with any of the elements, return -1.

Input: arr[] = {10, 20, 80, 30, 60, 50, 110, 100, 130, 170}
        x = 110;
Output: 6
Element x is present at index 6

Input: arr[] = {10, 20, 80, 30, 60, 50, 110, 100, 130, 170}
        x = 175;
Output: -1
Element x is not present in arr[].

2.2 Binary Search

Binary Search is defined as a searching algorithm used in a sorted array by repeatedly dividing the search interval in half. The idea of binary search is to use the information that the array is sorted and reduce the time complexity to O(log N).
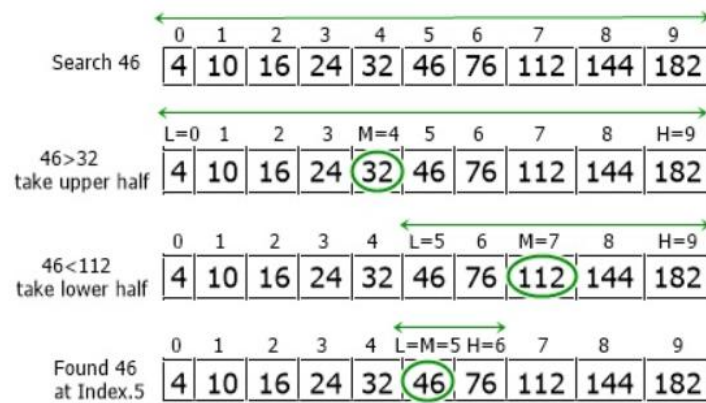
Conditions for Binary Search algorithm:

1. The data structure must be sorted.

2. Access to any element of the data structure takes constant time.

$$mid = low + (high - low)/2$$
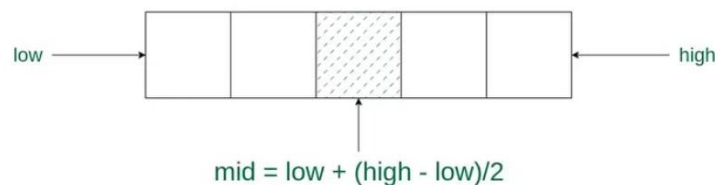
Binary Search Procedure:

1. Divide the search space into two halves by finding the middle index "mid".

2. Compare the middle element of the search space with the key.

3. If the key is found at middle element, the process is terminated.

4. If the key is not found at middle element, choose which half will be used as the next search space.

       a. If the key is smaller than the middle element, then the left side is used for next search.

       b. If the key is larger than the middle element, then the right side is used for next search.

5. This process is continued until the key is found or the total search space is exhausted.

Input: arr = [2, 5, 8, 12, 16, 23, 38, 56, 72, 91]

Output: target = 23

       Element 23 is present at index 5

2.3 Uniform Binary Search

Uniform Binary Search is an optimization of Binary Search algorithm when many searches are made on same array or many arrays of same size. In normal binary search, we do arithmetic operations to find the mid points. Here we precompute mid points and fills them in lookup table. The array look-up generally works faster than arithmetic done (addition and shift) to find the mid-point.

Input: array = {1, 3, 5, 6, 7, 8, 9}, v=3

Output: Position of 3 in array = 2

Input: array = {1, 3, 5, 6, 7, 8, 9}, v=7

Output: Position of 7 in array = 5

The algorithm is very similar to Binary Search algorithm, the only difference is a lookup table is created for an array and the lookup table is used to modify the index of the pointer in the array which makes the search faster. Instead of maintaining lower and upper bound the algorithm maintains an index and the index is modified using the lookup table.

2.4 Interpolation Search

Interpolation search works better than Binary Search for a Sorted and Uniformly Distributed array. Binary search goes to the middle element to check irrespective of search-key. On the other hand, Interpolation search may go to different locations according to search-key. If the value of the search-key is close to the last element, Interpolation Search is likely to start search toward the end side. Interpolation search is more efficient than binary search when the elements in the list are uniformly distributed, while binary search is more efficient when the elements in the list are not uniformly distributed.

Interpolation search can take longer to implement than binary search, as it requires the use of additional calculations to estimate the position of the target element.

Input: arr = [1, 2, 3, 4, 5, 6, 7, 8, 9]

Output: target = 5

2.5 Fibonacci Search

Given a sorted array arr[] of size n and an element x to be searched in it. Return index of x if it is present in array else return -1.

Input: arr[] = {2, 3, 4, 10, 40}, x = 10

Output: 3

Element x is present at index 3.

Input: arr[] = {2, 3, 4, 10, 40}, x = 11

Output: -1

Element x is not present.

Fibonacci Search is a comparison-based technique that uses Fibonacci numbers to search an element in a sorted array.

Fibonacci Numbers are recursively defined as F(n) = F(n-1) + F(n-2), F(0) = 0, F(1) = 1. First few Fibonacci Numbers are 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, ...

Fibonacci Search Procedure:

Let the searched element be x. The idea is to first find the smallest Fibonacci number that is greater than or equal to the length of the given array. Let the found Fibonacci number be fib (m'th Fibonacci number). We use (m-2)'th Fibonacci number as the index (If it is a valid index). Let (m-2)'th Fibonacci Number be i, we compare arr[i] with x, if x is same, we return i. Else if x is greater, we recur for subarray after i, else we recur for subarray before i.

Let arr[0..n-1] be the input array and the element to be searched be x.

1. Find the smallest Fibonacci number greater than or equal to n. Let this number be fibM [m'th Fibonacci number]. Let the two Fibonacci numbers preceding it be fibMm1 [(m-1)'th Fibonacci Number] and fibMm2 [(m-2)'th Fibonacci Number].

2. While the array has elements to be inspected:

    i.   Compare x with the last element of the range covered by fibMm2

    ii. If x matches, return index

    iii. Else If x is less than the element, move the three Fibonacci variables two Fibonacci down, indicating elimination of approximately rear two-third of the remaining array.

    iv. Else x is greater than the element, move the three Fibonacci variables one Fibonacci down. Reset offset to index. Together these indicate the elimination of approximately front one-third of the remaining array.

3.   Since there might be a single element remaining for comparison, check if fibMm1 is 1. If Yes, compare x with that remaining element. If match, return index.

3. Sorting

3.1 Bubble Sort

Bubble Sort is the simplest sorting algorithm that works by repeatedly swapping the adjacent elements if they are in the wrong order. This algorithm is not suitable for large data sets as its average and worst-case time complexity is quite high.

Bubble Sort Procedure:

1. Traverse from left and compare adjacent elements and the higher one is placed at right side.

2. In this way, the largest element is moved to the rightmost end at first.

3. This process is then continued to find the second largest and place it and so on until the data is sorted.

Input: arr = [6, 3, 0, 5]

Output:

First Pass:
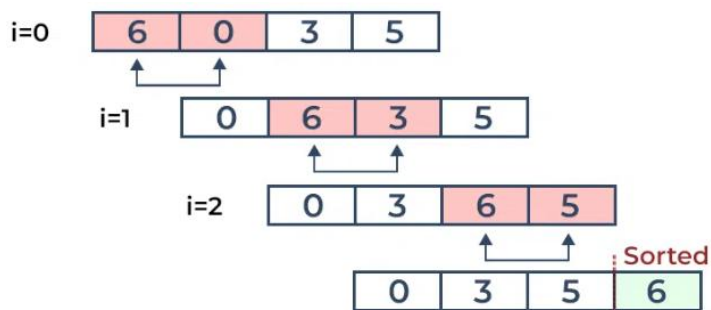
Second Pass:

Third Pass:

Sorted array
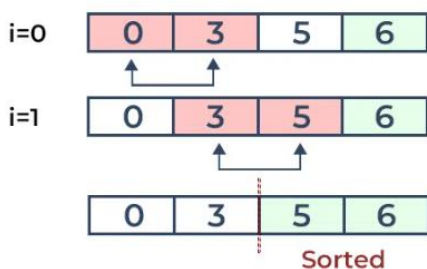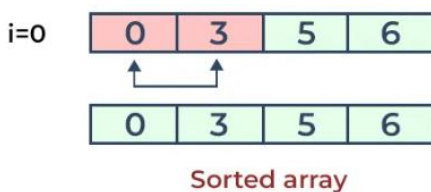
3.2 Selection Sort

Selection sort is a simple and efficient sorting algorithm that works by repeatedly selecting the smallest (or largest) element from the unsorted portion of the list and moving it to the sorted portion of the list.

The algorithm repeatedly selects the smallest (or largest) element from the unsorted portion of the list and swaps it with the first element of the unsorted part. This process is repeated for the remaining unsorted portion until the entire list is sorted.

Input: arr = [64, 25, 12, 22, 11]

Output: arr = [11, 12, 22, 25, 64]

First Pass: For the first position in the sorted array, the whole array is traversed from index 0 to 4 sequentially. The first position where 64 is stored presently, after traversing whole array it is clear that 11 is the lowest value. Thus, replace 64 with 11. After one iteration 11, which happens to be the least value in the array, tends to appear in the first position of the sorted list.
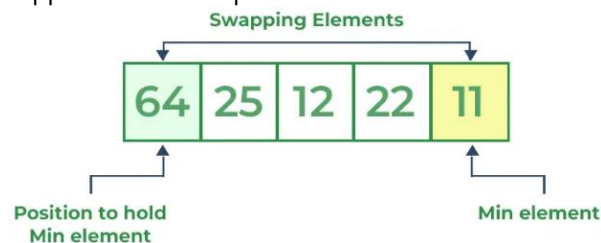
Second Pass: For the second position, where 25 is present, again traverse the rest of the array in a sequential manner. After traversing, we found that 12 is the second lowest value in the array and it should appear at the second place in the array, thus swap these values.

Third Pass: Now, for third place, where 25 is present again traverse the rest of the array and find the third least value present in the array. While traversing, 22 came out to be the third least value and it should appear at the third place in the array, thus swap 22 with element present at third position.
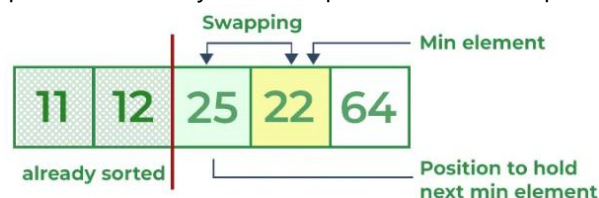
Fourth Pass: Similarly, for fourth position traverse the rest of the array and find the fourth least element in the array. As 25 is the 4th lowest value hence, it will place at the fourth position.

Fifth Pass: At last the largest value present in the array automatically get placed at the last position in the array. The resulted array is the sorted array.

Sorted array

3.3 Insertion Sort

Insertion sort is a simple sorting algorithm that works similar to the way you sort playing cards in your hands. The array is virtually split into a sorted and an unsorted part. Values from the unsorted part are picked and placed at the correct position in the sorted part.

Insertion Sort Procedure:

1. To sort an array of size N in ascending order iterate over the array and compare the current element

(key) to its predecessor, if the key element is smaller than its predecessor, compare it to the elements before.

2. Move the greater elements one position up to make space for the swapped element.
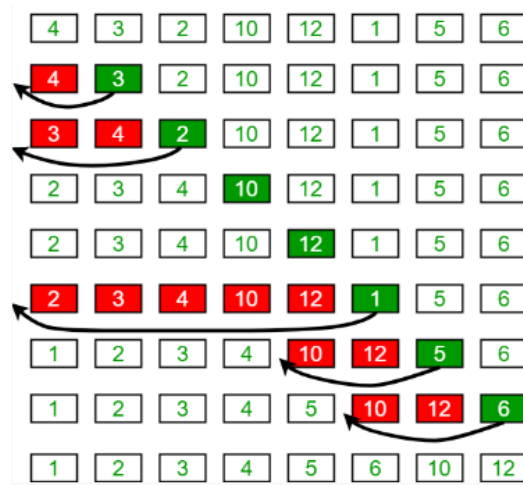
Input: arr = [4, 3, 2, 10, 12, 1, 5, 6]
Output: arr = [1, 2, 3, 4, 5, 6, 10, 12]

4. Divide and Conquer

4.1 Quick Sort

QuickSort is a sorting algorithm based on the Divide and Conquer algorithm that picks an element as a pivot and partitions the given array around the picked pivot by placing the pivot in its correct position in the sorted array. The key process in quickSort is a partition(). The target of partitions is to place the pivot (any element can be chosen to be a pivot) at its correct position in the sorted array and put all smaller elements to the left of the pivot, and all greater elements to the right of the pivot. Partition is done recursively on each side of the pivot after the pivot is placed in its correct position and this finally sorts the array.
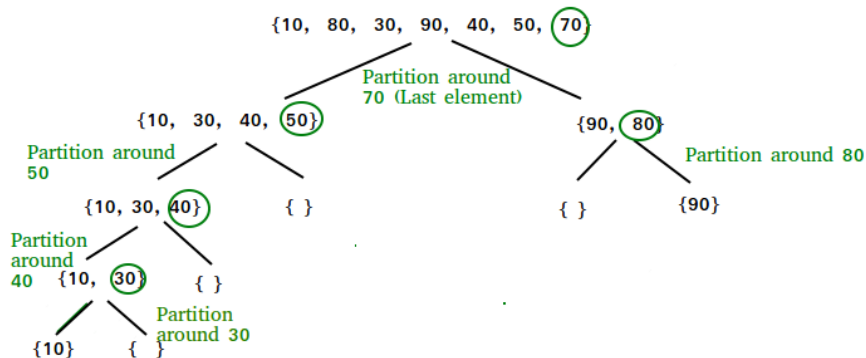
The quick sort method can be summarized in three steps:
1. **Pick:** Select a pivot element.
2. **Divide:** Split the problem set, move smaller parts to the left of the pivot and larger items to the right.
3. **Repeat and combine:** Repeat the steps and combine the arrays that have previously been sorted.

Algorithm for Quick Sort Function:
//start –> Starting index, end --> Ending index
Quicksort(array, start, end)
{

```
        if (start < end)
        {
                pIndex = Partition(A, start, end)
                Quicksort(A,start,pIndex-1)
                Quicksort(A,pIndex+1, end)
        }
}
```

Algorithm for Partition Function:

```
partition (array, start, end)
{
        // Setting rightmost Index as pivot
        pivot = arr[end];

        i = (start - 1)  // Index of smaller element and indicates the
             // right position of pivot found so far
        for (j = start; j <= end- 1; j++)
        {
                // If current element is smaller than the pivot
                if (arr[j] < pivot)
                {
                        i++;   // increment index of smaller element
                        swap arr[i] and arr[j]
                }
        }
        swap arr[i + 1] and arr[end])
        return (i + 1)
}
```

Input: arr = [10, 80, 30, 90, 40, 50, 70]
Output: arr = [10, 30, 40, 50, 70, 80, 90]

4.2 Merge Sort

Merge sort is defined as a sorting algorithm that works by dividing an array into smaller subarrays, sorting each subarray, and then merging the sorted subarrays back together to form the final sorted array. In simple terms, we can say that the process of merge sort is to divide the array into two halves, sort each half, and then merge the sorted halves back together. This process is repeated until the entire array is sorted.
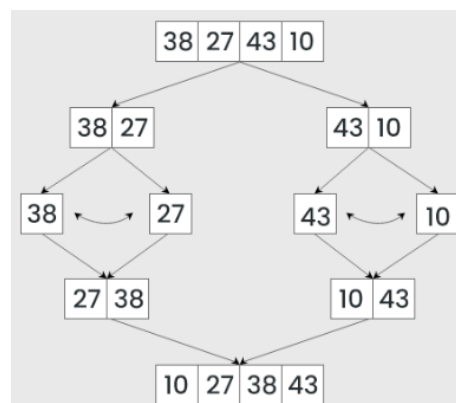
Input: arr = [12, 11, 13, 5, 6, 7]
Output: arr = [5, 6, 7, 11, 12, 13]

4.3 Heap Sort

Heap sort is a comparison-based sorting technique based on Binary Heap data structure. It is similar to the selection sort where we first find the minimum element and place the minimum element at the beginning. Repeat the same process for the remaining elements.

Heap Sort Procedure:

First convert the array into heap data structure using heapify, then one by one delete the root node of the Max-heap and replace it with the last node in the heap and then heapify the root of the heap. Repeat this process until size of heap is greater than 1.

- Build a heap from the given input array.
- Repeat the following steps until the heap contains only one element:
  - Swap the root element of the heap (which is the largest element) with the last element of the heap.
  - Remove the last element of the heap (which is now in the correct position).
  - Heapify the remaining elements of the heap.
- The sorted array is obtained by reversing the order of the elements in the input array.

Input: arr = [12, 11, 13, 5, 6, 7]
Output: Sorted array is 5 6 7 11 12 13

4.4 Radix Sort

Radix Sort is a linear sorting algorithm that sorts elements by processing them digit by digit. It is an efficient sorting algorithm for integers or strings with fixed-size keys. Rather than comparing elements directly, Radix Sort distributes the elements into buckets based on each digit's value. By repeatedly sorting the elements by their significant digits, from the least significant to the most significant, Radix Sort achieves the final sorted order.

Radix Sort Procedure:

The key idea behind Radix Sort is to exploit the concept of place value.

1. It assumes that sorting numbers digit by digit will eventually result in a fully sorted list.

2. Radix Sort can be performed using different variations, such as Least Significant Digit (LSD) Radix Sort

   or Most Significant Digit (MSD) Radix Sort.

To perform radix sort on the array [170, 45, 75, 90, 802, 24, 2, 66], we follow these steps:

| 170 | 45 | 75 | 90 | 802 | 24 | 2 | 66 |

Unsorted
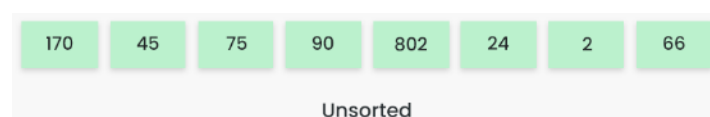
Step 1: Find the largest element in the array, which is 802. It has three digits, so we will iterate three times, once for each significant place.

Step 2: Sort the elements based on the unit place digits (X=0). We use a stable sorting technique, such as counting sort, to sort the digits at each significant place.

Sorting based on the unit place:

Perform counting sort on the array based on the unit place digits.

The sorted array based on the unit place is [170, 90, 802, 2, 24, 45, 75, 66]

Sorted For Unit Digit

Step 3: Sort the elements based on the tens place digits.
Sorting based on the tens place:
Perform counting sort on the array based on the tens place digits.
The sorted array based on the tens place is [802, 2, 24, 45, 66, 170, 75, 90]

Sorted Till 10'S Digit
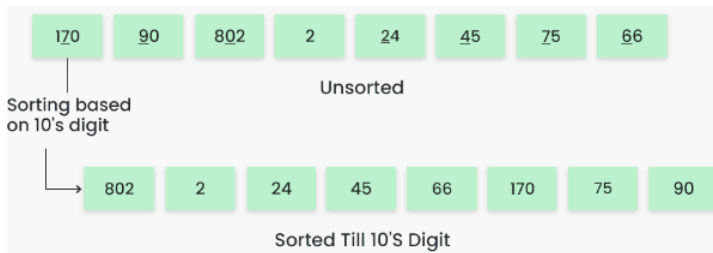
Step 4: Sort the elements based on the hundreds place digits.
Sorting based on the hundreds place:
Perform counting sort on the array based on the hundreds place digits.
The sorted array based on the hundreds place is [2, 24, 45, 66, 75, 90, 170, 802]

Sorting Till 100'S Digit
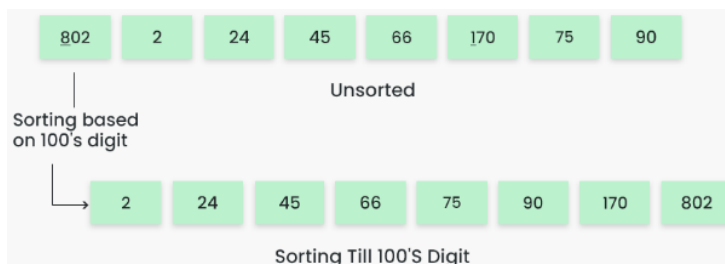
Step 5: The array is now sorted in ascending order.
The final sorted array using radix sort is [2, 24, 45, 66, 75, 90, 170, 802]

Array after performing Radix Sort for all digits
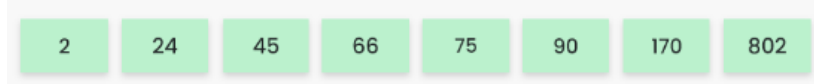
4.5 Shell Sort

Shell sort is mainly a variation of Insertion Sort. In insertion sort, we move elements only one position ahead. When an element has to be moved far ahead, many movements are involved. The idea of ShellSort is to allow the exchange of far items. In Shell sort, we make the array h-sorted for a large value of h. We keep reducing the value of h until it becomes 1. An array is said to be h-sorted if all sublists of every h'th element are sorted.

Shell Sort Procedure:
1. Initialize the value of gap size h
2. Divide the list into smaller sub-part. Each must have equal intervals to h
3. Sort these sub-lists using insertion sort

4. Repeat this step 1 until the list is sorted.

5. Print a sorted list.

```
Procedure Shell_Sort(Array, N)
   While Gap < Length(Array) /3 :
           Gap = ( Interval * 3 ) + 1
   End While Loop
   While Gap > 0 :
     For (Outer = Gap; Outer < Length(Array); Outer++):
         Insertion_Value = Array[Outer]
             Inner = Outer;
         While Inner > Gap-1 And Array[Inner – Gap] >= Insertion_Value:
             Array[Inner] = Array[Inner – Gap]
             Inner = Inner – Gap
          End While Loop
             Array[Inner] = Insertion_Value
     End For Loop
     Gap = (Gap -1) /3;
   End While Loop
End Shell_Sort
```

5. Stack

5.1 Implementation of Stack

A stack is a linear data structure that stores items in a Last-In/First-Out (LIFO) or First-In/Last-Out (FILO) manner. In stack, a new element is added at one end and an element is removed from that end only. The insert and delete operations are often called push and pop.
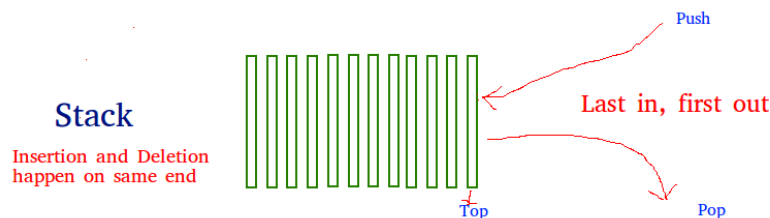
The functions associated with stack are:

- **empty()** – Returns whether the stack is empty
- **size()** – Returns the size of the stack
- **top() / peek()** – Returns a reference to the topmost element of the stack
- **push(a)** – Inserts the element 'a' at the top of the stack
- **pop()** – Deletes the topmost element of the stack

5.2 Balanced Parenthesis Checking

Given an expression string, write a java program to find whether a given string has balanced parentheses or not.

Input: "{(a+b)*(c-d)}"
Output: true
Input: "{(a+b)*[c-d)}"
Output: false

One approach to check balanced parentheses is to use stack. Each time, when an open parentheses is encountered push it in the stack, and when closed parenthesis is encountered, match it with the top of stack and pop it. If stack is empty at the end, return true otherwise, false

5.3 Evaluation of Postfix Expression

Given a postfix expression, the task is to evaluate the postfix expression. Postfix expression: The expression of the form "a b operator" (ab+) i.e., when a pair of operands is followed by an operator.
Input: str = "2 3 1 * + 9 -"
Output: -4
Explanation: If the expression is converted into an infix expression, it will be 2 + (3 * 1) – 9 = 5 – 9 = -4.
Input: str = "100 200 + 2 / 5 * 7 +"
Output: 757
Procedure for evaluation postfix expression using stack:
- Create a stack to store operands (or values).
- Scan the given expression from left to right and do the following for every scanned element.
    - If the element is a number, push it into the stack.
    - If the element is an operator, pop operands for the operator from the stack. Evaluate the operator and push the result back to the stack.
- When the expression is ended, the number in the stack is the final answer.

5.4 Infix to Postfix Expression Conversion

For a given Infix expression, convert it into Postfix form.
Infix expression: The expression of the form "a operator b" (a + b) i.e., when an operator is in-between every pair of operands.
Postfix expression: The expression of the form "a b operator" (ab+) i.e., When every pair of operands is followed by an operator.
Infix to postfix expression conversion procedure:
1.   Scan the infix expression from left to right.
2.   If the scanned character is an operand, put it in the postfix expression.
3.   Otherwise, do the following
   - If the precedence and associativity of the scanned operator are greater than the precedence and associativity of the operator in the stack [or the stack is empty or the stack contains a '('], then push it in the stack. ['^' operator is right associative and other operators like '+','−','*' and '/' are left-associative].
      - Check especially for a condition when the operator at the top of the stack and the scanned operator both are '^'. In this condition, the precedence of the scanned operator is higher due to its right associativity. So it will be pushed into the operator stack.
      - In all the other cases when the top of the operator stack is the same as the scanned operator, then pop the operator from the stack because of left associativity due to which the scanned operator has less precedence.
   - Else, Pop all the operators from the stack which are greater than or equal to in precedence than that of the scanned operator.
      - After doing that Push the scanned operator to the stack. (If you encounter parenthesis while popping then stop there and push the scanned operator in the stack.)
4.   If the scanned character is a '(', push it to the stack.
5.   If the scanned character is a ')', pop the stack and output it until a '(' is encountered, and discard both the parenthesis.
6.   Repeat steps 2-5 until the infix expression is scanned.

7.   Once the scanning is over, Pop the stack and add the operators in the postfix expression until it is not empty.

8.   Finally, print the postfix expression.

Input: A + B * C + D
Output: A B C * + D +
Input: ((A + B) – C * (D / E)) + F
Output: A B + C D E / * - F +

5.5 Reverse a Stack

The stack is a linear data structure which works on the LIFO concept. LIFO stands for last in first out. In the stack, the insertion and deletion are possible at one end the end is called the top of the stack. Define two recursive functions BottomInsertion() and Reverse() to reverse a stack using Python. Define some basic function of the stack like push(), pop(), show(), empty(), for basic operation like respectively append an item in stack, remove an item in stack, display the stack, check the given stack is empty or not.

BottomInsertion(): this method append element at the bottom of the stack and BottomInsertion accept two values as an argument first is stack and the second is elements, this is a recursive method.

Reverse(): the method is reverse elements of the stack, this method accept stack as an argument Reverse() is also a Recursive() function. Reverse() is invoked BottomInsertion() method for completing the reverse operation on the stack.

Input: Elements = [1, 2, 3, 4, 5]
Output: Original Stack

5

4

3

2

1

Stack after Reversing

1

2

3

4

5

6. Queue

6.1 Linear Queue

Linear queue is a linear data structure that stores items in First in First out (FIFO) manner. With a queue the least recently added item is removed first. A good example of queue is any queue of consumers for a resource where the consumer that came first is served first.
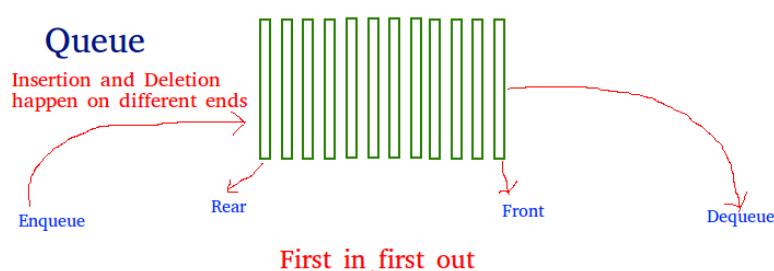
6.2 Stack using Queues

Implement a last-in-first-out (LIFO) stack using only two queues. The implemented stack should support all the functions of a normal stack (push, top, pop, and empty).

- void push(int x) Pushes element x to the top of the stack.
- int pop() Removes the element on the top of the stack and returns it.
- int top() Returns the element on the top of the stack.
- boolean empty() Returns true if the stack is empty, false otherwise.

Input:

["MyStack", "push", "push", "top", "pop", "empty"]

[[], [1], [2], [], [], []]

Output:

[null, null, null, 2, 2, false]

6.3 Queue using Stacks

Implement a first in first out (FIFO) queue using only two stacks. The implemented queue should support all the functions of a normal queue (push, peek, pop, and empty).

- void push(int x) Pushes element x to the back of the queue.
- int pop() Removes the element from the front of the queue and returns it.
- int peek() Returns the element at the front of the queue.
- boolean empty() Returns true if the queue is empty, false otherwise.

Input:

["MyQueue", "push", "push", "peek", "pop", "empty"]

[[], [1], [2], [], [], []]

Output:

[null, null, null, 1, 1, false]

6.4 Circular Queue

A Circular Queue is an extended version of a normal queue where the last element of the queue is connected to the first element of the queue forming a circle. The operations are performed based on FIFO (First In First Out) principle. It is also called 'Ring Buffer'.

Operations on Circular Queue:

- **Front:** Get the front item from the queue.
- **Rear:** Get the last item from the queue.
- **enQueue(value)** This function is used to insert an element into the circular queue. In a circular queue, the new element is always inserted at the rear position.
    - Check whether the queue is full – [i.e., the rear end is in just before the front end in a circular manner].
    - If it is full then display Queue is full.
        - If the queue is not full then, insert an element at the end of the queue.
- **deQueue()** This function is used to delete an element from the circular queue. In a circular queue, the element is always deleted from the front position.
    - Check whether the queue is Empty.
    - If it is empty then display Queue is empty.
        - If the queue is not empty, then get the last element and remove it from the queue.

enQueue(14)   enQueue(22)   enQueue(13)   enQueue(-6)

deQueue()   deQueue()   enQueue(9)   enQueue(20)   enQueue(5)
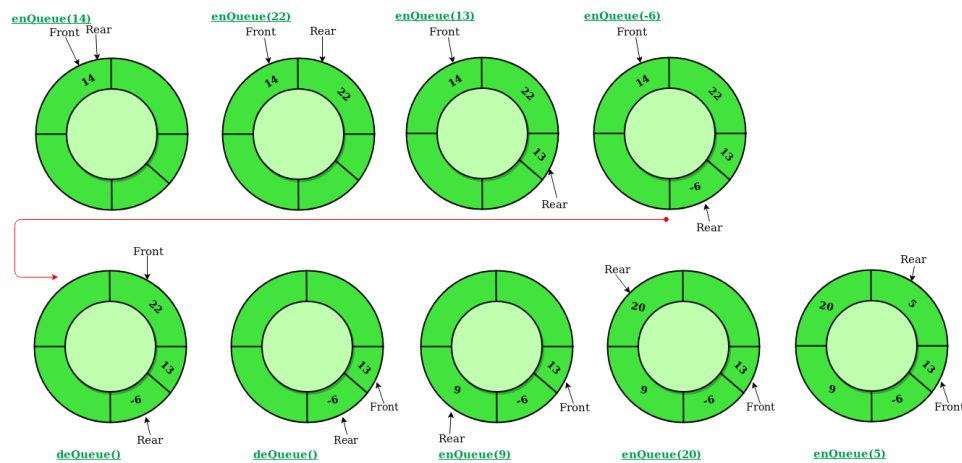
Implement Circular Queue using Array:

1.   Initialize an array queue of size **n**, where n is the maximum number of elements that the queue can hold.
2.   Initialize two variables front and rear to -1.
3.   **Enqueue:** To enqueue an element **x** into the queue, do the following:
   - Increment rear by 1.
     - If **rear** is equal to n, set **rear** to 0.
   - If **front** is -1, set **front** to 0.
   - Set queue[rear] to x.
4.   **Dequeue:** To dequeue an element from the queue, do the following:
   - Check if the queue is empty by checking if **front** is -1.
     - If it is, return an error message indicating that the queue is empty.
   - Set **x** to queue [front].
   - If **front** is equal to **rear**, set **front** and **rear** to -1.
   - Otherwise, increment **front** by 1 and if **front** is equal to n, set **front** to 0.
   - Return x.

6.5 Deque (Doubly Ended Queue)

A Deque (Double-Ended Queue) is a linear data structure that allows insertion and deletion of elements from both ends — front and rear. It generalizes both stacks and queues because:

It can act as a queue (FIFO – insert at rear, delete from front). It can act as a stack (LIFO – insert and delete from the same end).

Write a program to implement a Deque using Java's built-in ArrayDeque class.

Your program should:

Accept a series of operations from the user.

Perform insertion and deletion from both ends.

Display the deque contents after each operation.

The supported operations are:
- addFront x → Insert element x at the front.
- addRear x → Insert element x at the rear.
- removeFront → Remove element from the front.
- removeRear → Remove element from the rear.

- display → Show all elements in the deque.
- exit → Terminate the program.

Input:
7
addRear 10
addRear 20
addFront 5
display
removeFront
addFront 2
display

Output:
Added 10 at rear.
Added 20 at rear.
Added 5 at front.
Deque elements: [5, 10, 20]
Removed 5 from front.
Added 2 at front.
Deque elements: [2, 10, 20]

7. Linked List

7.1 Singly Linked List

A singly linked list is a linear data structure in which the elements are not stored in contiguous memory locations and each element is connected only to its next element using a pointer.
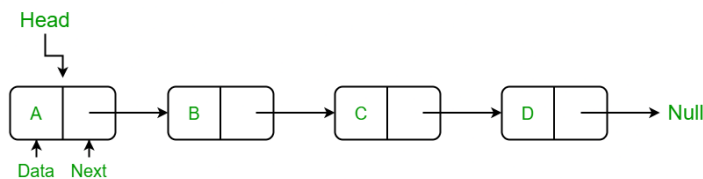
Creating a linked list involves the following operations:
1. Creating a Node class:
2. Insertion at beginning:
3. Insertion at end
4. Insertion at middle
5. Update the node
6. Deletion at beginning
7. Deletion at end
8. Deletion at middle
9. Remove last node
10. Linked list traversal
11. Get length

7.2 Linked List Cycle

Given head, the head of a linked list, determine if the linked list has a cycle in it. There is a cycle in a linked list if there is some node in the list that can be reached again by continuously following the next pointer. Internally, pos is used to denote the index of the node that tail's next pointer is connected to. Note that pos is not passed as a parameter.

Return true if there is a cycle in the linked list. Otherwise, return false.
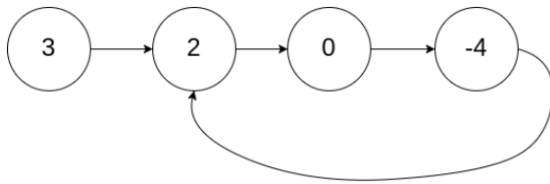
Input: head = [3, 2, 0, -4], pos = 1
Output: true
Explanation: There is a cycle in the linked list, where the tail connects to the 1st node (0-indexed).
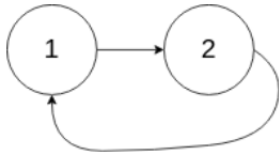
Input: head = [1, 2], pos = 0
Output: true
Explanation: There is a cycle in the linked list, where the tail connects to the 0th node.
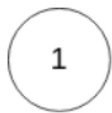
Input: head = [1], pos = -1
Output: false
Explanation: There is no cycle in the linked list.

7.3 Remove Linked List Elements

Given the head of a linked list and an integer val, remove all the nodes of the linked list that has Node.val == val, and return the new head.
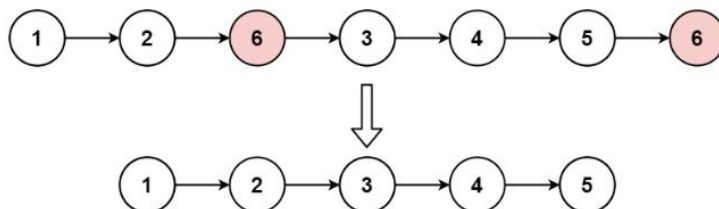
Input: head = [1, 2, 6, 3, 4, 5, 6], val = 6
Output: [1, 2, 3, 4, 5]
Input: head = [ ], val = 1
Output: [ ]
Input: head = [7, 7, 7, 7], val = 7
Output: [ ]

7.4 Reverse Linked List

Given the head of a singly linked list, reverse the list, and return the reversed list.
Input: head = [1, 2, 3, 4, 5]
Output: [5, 4, 3, 2, 1]
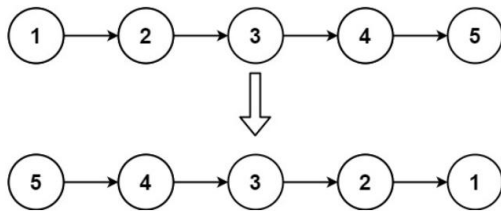
Input: head = [1, 2]
Output: [2, 1]
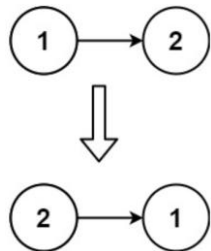
7.5 Palindrome Linked List

Given the head of a singly linked list, return true if it is a palindrome or false otherwise.
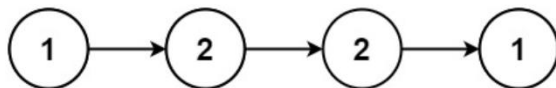
Input: head = [1, 2, 2, 1]
Output: true
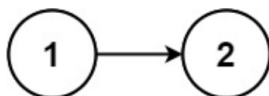
Input: head = [1, 2]
Output: false

7.6 Middle of the Linked List

Given the head of a singly linked list, return the middle node of the linked list. If there are two middle nodes, return the second middle node.

Input: head = [1, 2, 3, 4, 5]
Output: [3, 4, 5]
Explanation: The middle node of the list is node 3.

Input: head = [1, 2, 3, 4, 5, 6]
Output: [4, 5, 6]
Explanation: Since the list has two middle nodes with values 3 and 4, we return the second one.

7.7 Convert Binary Number in a Linked List to Integer

Given head which is a reference node to a singly-linked list. The value of each node in the linked list is either 0 or 1. The linked list holds the binary representation of a number.

Return the decimal value of the number in the linked list. The most significant bit is at the head of the linked list.
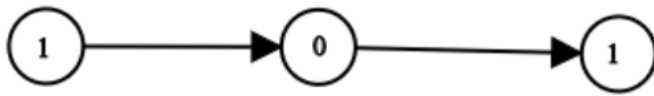
Input: head = [1, 0, 1]

Output: 5

Explanation: (101) in base 2 = (5) in base 10

Input: head = [0]

Output: 0

8. Circular Single Linked List and Doubly Linked List

8.1 Circular Linked List

The circular linked list is a linked list where all nodes are connected to form a circle. In a circular linked list, the first node and the last node are connected to each other which forms a circle. There is no NULL at the end.
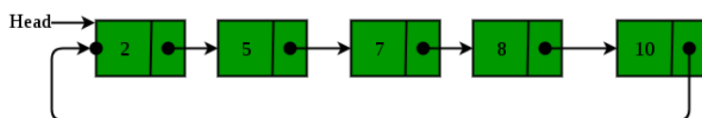
Operations on the circular linked list:
1. Insertion at the beginning
2. Insertion at the end
3. Insertion in between the nodes
4. Deletion at the beginning
5. Deletion at the end
6. Deletion in between the nodes
7. Traversal

8.2 Doubly Linked List

The A doubly linked list is a type of linked list in which each node consists of 3 components:

1. *prev - address of the previous node
2. data - data item
3. *next - address of next node.

Double Linked List Node
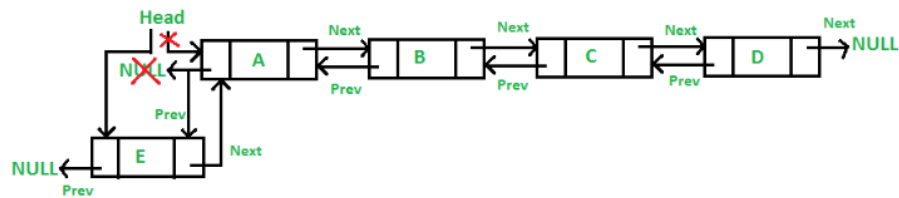
Operations on the Double Linked List:
1. Insertion at the beginning
2. Insertion at the end
3. Insertion in between the nodes
4. Deletion at the beginning
5. Deletion at the end
6. Deletion in between the nodes
7. Traversal

8.3 Sorted Merge of Two Sorted Doubly Circular Linked Lists

Given two sorted Doubly circular Linked List containing n1 and n2 nodes respectively. The problem is to merge the two lists such that resultant list is also in sorted order.

Input: List 1 and List 2
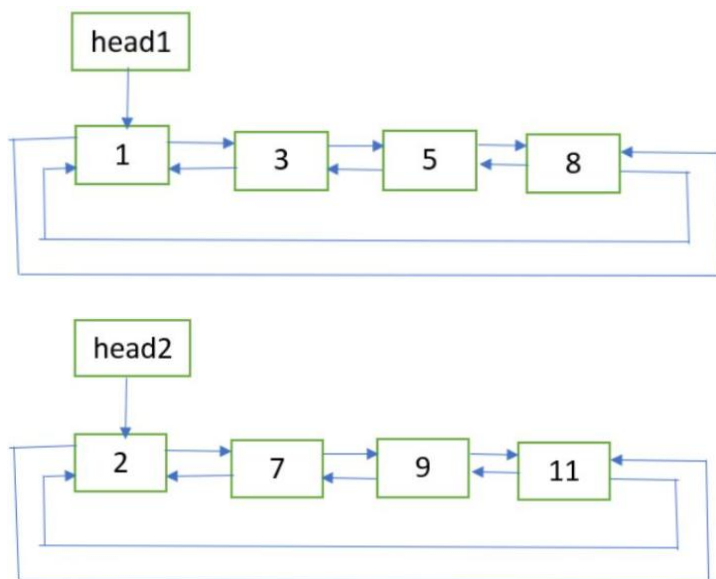
Output: Merged List
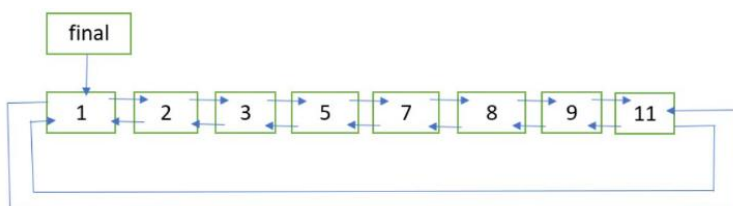
Procedure for Merging Doubly Linked List:
1. If head1 == NULL, return head2.

2.   If head2 == NULL, return head1.
3.   Let **last1** and **last2** be the last nodes of the two lists respectively. They can be obtained with the help of the previous links of the first nodes.
4.   Get pointer to the node which will be the last node of the final list. If last1.data < last2.data, then **last_node** = last2, Else **last_node** = last1.
5.   Update last1.next = last2.next = NULL.
6.   Now merge the two lists as two sorted doubly linked list are being merged.
      Refer **merge** procedure of this post. Let the first node of the final list be **finalHead**.
7.   Update finalHead.prev = last_node and last_node.next = finalHead.
8.   Return **finalHead**.

8.4 Delete all occurrences of a given key in a Doubly Linked List

Given a doubly linked list and a key x. The problem is to delete all occurrences of the given key x from the doubly linked list.

Input: 2 <-> 2 <-> 10 <-> 8 <-> 4 <-> 2 <-> 5 <-> 2
        x = 2
Output: 10 <-> 8 <-> 4 <-> 5

Algorithm:
delAllOccurOfGivenKey (head_ref, x)
    if head_ref == NULL
        return
    Initialize **current** = head_ref
    Declare **next**
    while current != NULL
        if current->data == x
            next = current->next
            deleteNode(head_ref, current)
            current = next
        else
            current = current->next

8.5 Delete a Doubly Linked List Node at a Given Position

Given a doubly linked list and a position n. The task is to delete the node at the given position n from the beginning.

Input: Initial doubly linked list

Output: Doubly Linked List after deletion of node at position n = 2

Procedure:

1. Get the pointer to the node at position n by traversing the doubly linked list up to the nth node from the beginning.
2. Delete the node using the pointer obtained in Step 1.

9. Trees

9.1 Tree Creation and Basic Tree Terminologies

A tree data structure is a hierarchical structure that is used to represent and organize data in a way that is easy to navigate and search. It is a collection of nodes that are connected by edges and has a hierarchical relationship between the nodes.
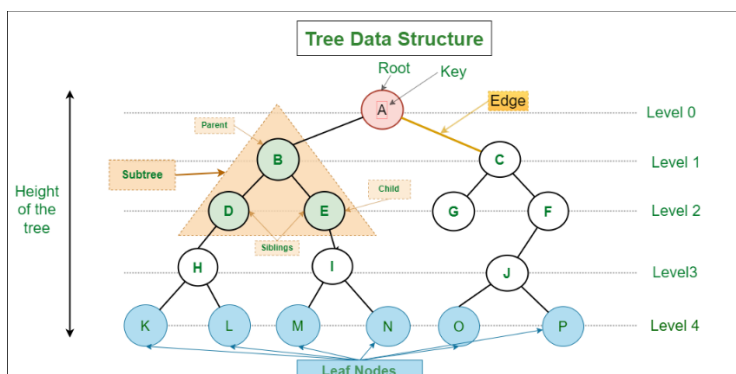
Basic Terminologies in Tree:

1. **Parent Node:** The node which is a predecessor of a node is called the parent node of that node. {B} is the parent node of {D, E}.

2. **Child Node:** The node which is the immediate successor of a node is called the child node of that node. Examples: {D, E} are the child nodes of {B}.

3. **Root Node:** The topmost node of a tree or the node which does not have any parent node is called the root node. {A} is the root node of the tree. A non-empty tree must contain exactly one root node and exactly one path from the root to all other nodes of the tree.

4. **Leaf Node or External Node:** The nodes which do not have any child nodes are called leaf nodes. {K, L, M, N, O, P} are the leaf nodes of the tree.

5. **Ancestor of a Node:** Any predecessor nodes on the path of the root to that node are called Ancestors of that node. {A, B} are the ancestor nodes of the node {E}

6. **Descendant:** Any successor node on the path from the leaf node to that node. {E, I} are the descendants of the node {B}.

7. **Sibling:** Children of the same parent node are called siblings. {D, E} are called siblings.

8. **Level of a node:** The count of edges on the path from the root node to that node. The root node has level 0.

9. **Internal node:** A node with at least one child is called Internal Node.

10. **Neighbour of a Node:** Parent or child nodes of that node are called neighbors of that node.

11. **Subtree:** Any node of the tree along with its descendant.

9.2 Binary Tree Traversal Techniques

A binary tree data structure can be traversed in following ways:
1. Inorder Traversal
2. Preorder Traversal
3. Postorder Traversal
4. Level Order Traversal
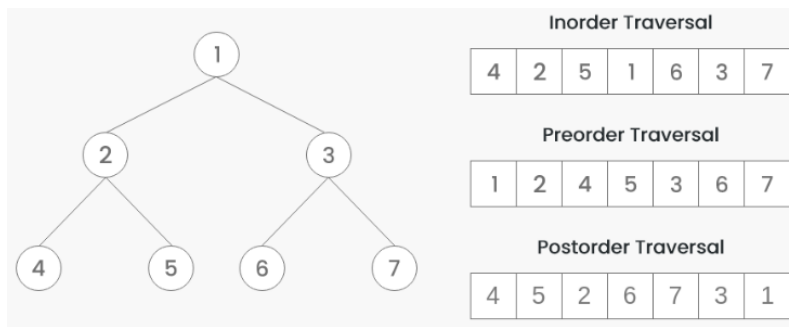
Algorithm Inorder (tree)

1. Traverse the left subtree, i.e., call Inorder(left->subtree)
2. Visit the root.
3. Traverse the right subtree, i.e., call Inorder(right->subtree)

Algorithm Preorder (tree)

1. Visit the root.
2. Traverse the left subtree, i.e., call Preorder(left->subtree)
3. Traverse the right subtree, i.e., call Preorder(right->subtree)

Algorithm Postorder (tree)

1. Traverse the left subtree, i.e., call Postorder(left->subtree)
2. Traverse the right subtree, i.e., call Postorder(right->subtree)
3. Visit the root.

9.3 Insertion in a Binary Tree in Level Order

Given a binary tree and a key, insert the key into the binary tree at the first position available in level order.

Input: Consider the tree given below
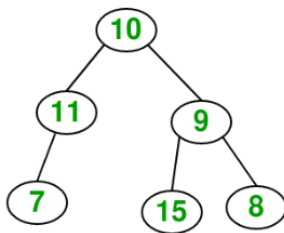
Output:
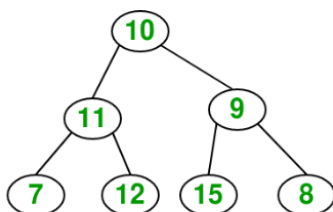
After inserting 12

The idea is to do an iterative level order traversal of the given tree using queue. If we find a node whose left child is empty, we make a new key as the left child of the node. Else if we find a node whose

right child is empty, we make the new key as the right child. We keep traversing the tree until we find a node whose either left or right child is empty.

9.4 Finding the Maximum Height or Depth of a Binary Tree

Given a binary tree, the task is to find the height of the tree. The height of the tree is the number of edges in the tree from the root to the deepest node.

Note: The height of an empty tree is 0.

Input: Consider the tree below
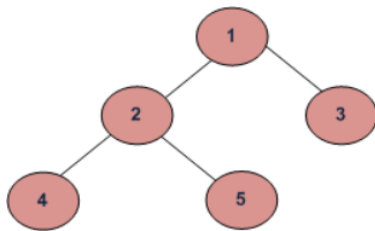
Recursively calculate the height of the left and the right subtrees of a node and assign height to the node as max of the heights of two children plus 1.
maxDepth('1') = max(maxDepth('2'), maxDepth('3')) + 1 = 2 + 1
because recursively
maxDepth('2') = max (maxDepth('4'), maxDepth('5')) + 1 = 1 + 1 and (as height of both '4' and '5' are 1)
maxDepth('3') = 1
Procedure:
- Recursively do a Depth-first search.
- If the tree is empty then return 0
- Otherwise, do the following
  - Get the max depth of the left subtree recursively i.e. call maxDepth(tree->left-subtree)
  - Get the max depth of the right subtree recursively i.e. call maxDepth(tree->right-subtree)
  - Get the max of max depths of left and right subtrees and add 1 to it for the current node.
  $$max_depth = max(maxdeptofleftsubtree, maxdepthofrightsubtree) + 1$$
- Return max_depth.

9.5 Deletion in a Binary Tree

Given a binary tree, delete a node from it by making sure that the tree shrinks from the bottom (i.e. the deleted node is replaced by the bottom-most and rightmost node).

Input: Delete 10 in below tree

```
    10
   /  \
  20   30
```
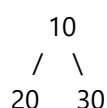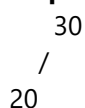
Output:
```
    30
   /
  20
```

Input: Delete 20 in below tree
```
      10
    /    \
  20     30
            \
            40
```
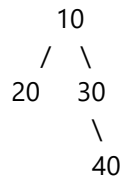
Output:
```
      10
    /    \
  40      30
```
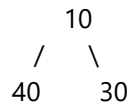
Algorithm:
1. Starting at the root, find the deepest and rightmost node in the binary tree and the node which we want to delete.
2. Replace the deepest rightmost node's data with the node to be deleted.
3. Then delete the deepest rightmost node.

Node to be deleted is 12

Replacing 12 with deepest node

Deleting the deepest node
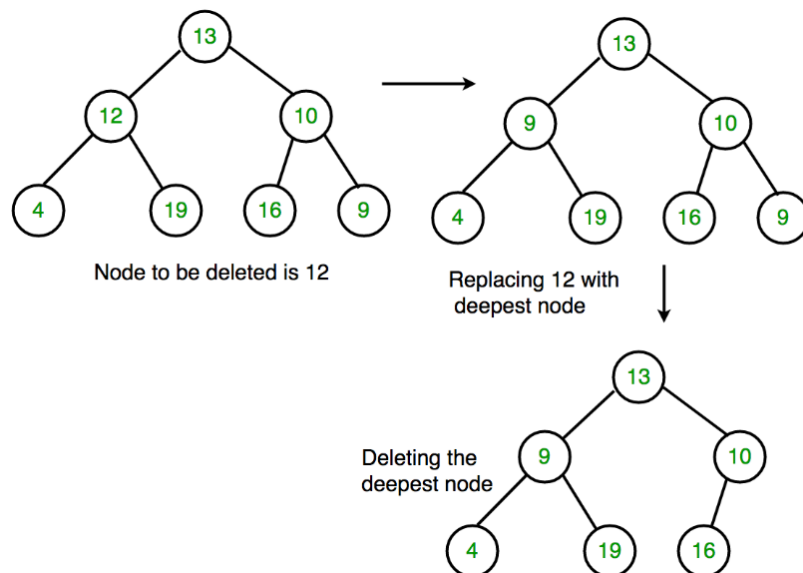
10. Binary Search Tree (BST)

10.1 Searching in Binary Search Tree

Given a BST, the task is to delete a node in this BST. For searching a value in BST, consider it as a sorted array. Perform search operation in BST using Binary Search Algorithm.

Algorithm to search for a key in a given Binary Search Tree:

Let's say we want to search for the number **X,** We start at the root. Then:
- We compare the value to be searched with the value of the root.
  - If it's equal we are done with the search if it's smaller we know that we need to go to the left subtree because in a binary search tree all the elements in the left subtree are smaller and all the elements in the right subtree are larger.
- Repeat the above step till no more traversal is possible
- If at any iteration, key is found, return True. Else False.

Consider The Following BST
Key = 6

Compare Key With Root, i.e 8
as 6<8, search in left subtree
of 8

As Key (6) Is Greater Than 3,
Search In The Right Subtree Of 3

As 6 Is Equal To Key (6), So We Have
Found The Key
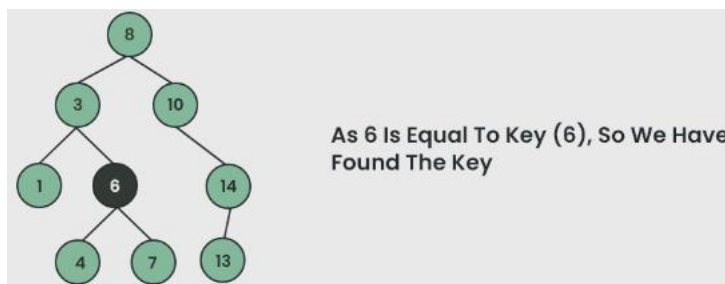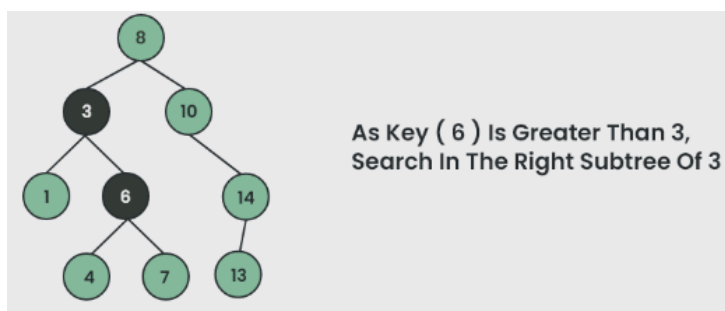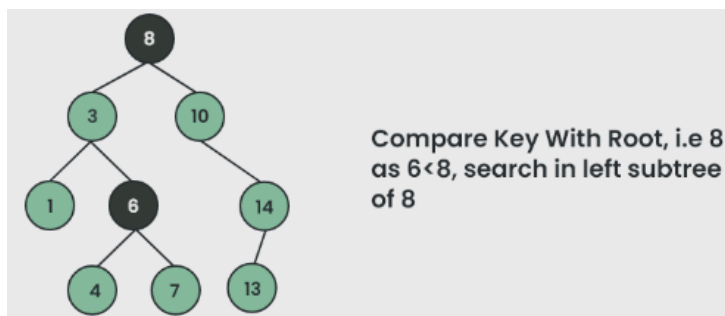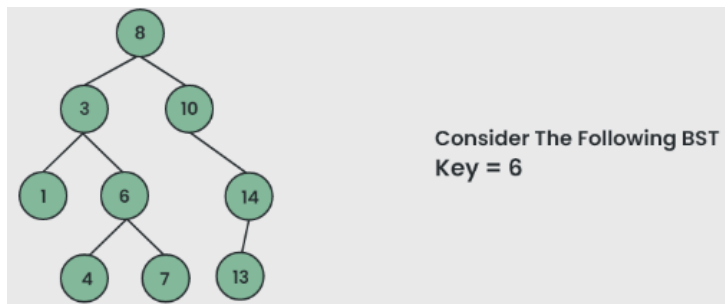
10.2 Find the node with Minimum Value in a BST

Write a function to find the node with minimum value in a Binary Search Tree.

Input: Consider the tree given below
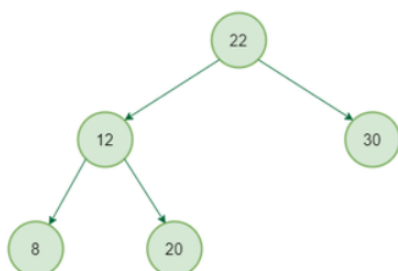
Output: 8

Input: Consider the tree given below
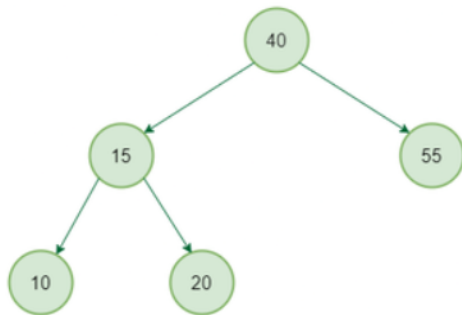
Output: 10

10.3 Check if a Binary Tree is BST or not

A binary search tree (BST) is a node-based binary tree data structure that has the following properties.

1. The left subtree of a node contains only nodes with keys less than the node's key.
2. The right subtree of a node contains only nodes with keys greater than the node's key.
3. Both the left and right subtrees must also be binary search trees.
4. Each node (item in the tree) has a distinct key.

Input: Consider the tree given below
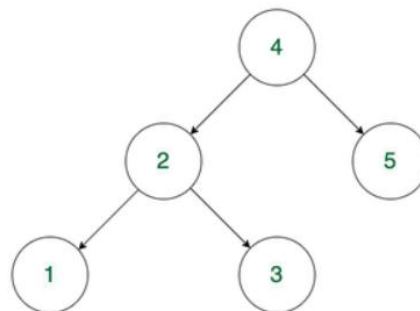
Output: Check if max value in left subtree is smaller than the node and min value in right subtree greater than the node, then print it "Is BST" otherwise "Not a BST"

Procedure:
1. If the current node is null then return true
2. If the value of the left child of the node is greater than or equal to the current node then return false
3. If the value of the right child of the node is less than or equal to the current node then return false
4. If the left subtree or the right subtree is not a BST then return false
5. Else return true

10.4 Second Largest Element in BST

Given a Binary search tree (BST), find the second largest element.

Input: Root of below BST

```
        10
       /
      5
```
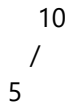
Output: 5

Input: Root of below BST
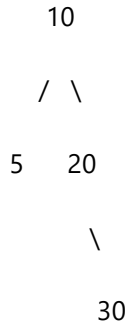
```
        10

       / \

      5   20

            \

             30
```
Output: 20

Procedure: The second largest element is second last element in inorder traversal and second element in reverse inorder traversal. We traverse given Binary Search Tree in reverse inorder and keep track of counts of nodes visited. Once the count becomes 2, we print the node.

Try:
1. **Kth largest element in BST when modification to BST is not allowed:** Given a Binary Search Tree (BST) and a positive integer k, find the k'th largest element in the Binary Search Tree. For a given BST, if k = 3, then output should be 14, and if k = 5, then output should be 10.
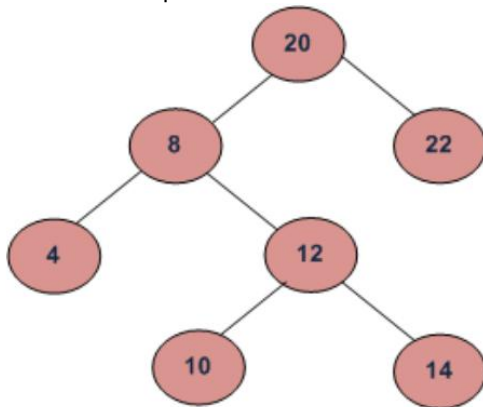
10.5 Insertion in Binary Search Tree (BST)

Given a Binary search tree (BST), the task is to insert a new node in this BST.

Input: Consider a BST and insert the element 40 into it.
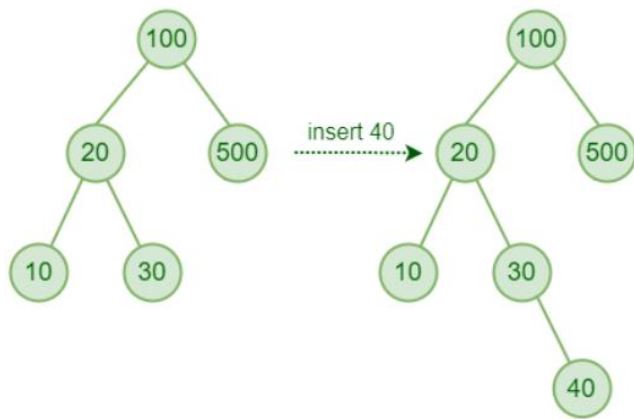
Procedure for inserting a value in a BST:

A new key is always inserted at the leaf by maintaining the property of the binary search tree. We start searching for a key from the root until we hit a leaf node. Once a leaf node is found, the new node is added as a child of the leaf node. The below steps are followed while we try to insert a node into a binary search tree:

- Check the value to be inserted (say X) with the value of the current node (say val) we are in:
  - If X is less than val move to the left subtree.
  - Otherwise, move to the right subtree.
- Once the leaf node is reached, insert X to its right or left based on the relation between X and the leaf node's value.

Try:

1. **Check if two BSTs contain same set of elements:** Given two Binary Search Trees consisting of unique positive elements, we have to check whether the two BSTs contain the same set of elements or not.

Input: Consider two BSTs which contains same set of elements {5, 10, 12, 15, 20, 25}, but the structure of the two given BSTs can be different.
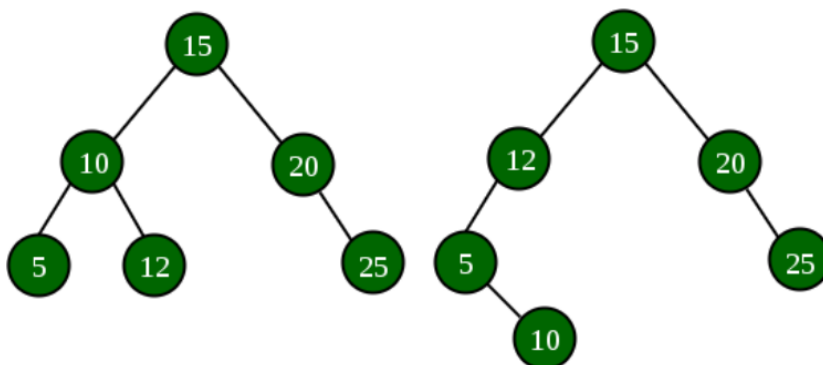
11. AVL Tree

11.1 Insertion in an AVL Tree

AVL tree is a self-balancing Binary Search Tree (BST) where the difference between heights of left and right subtrees cannot be more than one for all nodes. To make sure that the given tree remains AVL after every insertion, we must augment the standard BST insert operation to perform some re-balancing.

Following are two basic operations that can be performed to balance a BST without violating the BST property (keys(left) < key(root) < keys(right)).

- Left Rotation
- Right Rotation

T1, T2 and T3 are subtrees of the tree, rooted with y (on the left side) or x (on the right side)
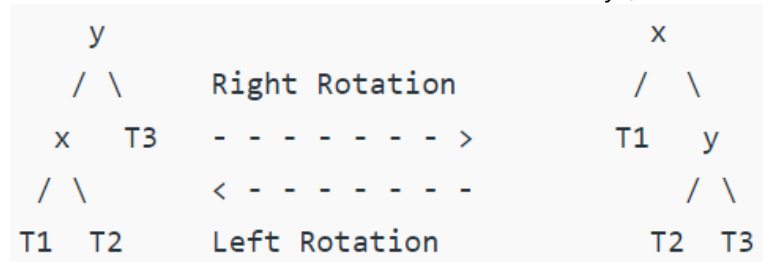
```
    y                                    x
   / \      Right Rotation              / \
  x   T3    - - - - - - - >           T1   y
 / \        < - - - - - - -               / \
T1  T2      Left Rotation               T2   T3
```

Keys in both of the above trees follow the following order
keys(T1) < key(x) < keys(T2) < key(y) < keys(T3)
So BST property is not violated anywhere.

Procedure for inserting a node into an AVL tree

Let the newly inserted node be w

- Perform standard BST insert for w.
- Starting from w, travel up and find the first unbalanced node. Let z be the first unbalanced node, y be the child of z that comes on the path from w to z and x be the grandchild of z that comes on the path from w to z.
- Re-balance the tree by performing appropriate rotations on the subtree rooted with z. There can be 4 possible cases that need to be handled as x, y and z can be arranged in 4 ways.
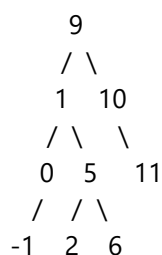- Following are the possible 4 arrangements:
- y is the left child of z and x is the left child of y (Left Left Case)
- y is the left child of z and x is the right child of y (Left Right Case)
- y is the right child of z and x is the right child of y (Right Right Case)
- y is the right child of z and x is the left child of y (Right Left Case)

11.2 Deletion in an AVL Tree

Given an AVL tree, make sure that the given tree remains AVL after every deletion, we must augment the standard BST delete operation to perform some re-balancing. Following are two basic operations that can be performed to re-balance a BST without violating the BST property (keys(left) < key(root) < keys(right)).

1. Left Rotation
2. Right Rotation

T1, T2 and T3 are subtrees of the tree rooted with y (on left side)
or x (on right side)
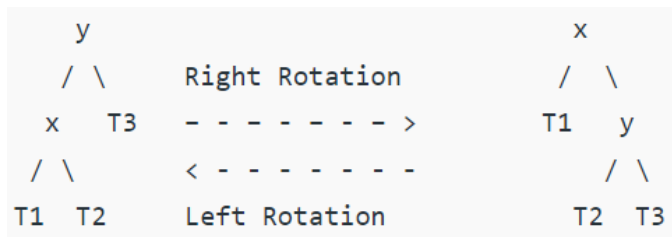
```
    y                                        x
   / \        Right Rotation               /  \
  x   T3    - - - - - - - >               T1   y
 / \          < - - - - - - -                 / \
T1  T2       Left Rotation                   T2  T3
```

Keys in both of the above trees follow the following order
    keys(T1) < key(x) < keys(T2) < key(y) < keys(T3)
So BST property is not violated anywhere.

Procedure to delete a node from AVL tree:

Let w be the node to be deleted
1. Perform standard BST delete for w.
2. Starting from w, travel up and find the first unbalanced node. Let z be the first unbalanced node, y be the larger height child of z, and x be the larger height child of y. Note that the definitions of x and y are different from insertion here.
3. Re-balance the tree by performing appropriate rotations on the subtree rooted with z. There can be 4 possible cases that needs to be handled as x, y and z can be arranged in 4 ways. Following are the possible 4 arrangements:
    i. y is left child of z and x is left child of y (Left Left Case)
    ii. y is left child of z and x is right child of y (Left Right Case)
    iii. y is right child of z and x is right child of y (Right Right Case)
    iv. y is right child of z and x is left child of y (Right Left Case)

11.3 Count Greater Nodes in AVL Tree

Given an AVL tree, calculate number of elements which are greater than given value in AVL tree.

Input: x = 5
    Root of below AVL tree
```
      9
     / \
    1   10
   / \   \
  0   5   11
 /   / \
-1  2   6
```
Output: 4
Explanation: There are 4 values which are greater than 5 in AVL tree which are 6, 9, 10 and 11.

11.4 Minimum Number of Nodes in an AVL Tree with given Height

Given the height of an AVL tree 'h', the task is to find the minimum number of nodes the tree can have.

Input: H = 0
Output: N = 1
Only '1' node is possible if the height
of the tree is '0' which is the root node.

Input: H = 3
Output: N = 7

Recursive approach:
In an AVL tree, we have to maintain the height balance property, i.e. difference in the height of the left and the right subtrees cannot be other than -1, 0 or 1 for each node.
We will try to create a recurrence relation to find minimum number of nodes for a given height, n(h).

- For height = 0, we can only have a single node in an AVL tree, i.e. n(0) = 1
- For height = 1, we can have a minimum of two nodes in an AVL tree, i.e. n(1) = 2
- Now for any height 'h', root will have two subtrees (left and right). Out of which one has to be of height h-1 and other of h-2. [root node excluded]
- So, n(h) = 1 + n(h-1) + n(h-2) is the required recurrence relation for h>=2 [1 is added for the root node]

12. Graph Traversal

12.1 Breadth First Search

Given a connected undirected graph containing V vertices, represented by a 2-d adjacency list adj[][], where each adj[i] represents the list of vertices connected to vertex i. Perform a Breadth First Search (BFS) traversal starting from vertex 0, visiting vertices from left to right according to the given adjacency list, and return a list containing the BFS traversal of the graph.

Note: Do traverse in the same order as they are in the given adjacency list.

Input: adj[][] = [[2, 3, 1], [0], [0, 4], [0], [2]]
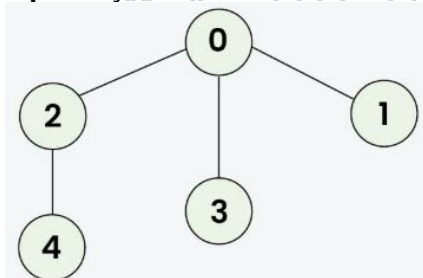
Output: [0, 2, 3, 1, 4]
Explanation: Starting from 0, the BFS traversal will follow these steps:
Visit 0 → Output: 0
Visit 2 (first neighbor of 0) → Output: 0, 2
Visit 3 (next neighbor of 0) → Output: 0, 2, 3
Visit 1 (next neighbor of 0) → Output: 0, 2, 3, 1
Visit 4 (neighbor of 2) → Final Output: 0, 2, 3, 1, 4

Input: adj[][] = [[1, 2], [0, 2], [0, 1, 3, 4], [2], [2]]
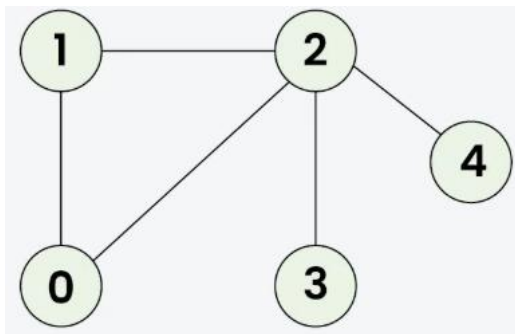
Output: [0, 1, 2, 3, 4]

Explanation: Starting from 0, the BFS traversal proceeds as follows:

Visit 0 → Output: 0

Visit 1 (the first neighbor of 0) → Output: 0, 1

Visit 2 (the next neighbor of 0) → Output: 0, 1, 2

Visit 3 (the first neighbor of 2 that hasn't been visited yet) → Output: 0, 1, 2, 3

Visit 4 (the next neighbor of 2) → Final Output: 0, 1, 2, 3, 4

12.2 Depth First Search

Depth First Traversal (or DFS) for a graph is similar to Depth First Traversal of a tree. The only catch here is, that, unlike trees, graphs may contain cycles (a node may be visited twice). To avoid processing a node more than once, use a boolean visited array. A graph can have more than one DFS traversal.

For a given graph G, print DFS traversal from a given source vertex.

Input: n = 4, e = 6

0 -> 1, 0 -> 2, 1 -> 2, 2 -> 0, 2 -> 3, 3 -> 3

Output: DFS from vertex 1: 1 2 0 3

Explanation:
DFS Diagram:
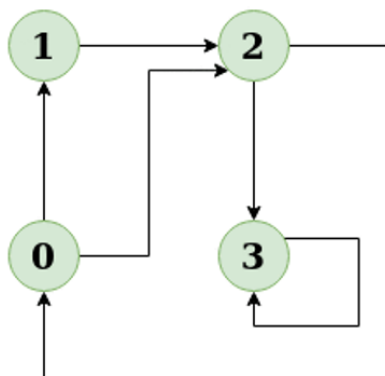
Input: n = 4, e = 6

2 -> 0, 0 -> 2, 1 -> 2, 0 -> 1, 3 -> 3, 1 -> 3

Output: DFS from vertex 2: 2 0 1 3

Explanation:
DFS Diagram:
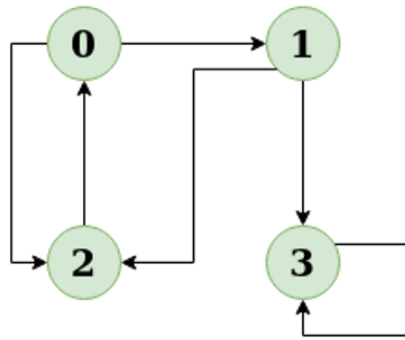
12.3 Best First Search (Informed Search)

The idea of Best First Search is to use an evaluation function to decide which adjacent is most promising and then explore. Best First Search falls under the category of Heuristic Search or Informed Search.

Implementation of Best First Search:

We use a priority queue or heap to store the costs of nodes that have the lowest evaluation function value. So the implementation is a variation of BFS, we just need to change Queue to PriorityQueue.

Algorithm:
Best-First-Search(Graph g, Node start)
    1) Create an empty PriorityQueue
       PriorityQueue pq;
    2) Insert "start" in pq.
       pq.insert(start)
    3) Until PriorityQueue is empty
         u = PriorityQueue.DeleteMin
         If u is the goal
           Exit
         Else
           Foreach neighbor v of u
             If v "Unvisited"
               Mark v "Visited"
               pq.insert(v)
           Mark u "Examined"
End procedure

Input: Consider the graph given below.
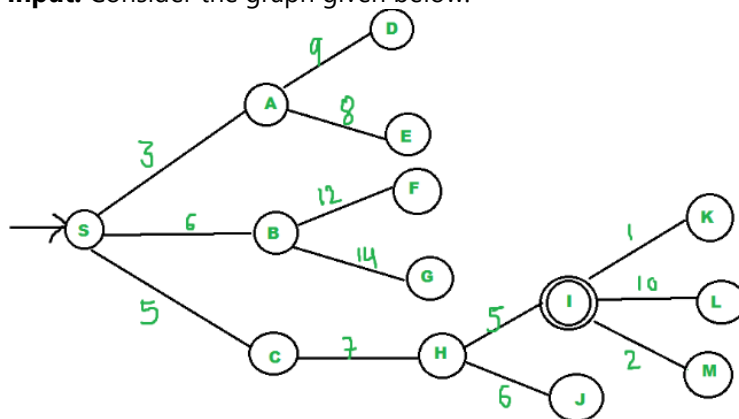
- We start from source "S" and search for goal "I" using given costs and Best First search.
- pq initially contains S
  - We remove S from pq and process unvisited neighbors of S to pq.
  - pq now contains {A, C, B} (C is put before B because C has lesser cost)
- We remove A from pq and process unvisited neighbors of A to pq.
  - pq now contains {C, B, E, D}
- We remove C from pq and process unvisited neighbors of C to pq.
  - pq now contains {B, H, E, D}
- We remove B from pq and process unvisited neighbors of B to pq.
  - pq now contains {H, E, D, F, G}
- We remove H from pq.
- Since our goal "I" is a neighbor of H, we return.

12.4 Breadth First Traversal of a Graph

Given a directed graph. The task is to do Breadth First Traversal of this graph starting from 0.
One can move from node u to node v only if there's an edge from u to v. Find the BFS traversal of the graph starting from the 0th vertex, from left to right according to the input graph. Also, you should only take nodes directly or indirectly connected from Node 0 in consideration.

Input: Consider the graph given below where V = 5, E = 4, edges = {(0,1), (0,2), (0,3), (2,4)}
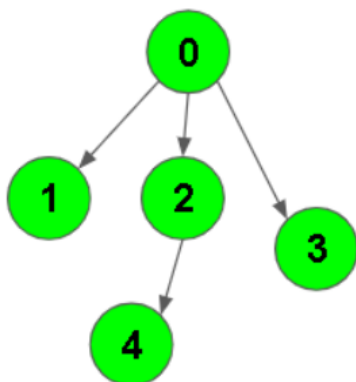
Output: 0 1 2 3 4
Explanation:
0 is connected to 1, 2, and 3.
2 is connected to 4.
So starting from 0, it will go to 1 then 2 then 3. After this 2 to 4, thus BFS will be 0 1 2 3 4.

Input: Consider the graph given below where V = 3, E = 2, edges = {(0, 1), (0, 2)}
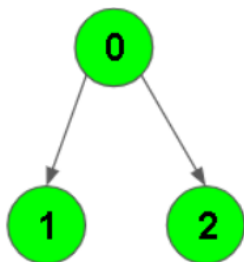
Output: 0 1 2

Explanation:
0 is connected to 1, 2. So starting from 0, it will go to 1 then 2, thus BFS will be 0 1 2.
Your task is to complete the function **bfsOfGraph()** which takes the integer V denoting the number of vertices and adjacency list as input parameters and returns a list containing the BFS traversal of the graph starting from the 0th vertex from left to right.

12.5 Depth First Search (DFS) for Disconnected Graph

Given a Disconnected Graph, the task is to implement DFS or Depth First Search Algorithm for this Disconnected Graph.

Input: Consider the graph given below.
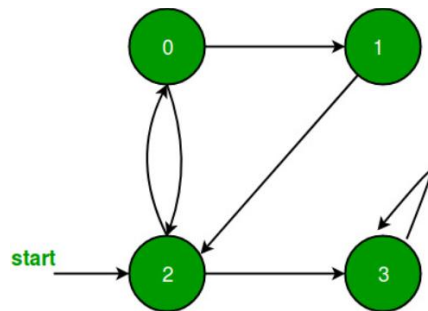
Output: 0 1 2 3

Procedure for DFS on Disconnected Graph:
Iterate over all the vertices of the graph and for any unvisited vertex, run a DFS from that vertex.

Try:
1. **Detect a negative cycle in a Graph (Bellman Ford):** A Bellman-Ford algorithm is also guaranteed to find the shortest path in a graph, similar to Dijkstra's algorithm. Although Bellman-Ford is slower than Dijkstra's algorithm, it is capable of handling graphs with negative edge weights, which makes it more versatile. The shortest path cannot be found if there exists a negative cycle in the graph. If we continue to go around the negative cycle an infinite number of times, then the cost of the path will continue to decrease (even though the length of the path is increasing).

Consider a graph G and detect a negative cycle in the graph using Bellman Ford algorithm.
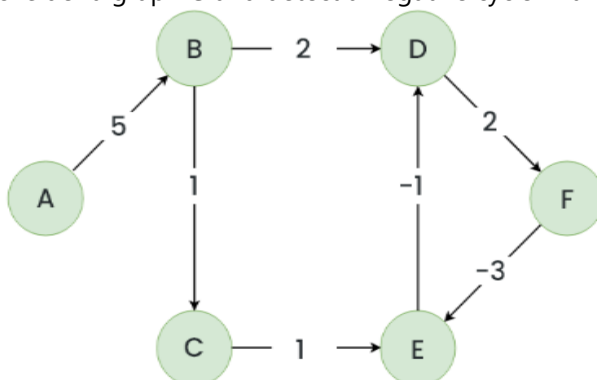
13. Minimum Spanning Tree (MST)

13.1 Kruskal's Algorithm

In Kruskal's algorithm, sort all edges of the given graph in increasing order. Then it keeps on adding new edges and nodes in the MST if the newly added edge does not form a cycle. It picks the minimum weighted edge at first and the maximum weighted edge at last.

MST using Kruskal's algorithm:
1.   Sort all the edges in non-decreasing order of their weight.
2.   Pick the smallest edge. Check if it forms a cycle with the spanning tree formed so far. If the cycle is not formed, include this edge. Else, discard it.
3.   Repeat step#2 until there are (V-1) edges in the spanning tree.

Kruskal's algorithm to find the minimum cost spanning tree uses the greedy approach. The Greedy Choice is to pick the smallest weight edge that does not cause a cycle in the MST constructed so far.

Input: For the given graph G find the minimum cost spanning tree.
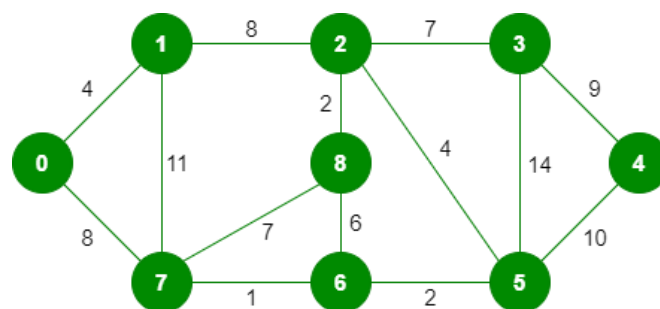
The graph contains 9 vertices and 14 edges. So, the minimum spanning tree formed will be having (9 – 1) = 8 edges.

After sorting:

Weight	Source	Destination
1	7	6
2	8	2
2	6	5
4	0	1
4	2	5
6	8	6
7	2	3
7	7	8
8	0	7
8	1	2
9	3	4
10	5	4
11	1	7
14	3	5

Now pick all edges one by one from the sorted list of edges.

Output:
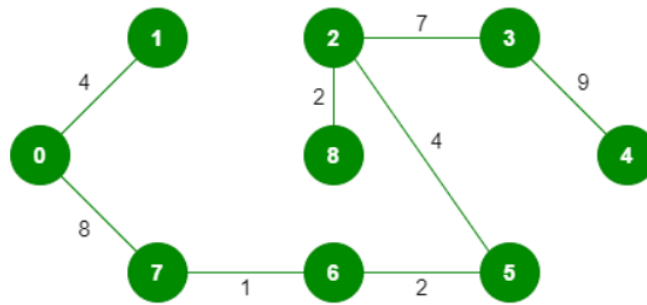
Output: Following are the edges in the constructed MST

2 -- 3 == 4

0 -- 3 == 5

0 -- 1 == 10

Minimum Cost Spanning Tree: 19

13.2 Prim's Algorithm

The Prim's algorithm starts with an empty spanning tree. The idea is to maintain two sets of vertices. The first set contains the vertices already included in the MST, and the other set contains the vertices not yet included. At every step, it considers all the edges that connect the two sets and picks the minimum weight edge from these edges. After picking the edge, it moves the other endpoint of the edge to the set containing MST.

Prim's Algorithm:

The working of Prim's algorithm can be described by using the following steps:

1. Determine an arbitrary vertex as the starting vertex of the MST.
2. Follow steps 3 to 5 till there are vertices that are not included in the MST (known as fringe vertex).
3. Find edges connecting any tree vertex with the fringe vertices.
4. Find the minimum among these edges.
5. Add the chosen edge to the MST if it does not form any cycle.
6. Return the MST and exit

Input: For the given graph G find the minimum cost spanning tree.
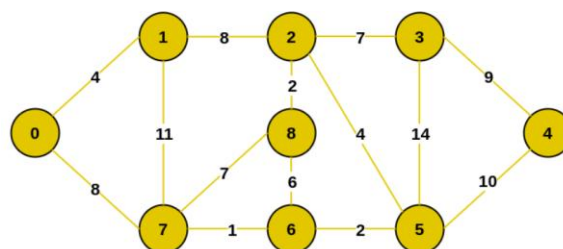
Output: The final structure of the MST is as follows and the weight of the edges of the MST is (4 + 8 + 1 + 2 + 4 + 2 + 7 + 9) = 37.
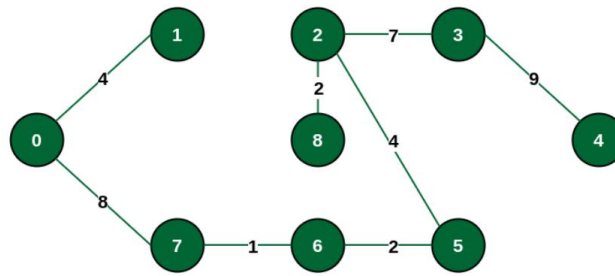
Output:

Edge   Weight
0 - 1   2
1 - 2   3
0 - 3   6
1 - 4   5

13.3 Total Number of Spanning Trees in a Graph

If a graph is a complete graph with n vertices, then total number of spanning trees is $n^{(n-2)}$ where n is the number of nodes in the graph. In complete graph, the task is equal to counting different labeled trees with n nodes for which have Cayley's formula.
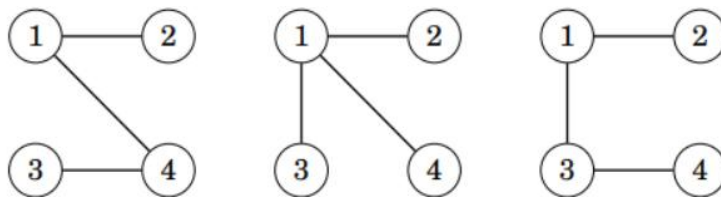
Laplacian matrix:

A Laplacian matrix L, where L[i, i] is the degree of node i and L[i, j] = −1 if there is an edge between nodes i and j, and otherwise L[i, j] = 0.

Kirchhoff's theorem provides a way to calculate the number of spanning trees for a given graph as a determinant of a special matrix. Consider the following graph,
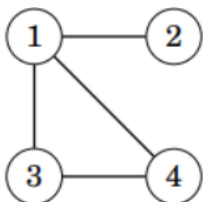
All possible spanning trees are as follows:

In order to calculate the number of spanning trees, construct a Laplacian matrix L, where L[i, i] is the degree of node i and L[i, j] = −1 if there is an edge between nodes i and j, and otherwise L[i, j] = 0.
for the above graph, The Laplacian matrix will look like this

$$L = \begin{bmatrix} 3 & -1 & -1 & -1 \\ -1 & 1 & 0 & 0 \\ -1 & 0 & 2 & -1 \\ -1 & 0 & -1 & 2 \end{bmatrix}$$

The number of spanning trees equals the determinant of a matrix.
The Determinant of a matrix that can be obtained when we remove any row and any column from L.
For example, if we remove the first row and column, the result will be,

$$\det\left(\begin{bmatrix} 1 & 0 & 0 \\ 0 & 2 & -1 \\ 0 & -1 & 2 \end{bmatrix}\right) = 3.$$

The determinant is always the same, regardless of which row and column we remove from L.

13.4 Minimum Product Spanning Tree

A minimum product spanning tree for a weighted, connected, and undirected graph is a spanning tree with a weight product less than or equal to the weight product of every other spanning tree. The weight product of a spanning tree is the product of weights corresponding to each edge of the spanning tree. All weights of the given graph will be positive for simplicity.

Input:
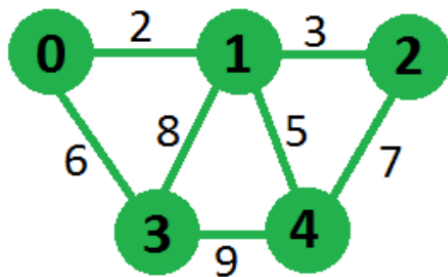
Output: Minimum Product that we can obtain is 180 for above graph by choosing edges 0-1, 1-2, 0-3 and 1-4

This problem can be solved using standard minimum spanning tree algorithms like Kruskal and prim's algorithm, but we need to modify our graph to use these algorithms. Minimum spanning tree algorithms tries to minimize the total sum of weights, here we need to minimize the total product of weights. We can use the property of logarithms to overcome this problem.
log(w1* w2 * w3 * .... * wN) = log(w1) + log(w2) + log(w3) ..... + log(wN)
We can replace each weight of the graph by its log value, then we apply any minimum spanning tree algorithm which will try to minimize the sum of log(wi) which in turn minimizes the weight product.

13.5 Reverse Delete Algorithm for Minimum Spanning Tree

In Reverse Delete algorithm, we sort all edges in decreasing order of their weights. After sorting, we one by one pick edges in decreasing order. We include current picked edge if excluding current edge causes disconnection in current graph. The main idea is delete edge if its deletion does not lead to disconnection of graph.

Algorithm:
1.   Sort all edges of graph in non-increasing order of edge weights.
2.   Initialize MST as original graph and remove extra edges using step 3.
3.   Pick highest weight edge from remaining edges and check if deleting the edge disconnects the graph   or not.
     If disconnects, then we don't delete the edge.
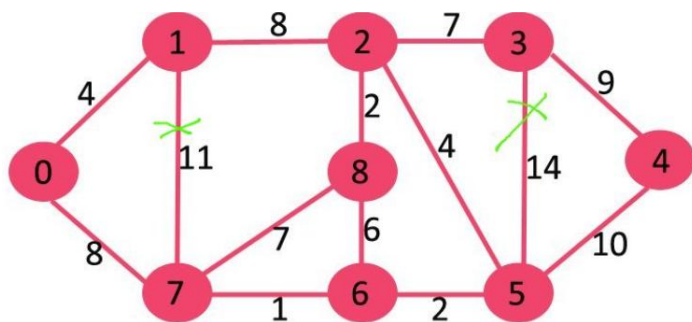   Else we delete the edge and continue.

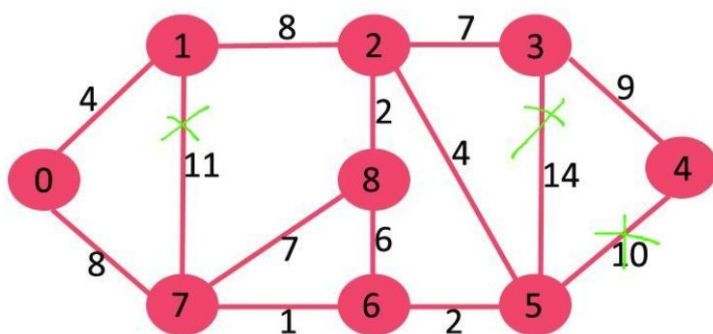**Input:** Consider the graph below
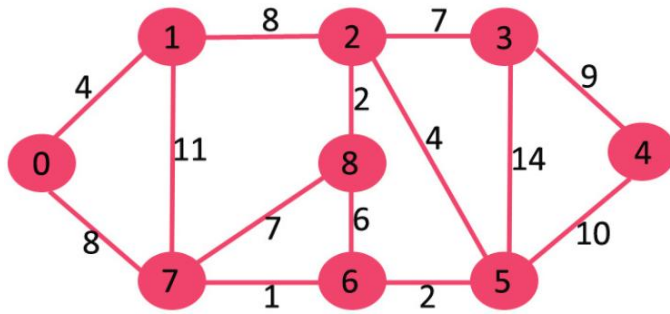
If we delete highest weight edge of weight 14, graph doesn't become disconnected, so we remove it.
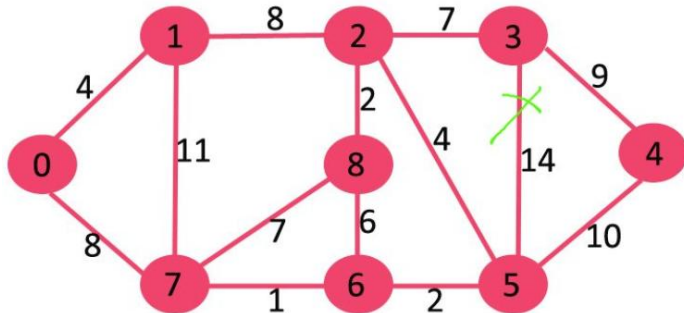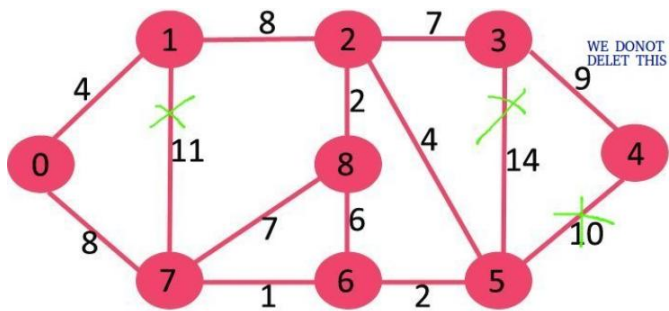

Next we delete 11 as deleting it doesn't disconnect the graph.

Next we delete 10 as deleting it doesn't disconnect the graph.

Next is 9. We cannot delete 9 as deleting it causes disconnection.

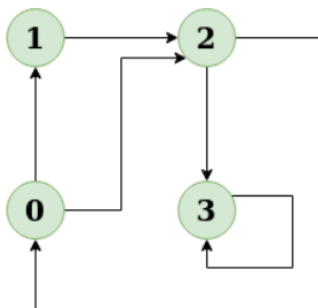We continue this way and following edges remain in final MST.

Edges in MST

(3, 4)

(0, 7)

(2, 3)

(2, 5)

(0, 1)

(5, 6)

(2, 8)

(6, 7)

Try:

1. **Detect Cycle in a Directed Graph:** Given the root of a Directed graph, The task is to check whether the graph contains a cycle or not.

Input: N = 4, E = 6

Output: Yes

Explanation: The diagram clearly shows a cycle 0 -> 2 -> 0

14. Final Notes

The only way to learn programming is program, program and program on challenging problems. The problems in this tutorial are certainly NOT challenging. There are tens of thousands of challenging problems available – used in training for various programming contests (such as International Collegiate Programming Contest (ICPC), International Olympiad in Informatics (IOI)). Check out these sites:

- The ACM - ICPC International collegiate programming contest (https://icpc.global/)
- The Topcoder Open (TCO) annual programming and design contest (https://www.topcoder.com/)
- Universidad de Valladolid's online judge (https://uva.onlinejudge.org/).
- Peking University's online judge (http://poj.org/).
- USA Computing Olympiad (USACO) Training Program @ http://train.usaco.org/usacogate.
- Google's coding competitions (https://codingcompetitions.withgoogle.com/codejam, https://codingcompetitions.withgoogle.com/hashcode)
- The ICFP programming contest (https://www.icfpconference.org/)
- BME International 24-hours programming contest (https://www.challenge24.org/)
- The International Obfuscated C Code Contest (https://www0.us.ioccc.org/main.html)
- Internet Problem Solving Contest (https://ipsc.ksp.sk/)
- Microsoft Imagine Cup (https://imaginecup.microsoft.com/en-us)
- Hewlett Packard Enterprise (HPE) Codewars (https://hpecodewars.org/)
- OpenChallenge (https://www.openchallenge.org/)

Coding Contests Scores

Students must solve problems and attain scores in the following coding contests:

Name of the contest	Minimum number of problems to solve	Required score
CodeChef	20	200
Leetcode	20	200
GeeksforGeeks	20	200
SPOJ	5	50
InterviewBit	10	1000
Hackerrank	25	250
Codeforces	10	100
BuildIT	50	500
Total score need to obtain		2500

Student must have any one of the following certification:

3. HackerRank - Problem Solving Skills Certification (Basic and Intermediate)
2. GeeksforGeeks – Data Structures and Algorithms Certification
3. CodeChef - Learn Data Structures and Algorithms Certification
4. Interviewbit – DSA pro / Python pro
5. Edx – Data Structures and Algorithms
5. NPTEL – Programming, Data Structures and Algorithms
6. NPTEL – Introduction to Data Structures and Algorithms
7. NPTEL – Data Structures and Algorithms
8. NPTEL – Programming and Data Structure

V. TEXT BOOKS:

1. Rance D. Necaise, "Data Structures and Algorithms using Python", Wiley Student Edition.
2. Benjamin Baka, David Julian, "Python Data Structures and Algorithms", Packt Publishers, 2017.

VI. REFERENCE BOOKS:
1. S. Lipschutz, "Data Structures", Tata McGraw Hill Education, 1st Edition, 2008.
2. D. Samanta, "Classic Data Structures", PHI Learning, 2nd Edition, 2004.

VII. ELECTRONICS RESOURCES:
1. https://www.tutorialspoint.com/data_structures_algorithms/algorithms_basics.htm
2. https://www.codechef.com/certification/data-structures-and-algorithms/prepare
3. https://www.cs.auckland.ac.nz/software/AlgAnim/dsToC.html
4. https://online-learning.harvard.edu/course/data-structures-and-algorithms

VIII. MATERIALS ONLINE
3. Syllabus
4. Lab manual

UNDERTAKING BY STUDENT / PARENT

"To make the students attend the classes regularly from the first day of starting of classes and be aware of the College regulations, the following undertaking form is introduced which should be signed by both student and parent. The same should be submitted to the Dean of Academic".

I, Mr. / Ms. --- joining I Semester / III Semester for the academic year 20   - 20   / 20   - 20   in Institute of Aeronautical Engineering, Hyderabad, do hereby undertake and abide by the following terms, and I will bring the ACKNOWLEDGEMENT duly signed by me and my parent and submit it to the Dean of Academic.

1. I will attend all the classes as per the timetable from the starting day of the semester specified in the institute Academic Calendar. In case, I do not turn up even after two weeks of starting of classes, I shall be ineligible to continue for the current academic year.
2. I will be regular and punctual to all the classes (theory/laboratory/project) and secure attendance of not less than 75% in every course as stipulated by Institute. I am fully aware that an attendance of less than 65% in more than 60% of theory courses in a semester will make me lose one year.
3. I will compulsorily follow the dress code prescribed by the college.
4. I will conduct myself in a highly disciplined and decent manner both inside the classroom and on campus, failing which suitable action may be taken against me as per the rules and regulations of the institute.
5. I will concentrate on my studies without wasting time in the Campus/Hostel/Residence and attend all the tests to secure more than the minimum prescribed Class/Sessional Marks in each course. I will submit the assignments given in time to improve my performance.
6. I will not use Mobile Phone in the institute premises and also, I will not involve in any form of ragging inside or outside the campus. I am fully aware that using mobile phone to the institute premises is not permissible and involving in Ragging is an offence and punishable as per JNTUH/UGC rules and the law.
7. I declare that I shall not indulge in ragging, eve-teasing, smoking, consuming alcohol drug abuse or any other anti-social activity in the college premises, hostel, on educational tours, industrial visits or elsewhere.
8. I will pay tuition fees, examination fees and any other dues within the stipulated time as required by the Institution / authorities, failing which I will not be permitted to attend the classes.
9. I will not cause or involve in any sort of violence or disturbance both within and outside the college campus.
10. If I absent myself continuously for 3 days, my parents will have to meet the HOD concerned / Principal.
11. I hereby acknowledge that I have received a copy of BT23 Academic Rules and Regulations, course catalogue and syllabus copy and hence, I shall abide by all the rules specified in it.

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ACKNOWLEDGEMENT

I have carefully gone through the terms of the undertaking mentioned above and I understand that following these are for my/his/her own benefit and improvement. I also understand that if I/he/she fail to comply with these terms, shall be liable for suitable action as per Institute/JNTUH/AICTE/UGC rules and the law. I undertake that I/he/she will strictly follow the above terms.

Signature of Student with Date   **Signature of Parent with Date**
                                                                     Name & Address with Phone Number