



**IARE**  
INSTITUTE OF  
AERONAUTICAL ENGINEERING

**Outcome Based Education (OBE) Manual**  
IARE - UG20



**Department of Computer Science and  
Engineering(Data Science)**

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## OVERVIEW

**Outcome Based Education (OBE)** is an educational model that forms the base of a quality education system. There is no single specified style of teaching or assessment in OBE. All educational activities carried out in OBE should help the students to achieve the set goals. The faculty may adapt the role of instructor, trainer, facilitator, and/or mentor, based on the outcomes targeted.

OBE enhances the traditional methods and focuses on what the Institute provides to students. It shows the success by making or demonstrating outcomes using statements "able to do" in favour of students. OBE provides clear standards for observable and measurable outcomes.

National Board of Accreditation (NBA) is an authorised body for the accreditation of higher education institutions in India. NBA is also a full member of the Washington Accord. NBA accredited programmes and not the institutions.

### **Higher Education Institutions are classified into two categories by NBA**

**Tier – 1:** Institutions consists of all IITs, NITs, Central Universities, State Universities and Autonomous Institutions. Tier - 1 institutions can also claim the benefits as per the Washington Accord.

**Tier - 2** Institutions consists of affiliated colleges of universities.

### **What is Outcome Based Education (OBE)?**

Institutions adopting OBE try to bring changes to the curriculum by dynamically adapting to the requirements of the different stakeholders like Students, Parents, Industry Personnel and Recruiters. OBE is all about feedback and outcomes.

### **Four levels of outcomes from OBE are:**

1. Program Educational Objectives (PEOs)
2. Program Outcomes (POs)
3. Program Specific Outcomes (PSOs)
4. Course Outcomes (COs)

### **Why OBE?**

1. International recognition and global employment opportunities.
2. More employable and innovative graduates with professional and soft skills, social responsibility and ethics.
3. Better visibility and reputation of the technical institution among stakeholders.
4. Improving the commitment and involvement of all the stakeholders.
5. Enabling graduates to excel in their profession and accomplish greater heights in their careers.
6. Preparing graduates for the leadership positions and challenging them and making them aware of the opportunities in the technology development.

## **Benefits of OBE**

**Clarity:** The focus on outcome creates a clear expectation of what needs to be accomplished by the end of the course.

**Flexibility:** With a clear sense of what needs to be accomplished, instructors will be able to structure their lessons around the students' needs.

**Comparison:** OBE can be compared across the individual, class, batch, program and institute levels.

**Involvement:** Students are expected to do their own learning. Increased student's involvement allows them to feel responsible for their own learning, and they should learn more through this individual learning.

- Teaching will become a far more creative and innovative career
- Faculty members will no longer feel the pressure of having to be the "source of all knowledge".
- Faculty members shape the thinking and vision of students towards a course.

## **India, OBE and Accreditation:**

From 13 June 2014, India has become the permanent signatory member of the Washington Accord. Implementation of OBE in higher technical education also started in India. The National Assessment and Accreditation Council (NAAC) and National Board of Accreditation (NBA) are the autonomous bodies for promoting global quality standards for technical education in India. NBA has started accrediting only the programs running with OBE from 2013.

The National Board of Accreditation mandates establishing a culture of outcome-based education in institutions that offer Engineering, Pharmacy, Management program. Reports of outcome analysis help to find gaps and carryout continuous improvements in the education system of an Institute, which is very essential.

# 1 Vision, Mission, Quality Policy, Philosophy & Core Values

## 1.1 Vision and Mission of the Institution

### Institute Vision

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

### Institute 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.

### Philosophy

The essence of learning lies in pursuing the truth that liberates one from the darkness of ignorance and Institute of Aeronautical Engineering firmly believes that education is for liberation.

Contained therein is the notion that engineering education includes all fields of science that plays a pivotal role in the development of world-wide community contributing to the progress of civilization. This institute, adhering to the above understanding, is committed to the development of science and technology in congruence with the natural environs. It lays great emphasis on intensive research and education that blends professional skills and high moral standards with a sense of individuality and humanity. We thus promote ties with local communities and encourage transnational interactions in order to be socially accountable. This accelerates the process of transfiguring the students into complete human beings making the learning process relevant to life, instilling in them a sense of courtesy and responsibility.

### Core Values

**Excellence:** All activities are conducted according to the highest international standards.

**Integrity:** Adheres to the principles of honesty, trustworthiness, reliability, transparency and accountability.

**Inclusiveness:** To show respect for ethics, cultural and religious diversity and freedom of thought.

**Social Responsibility:** Promotes community engagement, environmental sustainability, and global citizenship. It also promotes awareness of, and support for, the needs and challenges of the local and global communities.

**Innovation:** Supports creative activities that approach challenges and issues from multiple perspectives in order to find solutions and advance knowledge.

## 1.2 Vision and Mission of the Department

### Department Vision

To produce globally competent young data scientists to serve in one or more application areas of business analysis, supply chain, social media content analysis, bioinformatics, finance, health care and so on towards software development and/or research.

### Department Mission

To provide an open environment to foster professional and personal growth with a strong theoretical and practical background having an emphasis on hardware and software development making the graduates industry ready with social ethics.

Further the Department is to provide training and to partner with Global entities in education and research.

**M1:** To provide a sound learning environment for data science students to excel in computer programming and software development to suit to contemporary industry needs and research.

**M2:** To provide a conducive environment for data science students to excel in specific domains of data analytics and other data science related areas to serve the needs of industry and academics.

## 2 Program Educational Objectives (PEOs)

Program Educational Objectives (PEOs) should be defined by the Head of the Department in consultation with the faculty members. PEOs are a promise by the department to the aspiring students about what they will achieve once they join the programme. PEO assessment is not made compulsory by NBA as it is quite difficult to measure in Indian context. NBA assessors usually do not ask for PEO assessment. PEOs are about professional and career accomplishment after 4 to 5 years of graduation. PEOs can be written from different perspectives like Career, Technical Competency and Behaviour. While writing the PEOs do not use the technical terms as it will be read by prospective students who wants to join the programme. Three to five PEOs are recommended.

### Program Educational Objective – I: Success in Data Science and Engineering:

Students will establish themselves as effective professionals by solving problems through programming, leadership qualities, team work, effective communication skills, critical thinking to solve business solutions.

### Program Educational Objective – II: Successful employment and professional ethics:

Students will develop data science applications in advanced areas and employability in IT industry.



**Program Educational Objective – III: Industrial awareness and research:**

Students will understand the significance of Data Science tools and methodologies in global industry demands.

**Program Educational Objective – IV: Being a leader in professional and societal environment:**

Students will be provided with strong foundation in Data Science applications for their career paths.

With a view to challenge ourselves and to nurture diverse capabilities for professional and intellectual growth for our students it is important for the department to define departmental objectives in generalized and broad format. Adherence to these objectives is proposed to be demonstrated through actions or achievements. The department of Computer Science and Engineering(Data Science) periodically reviews these objectives and as part of this review process, encourages comments from all interested parties including current students, alumni, prospective students, faculty, teaching assistants and members of related professional organizations, and colleagues from other educational institutions.

**2.1 Mapping of program educational objectives to program outcomes and program specific outcomes:**

The following Figure 1 shows the correlation between the PEOs and the POs

| PEO-I                                     | PEO-II                                 | PEO-III                                | PEO-IV                     |
|---|--|--|----------------------------|
| PO: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 | PO: 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12 | PO: 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12 | PO: 6, 7, 8, 9, 10, 11, 12 |

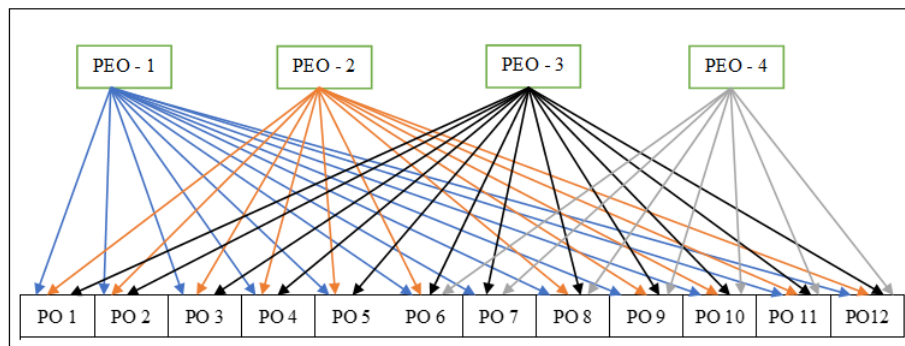


FIGURE 1: Correlation between the PEOs and the POs

The following Figure 2 shows the correlation between the PEOs and the PSOs

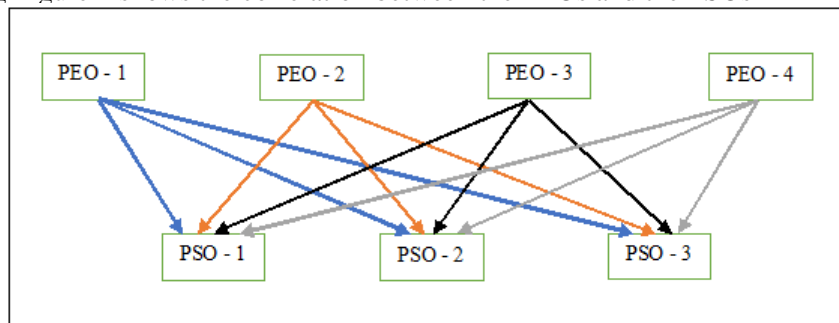


FIGURE 2: Correlation between the PEOs and the PSOs



|                     |                     |                     |                   |
|---------------------|---------------------|---------------------|-------------------|
| <b>PEO-I</b>        | <b>PEO-II</b>       | <b>PEO-III</b>      | <b>PEO-IV</b>     |
| <b>PSO: 1, 2, 3</b> | <b>PSO: 1, 2, 3</b> | <b>PSO: 1, 2, 3</b> | <b>PSO: 1,2,3</b> |

### 3 Program Outcomes (POs)

A Program Learning Outcome is broad in scope and be able to do at the end of the programme. POs are to be in line with the graduate attributes as specified in the Washington Accord. POs are to be specific, measurable and achievable. NBA has defined 12 POs and you need not define those POs by yourself and it is common for all the institutions in India. In the syllabus book given to students, there should be clear mention of course objectives and course outcomes along with CO-PO course articulation matrix for all the courses.

| <b>B. Tech - PROGRAM OUTCOMES (PO's)</b>  |  |
|---|--|
| A graduate of the Electronics and Communication Engineering Program will demonstrate: |  |
| <b>PO1</b>  | <b>Engineering knowledge:</b> Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.  |
| <b>PO2</b>  | <b>Problem analysis:</b> Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences  |
| <b>PO3</b>  | <b>Design/development of solutions:</b> Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations. |
| <b>PO4</b>  | <b>Conduct investigations of complex problems:</b> Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.  |
| <b>PO5</b>  | <b>Modern tool usage:</b> Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.   |
| <b>PO6</b>  | <b>The engineer and society:</b> Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.   |
| <b>PO7</b>  | <b>Environment and sustainability:</b> Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.   |
| <b>PO8</b>  | <b>Ethics:</b> Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.  |
| <b>PO9</b>  | <b>Individual and team work:</b> Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.   |

|             |  |
|-------------|--|
| <b>PO10</b> | <b>Communication:</b> Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions. |
| <b>PO11</b> | <b>Project management and finance:</b> Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.   |
| <b>PO12</b> | <b>Life-long learning:</b> Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.   |

## 4 Program Specific Outcomes (PSOs)

Program Specific Outcomes (PSOs) are statements that describe what the graduates of a specific engineering program should be able to do. A list of PSOs written for the department of Electronics and Communication Engineering is given below.

| <b>B. Tech-CSE(DS) - PROGRAM SPECIFIC OUTCOMES (PSO's)</b>                            |   |
|---|---|
| A graduate of the Electronics and Communication Engineering Program will demonstrate: |   |
| <b>PSO1</b>   | Build suitable statistical models, tools and techniques to analyse large data sets for visualization and interpretation.                                |
| <b>PSO2</b>   | Focus on improving software reliability, network security or information retrieval systems.   |
| <b>PSO3</b>   | Make use of computing theory, mathematics, statistical methods and the principles of optimization techniques in data analytics for providing solutions. |

## 5 Relation between the Program Educational Objectives and the POs

Broad relationship between the program objectives and the program outcomes is given in the following Table below:

|                                 |   |  |  |  |
|---------------------------------|---|--|--|--|
| <b>PEO's</b> →<br>↓ <b>PO's</b> | (1)   | (2)  | (3)  | (4)  |
|                                 | <b>Success in<br/>Data<br/>Science<br/>and Engi-<br/>neering<br/>Fields</b> | <b>Successful<br/>employ-<br/>ment and<br/>professional<br/>ethics</b> | <b>Industrial<br/>awareness<br/>and<br/>research</b> | <b>Being a<br/>leader in<br/>professional<br/>and societal<br/>environ-<br/>ment</b> |

|            |  |   |   |   |   |
|------------|--|---|---|---|---|
| <b>PO1</b> | Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.  | 3 | 3 | 3 | 2 |
| <b>PO2</b> | Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.  | 3 | 3 | 2 | 2 |
| <b>PO3</b> | Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations. | 3 | 3 | 2 | 2 |
| <b>PO4</b> | Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.   | 3 | 3 | 2 | 2 |
| <b>PO5</b> | Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.   | 3 | 3 | 2 | 2 |

|             |  |   |   |   |   |
|-------------|--|---|---|---|---|
| <b>PO6</b>  | Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.  | 2 | 3 | 3 | 3 |
| <b>PO7</b>  | Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.  | 2 | 2 | 3 | 3 |
| <b>PO8</b>  | Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.   | 2 | 2 | 3 | 3 |
| <b>PO9</b>  | Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings   | 2 | 3 | 3 | 3 |
| <b>PO10</b> | Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions. | 2 | 3 | 3 | 3 |

|             |   |   |   |   |   |
|-------------|---|---|---|---|---|
| <b>PO11</b> | Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.   | 2 | 3 | 3 | 3 |
| <b>PO12</b> | Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments. | 2 | 2 | 3 | 3 |

**Relationship between Program Outcomes and Program Educational Objectives**

**Key: 3 = High; 2 = Medium; 1= Low**

## 6 Relation between the Program Specific Outcomes and the Program Educational Objectives:

| <b>PEO's →<br/>↓ PSO's</b> |  | <b>(1)</b>  | <b>(2)</b>   | <b>(3)</b>   | <b>(4)</b>   |
|----------------------------|--|---|--|--|--|
|                            |  | <b>Success in<br/>Data<br/>Science<br/>and Engi-<br/>neering<br/>Fields</b> | <b>Successful<br/>employ-<br/>ment and<br/>professional<br/>ethics</b> | <b>Industrial<br/>awareness<br/>and<br/>research</b> | <b>Successful<br/>employ-<br/>ment and<br/>professional<br/>ethics</b> |
| <b>PSO1</b>                | Build suitable statistical models, tools and techniques to analyse large data sets for visualization and interpretation. | 2   | 3  | 3  | 2  |
| <b>PSO2</b>                | Focus on improving software reliability, network security or information retrieval systems.                              | 3   | 2  | 3  | 2  |

|             |   |   |   |   |   |
|-------------|---|---|---|---|---|
| <b>PSO3</b> | Make use of computing theory, mathematics, statistical methods and the principles of optimization techniques in data analytics for providing solutions. | 2 | 2 | 2 | 3 |
|-------------|---|---|---|---|---|

**Relationship between Program Specific Outcomes and Program Educational Objectives**

**Key: 3 = High; 2 = Medium; 1= Low**

**Note:**

- The assessment process of POs and PSOs can be direct or indirect.
- The direct assessment will be done through interim assessment by conducting continuous internal exam and semester end exams.
- The indirect assessment on the other hand could be done through student’s programme exit questionnaire, alumni survey and employment survey.

## **7 Blooms Taxonomy**

Bloom’s taxonomy is considered as the global language for education. Bloom’s Taxonomy is frequently used by teachers in writing the course outcomes as it provides a readymade structure and list of action verbs. The stages ascend in complexity and what they demand of students. First students need to simply remember information provided to them — but reciting something doesn’t demonstrate having learned it, only memorization. With understanding comes the ability to explain the ideas and concepts to others. The students are then challenged to apply the information and use it in new ways, helping to gain a deeper understanding of previously covered material and demonstrating it moving forward. Questioning information is a vital part of learning, and both analysis and evaluation do just this. Analysing asks a student to examine the information in a new way, and evaluation demands the student appraise the material in a way that lets them defend or argue against it as they determine. The final step in the revised taxonomy is creating, which entails a developing new product or point of view. How does this learned information impact your world? How can it be used to impact not just your education but the way you interact with your surroundings? By utilizing Bloom’s Taxonomy, students are not going to forget the information as soon as the class ends - rather, they retain and apply the information as they continue to grow as a student and in their careers, staying one step ahead of the competition.

### **7.1 Incorporating Critical Thinking Skills into Course Outcome Statements**

Many faculty members choose to incorporate words that reflect critical or higher-order thinking into their learning outcome statements. Bloom (1956) developed a taxonomy outlining the different types of thinking skills people use in the learning process. Bloom argued that people use different levels of thinking skills to process different types of information and situations. Some of these are basic cognitive skills (such as memorization) while others are complex skills (such as creating new ways to apply information). These skills are often referred to as critical thinking skills or higher-order thinking skills.

Bloom proposed the following taxonomy of thinking skills. All levels of Bloom’s taxonomy of thinking skills can be incorporated into expected learning outcome statements. Recently, Anderson and Krathwohl (2001) adapted Bloom’s model to include language that is oriented towards the language used in expected learning outcome statements. A summary of Anderson and Krathwohl’s revised version of Bloom’s taxonomy of critical thinking is provided in Figure 3.



FIGURE 3: Revised version of Bloom’s taxonomy

## 7.2 Definitions of the different levels of thinking skills in Bloom’s taxonomy:

1. **Remember** –recalling relevant terminology, specific facts, or different procedures related to information and/or course topics. At this level, a student can remember something, but may not really understand it.
2. **Understand** –the ability to grasp the meaning of information (facts, definitions, concepts, etc.) that has been presented.
3. **Apply** –being able to use previously learned information in different situations or in problem solving.
4. **Analyze** –the ability to break information down into its component parts. Analysis also refers to the process of examining information in order to make conclusions regarding cause and effect, interpreting motives, making inferences, or finding evidence to support statements/arguments.
5. **Evaluate** –being able to judge the value of information and/or sources of information based on personal values or opinions.
6. **Create** –the ability to creatively or uniquely apply prior knowledge and/or skills to produce new and original thoughts, ideas, processes, etc. At this level, students are involved in creating their own thoughts and ideas.

## 7.3 List of Action Words Related to Critical Thinking Skills

Here is a list of action words that can be used when creating the expected student learning outcomes related to critical thinking skills in a course. These terms are organized according to the different levels of higher-order thinking skills contained in Anderson and Krathwohl’s (2001) revised version of Bloom’s taxonomy.

Here is the revised Bloom’s document with action verbs, which we frequently refer to while writing COs for our courses.



**The cognitive process dimensions- categories:**

| Lower Order of Thinking (LOT)  |   |                           | Higher Order of Thinking (HOT)               |  |   |
|--|---|---------------------------|--|--|---|
| Remember   | Understand  | Apply                     | Analyse                                      | Evaluate   | Create  |
| Interpreting<br>Illustrating<br>Classifying<br>Summarizing<br>Inferring<br>(concluding)<br>comparing<br>explaining | Recognizing<br>(identifying)<br>Recalling<br>(retrieving) | Executing<br>Implementing | Differentiating<br>Organizing<br>Attributing | Checking<br>(coordinating,<br>detecting,<br>testing,<br>monitoring)<br>Critiquing<br>(judging) | Planning<br>Generating<br>Producing<br>(constructing) |

| The Knowledge Dimension  |  |   |  |
|--|--|---|--|
| Concrete Knowledge → Abstract knowledge  |  |   |  |
| Factual  | Conceptual   | Procedural  | Metacognitive  |
| <ul style="list-style-type: none"> <li>• Knowledge of terminologies</li> <li>• Knowledge of specific details and elements</li> </ul> | <ul style="list-style-type: none"> <li>• Knowledge of classifications and categories</li> <li>• Knowledge of principles and generalizations</li> <li>• Knowledge of theories, models and structures</li> </ul> | <ul style="list-style-type: none"> <li>• Knowledge of subject specific skills and algorithms</li> <li>• Knowledge of subject specific techniques and methods</li> <li>• Knowledge of criteria for determining when to use appropriate procedures</li> </ul> | <ul style="list-style-type: none"> <li>• Strategic Knowledge</li> <li>• Knowledge about cognitive task, including appropriate contextual and conditional Knowledge</li> <li>• Self- Knowledge</li> </ul> |

**Action Verbs for Course Outcomes**

| Lower Order of Thinking (LOT) |   |   | Higher Order of Thinking (HOT)  |  |   |   |
|-------------------------------|---|---|---|--|---|---|
| Definitions                   | Remember  | Understand  | Apply   | Analyse  | Evaluate  | Create  |
| <b>Bloom's Definition</b>     | Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers.   | Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas.  | Solve problems to new situations by applying acquired knowledge, facts, techniques and rules in a different way.  | Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations.   | Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria.  | Compile information together in a different way by combining elements in a new pattern or proposing alternative solution.   |
| <b>Verbs</b>                  | <ul style="list-style-type: none"> <li>• Choose</li> <li>• Define</li> <li>• Find</li> <li>• How</li> <li>• Label</li> <li>• List</li> <li>• Match</li> <li>• Extend</li> </ul> | <ul style="list-style-type: none"> <li>• Classify</li> <li>• Compare</li> <li>• Contrast</li> <li>• Demonstrate</li> <li>• Explain</li> <li>• Illustrate</li> <li>• Infer</li> <li>• Interpret</li> </ul> | <ul style="list-style-type: none"> <li>• Apply</li> <li>• Build</li> <li>• Choose</li> <li>• Construct</li> <li>• Develop</li> <li>• Interview</li> <li>• Make use of</li> <li>• Model</li> </ul> | <ul style="list-style-type: none"> <li>• Analyze</li> <li>• Assume</li> <li>• Categorize</li> <li>• Classify</li> <li>• Compare</li> <li>• Discover</li> <li>• Dissect</li> <li>• Distinguish</li> </ul> | <ul style="list-style-type: none"> <li>• Agree</li> <li>• Appraise</li> <li>• Assess</li> <li>• Award</li> <li>• Choose</li> <li>• Criticize</li> <li>• Decide</li> <li>• Deduct</li> <li>• Importance</li> </ul> | <ul style="list-style-type: none"> <li>• Adapt</li> <li>• Build</li> <li>• Solve</li> <li>• Choose</li> <li>• Combine</li> <li>• Invent</li> <li>• Compile</li> <li>• Compose</li> <li>• Construct</li> </ul> |

**Action Verbs for Course Outcomes**

| Higher Order of Thinking (HOT) |   |  |   |
|--------------------------------|---|--|---|
| Definitions                    | Remember  | Understand   | Apply   |
| Verbs                          | <ul style="list-style-type: none"> <li>Name</li> <li>Omit</li> <li>Recall</li> <li>Relate</li> <li>Select</li> <li>Show</li> <li>Spell</li> <li>Tell</li> <li>What</li> <li>When</li> <li>Where</li> <li>Which</li> <li>Who</li> <li>Why</li> </ul> | <ul style="list-style-type: none"> <li>Outline</li> <li>Relate</li> <li>Rephrase</li> <li>Show</li> <li>Summarize</li> <li>Translate</li> <li>Experiment with</li> <li>Illustrate</li> <li>Infer</li> <li>Interpret</li> <li>Outline</li> <li>Relate</li> <li>Rephrase</li> <li>Show</li> <li>Summarize</li> <li>Translate</li> <li>Experiment with</li> </ul> | <ul style="list-style-type: none"> <li>Organize</li> <li>Plan</li> <li>Select</li> <li>Solve</li> <li>Utilize</li> <li>Identify</li> <li>Interview</li> <li>Make use of</li> <li>Model</li> <li>Organize</li> <li>Plan</li> <li>Select</li> <li>Solve</li> <li>Utilize</li> <li>Identify</li> </ul>   |
|                                |   |  |   |
|                                |   |  | <ul style="list-style-type: none"> <li>Defend</li> <li>Determine</li> <li>Disprove</li> <li>Estimate</li> <li>Evaluate</li> <li>Influence</li> <li>Interpret</li> <li>Judge</li> <li>Justify Mark</li> <li>Measure</li> <li>Opinion</li> <li>Perceive</li> <li>Prioritize</li> <li>Prove</li> <li>Criteria</li> <li>Criticize</li> <li>Compare</li> <li>Conclude</li> </ul> |
|                                |   |  | <ul style="list-style-type: none"> <li>Create</li> <li>Design</li> <li>Develop</li> <li>Estimate</li> <li>Formulate</li> <li>Happen</li> <li>Imagine</li> <li>Improve</li> <li>Make up</li> <li>Maximize</li> <li>Minimize</li> <li>Modify</li> <li>Original</li> <li>Originate</li> <li>Plan</li> <li>Predict</li> <li>Propose</li> <li>Solution</li> </ul>                |

## 8 Guidelines for writing Course Outcome Statements:

*Well-written course outcomes involve the following parts:*

1. Action verb
2. Subject content
3. Level of achievement as per BTL
4. Modes of performing task (if applicable)

### 8.1 Course Outcomes (COs)

A Course Outcome is a formal statement of what students are expected to learn in a course. When creating Course Outcomes remember that the outcomes should clearly state what students will do or produce to determine and/or demonstrate their learning. Course learning outcome statements refer to specific knowledge, practical skills, areas of professional development, attitudes, higher-order thinking skills, etc. that faculty members expect students to develop, learn, or master during a course.

A well-formulated set of Course Outcomes will describe what a faculty member hopes to successfully accomplish in offering their particular course(s) to prospective students, or what specific skills, competencies, and knowledge the faculty member believes that students will have attained once the course is completed. The learning outcomes need to be concise descriptions of what learning is expected to take place by course completion.

### 8.2 Developing Course Outcomes

When creating course outcomes consider the following guidelines as you develop them either individually or as part of a multi-section group:

- Limit the course outcomes to 8-12 statements for the entire course [more detailed outcomes can be developed for individual units, assignments, chapters, etc. if the instructor(s) wish (es)].
- Focus on overarching knowledge and/or skills rather than small or trivial details
- Focus on knowledge and skills that are central to the course topic and/or discipline.
- Create statements that have a student focus rather than an instructor centric approach (basic e.g., “upon completion of this course students will be able to list the names of the 28 states and 8 union territories” versus “one objective of this course is to teach the names of the 28 states and 8 union territories”).
- Focus on the learning that results from the course rather than describing activities or lessons that are in the course.
- Incorporate and/or reflect the institutional and departmental missions.
- Include various ways for students to show success (outlining, describing, modelling, depicting, etc.) rather than using a single statement such as “at the end of the course, students will know \_\_\_\_\_ “as the stem for each expected outcome statement.

**When developing learning outcomes, here are the core questions to ask yourself:**

- What do we want students in the course to learn?

- What do we want the students to be able to do?
- Are the outcomes observable, measurable and are they able to be performed by the students?

#### Course outcome statements on the course level describe:

- What faculty members want students to know at the end of the course AND
- What faculty members want students to be able to do at the end of the course?

#### Course outcomes have three major characteristics

- They specify an action by the students/learners that is observable
- They specify an action by the students/learners that is measurable
- They specify an action that is done by the students/learners rather than the faculty members

Effectively developed expected learning outcome statements should possess all three of these characteristics. When this is done, the expected learning outcomes for a course are designed so that they can be assessed. When stating expected learning outcomes, it is important to use verbs that describe exactly what the student(s) / learner(s) will be able to do upon completion of the course.

### 8.3 Relationship of Course Outcome to Program Outcome

The Course Outcomes need to link to the Program Outcomes.

#### Learning outcomes formula:

STUDENTS SHOULD BE ABLE TO + BEHAVIOR + RESULTING EVIDENCE

For example, you can use the following template to help you write an appropriate course level learning outcome.

*“Upon completion of this course students will be able to (knowledge, concept, rule or skill you expect them to acquire) by (how will they apply the knowledge or skill/how will you assess the learning).”*

### 8.4 Characteristics of Effective Course Outcomes

Describe what you want your students to learn in your course.

#### Well written course outcomes:

- Are aligned with program goals and objectives.
- Tell how you will know an instructional goal has been achieved.
- Use action words that specify definite, observable behaviours.
- Are assessable through one or more indicators (papers, quizzes, projects, presentations, journals, portfolios, etc.)
- Are realistic and achievable.
- Use simple language

### 8.5 Examples of Effective Course Outcomes

After successful completion of the course, Students will be able to:

- Critically review the methodology of a research study published in a scholarly sociology journal.
- Design a Web site using HTML and JavaScript.

- Describe and present the contributions of women to American history.
- Recognize the works of major Renaissance artists.
- Facilitate a group to achieve agreed-upon goals.
- Determine and apply the appropriate statistical procedures to analyze the results of simple experiments.
- Develop an individual learning plan for a child with a learning disability.
- Produce a strategic plan for a small manufacturing business.
- Analyse a character's motivation and portray that character before an audience.
- Differentiate among five major approaches to literary analysis
- List the major ethical issues one must consider when planning a human-subjects study.
- Locate and critically evaluate information on current political issues on the Web.
- List and describe the functions of the major components of the human nervous system.
- Correctly classify rock samples found in...
- Conduct a systems analysis of a group interaction.
- Demonstrate active listening skills when interviewing clients.
- Apply social psychological principles to suggest solutions to contemporary social problems.

A more detailed model for stating learning objectives requires that objectives have three parts: a condition, an observable behaviour, and a standard. The table below provides three examples.

| S No | Condition   | Observable Behaviour   | Standard  |
|------|---|--|---|
| 1    | Given a list of drugs   | the student will be able to classify each item as amphetamine or barbiturate       | with at least 70% accuracy                          |
| 2    | Immediately following a fifteen-minute discussion on a topic. | the student will be able to summarize in writing the major issues being discussed. | mentioning at least three of the five major topics. |
| 3    | Given an algebraic equation with one unknown.                 | the student will be able to correctly solve a simple linear equation               | within a period of five minutes.                    |

The following examples describe a course outcome that is not measurable as written, an explanation for why the course outcome is not considered measurable, and a suggested edit that improves the course outcome

| Original course outcome  | Evaluation of language used in this course outcome   | Improved course outcome  |
|--|--|--|
| Explore in depth the literature on an aspect of teaching strategies. | Exploration is not a measurable activity but the quality of the product of exploration would be measurable with a suitable rubric. | Upon completion of this course the students will be able to: write a paper based on an in-depth exploration of the literature on an aspect of teaching strategies. |

**Examples that are TOO general and VERY HARD to measure...**

- ... will appreciate the benefits of learning a foreign language.
- ... will be able to access resources at the Institute library.
- ... will develop problem-solving skills.
- ... will have more confidence in their knowledge of the subject matter. Examples that are still general and HARD to measure...
- ... will value knowing a second language as a communication tool.
- ... will develop and apply effective problem-solving skills that will enable one to adequately navigate through the proper resources within the institute library.
- ... will demonstrate the ability to resolve problems that occur in the field.
- ... will demonstrate critical thinking skills, such as problem solving as it relates to social issues.

### **Examples that are SPECIFIC and relatively EASY to measure...**

- ... will be able to read and demonstrate good comprehension of text in areas of the student's interest or professional field.
- ... will demonstrate the ability to apply basic research methods in psychology, including research design, data analysis, and interpretation.
- ... will be able to identify environmental problems, evaluate problem-solving strategies, and develop science-based solutions.
- ... will demonstrate the ability to evaluate, integrate, and apply appropriate information from various sources to create cohesive, persuasive arguments, and to propose design concepts.

### **An Introspection - Examine Your Own Course Outcomes**

- If you have written statements of broad course goals, take a look at them. If you do not have a written list of course goals, reflect on your course and list the four to six most important student outcomes you want your course to produce.
- Look over your list and check the one most important student outcome. If you could only achieve one outcome, which one would it be?
- Look for your outcome on the list of key competencies or outcomes society is asking us to produce. Is it there? If not, is the reason a compelling one?
- Check each of your other "most important" outcomes against the list of outcomes. How many are on the list of key competencies?
- Take stock. What can you learn from this exercise about what you are trying to accomplish as a teacher? How clear and how important are your statements of outcomes for your use and for your students'? Are they very specifically worded to avoid misunderstanding? Are they supporting important needs on the part of the students?

### **Write Your Course Outcomes!**

One of the first steps you take in identifying the expected learning outcomes for your course is identifying the purpose of teaching the course. By clarifying and specifying the purpose of the course, you will be able to discover the main topics or themes related to students' learning. Once discovered, these themes will help you to outline the expected learning outcomes for the course. Ask yourself:

- What role does this course play within the program?
- How is the course unique or different from other courses?



- Why should/do students take this course? What essential knowledge or skills should they gain from this experience?
- What knowledge or skills from this course will students need to have mastered to perform well in future classes or jobs?
- Why is this course important for students to take?

## 8.6 CO-PO Course Articulation Matrix (CAM) Mapping

Course Articulation Matrix shows the educational relationship (Level of Learning achieved) between course outcomes and program outcomes for a course. This matrix strongly indicates whether the students are able to achieve the course learning objectives. The matrix can be used for any course and is a good way to evaluate a course syllabus.

The Table 1 gives information about the action verbs used in the POs and the nature of POs, stating whether the POs are technical or non-technical. You need to understand the intention of each POs and the Bloom's level to which each of these action verbs in the POs correlates to. Once you have understood the POs then you can write the COs for a course and see to what extent each of those CO's correlate with the POs.

TABLE 9: Process for mapping the values for CO-PO Matrix

| Type          | POs  | Action Verb(s) in POs  | Bloom's level(s) for POs | Bloom's level(s) for COs   |
|---------------|------|--|--------------------------|--|
| Technical     | PO1  | Apply  | L3                       | Bloom's L1 to L4 for theory courses.<br>Bloom's L1 to L5 for laboratory courses.<br>Bloom's L1 to L6 for project work, experiential learning |
|               | PO2  | Identify   | L2                       |  |
|               |      | Formulate  | L6                       |  |
|               |      | Review   | L2                       |  |
|               | PO3  | Design   | L6                       |  |
|               |      | Develop  | L3, L6                   |  |
|               | PO4  | Analyse  | L4                       |  |
|               |      | Interpret  | L2, L3                   |  |
|               |      | Design   | L6                       |  |
|               | PO5  | Create   | L6                       |  |
|               |      | Select   | L1, L2, L6               |  |
|               |      | Apply  | L3                       |  |
| Non-Technical | PO6  | <b>Thumb Rule:</b>   |                          |  |
|               | PO7  | If Bloom's L1 Action Verbs of a CO: Correlates with any of PO6 to PO12, then assign 1.       |                          |  |
|               | PO8  |  |                          |  |
|               | PO9  | If Bloom's L2 to L3 Action Verbs of a CO: Correlates with any of PO6 to PO12, then assign 2. |                          |  |
|               | PO10 |  |                          |  |
|               | PO11 | If Bloom's L4 to L6 Action Verbs of a CO: Correlates with any of                             |                          |  |

TABLE 9: Process for mapping the values for CO-PO Matrix

| Type | POs  | Action Verb(s) in POs      | Bloom's level(s) for POs | Bloom's level(s) for COs |
|------|------|----------------------------|--------------------------|--------------------------|
|      | PO12 | PO6 to PO12, then assign 3 |                          |                          |

At the end, the POs can be calculated using various descriptors that you may define. The mapping of CO towards a PO is evaluated using descriptors such as High, Medium, Low etc. . .

**Observations:**

1. The first five POs are purely of technical in nature, while the other POs are non-technical.
2. For the theory courses, while writing the COs, you need to restrict yourself between Blooms Level 1 to Level 4. Again, if it is a programming course, restrict yourself between Blooms Level 1 to Level 3 but for the other courses, you can go up to Blooms Level 4.
3. For the laboratory courses, while composing COs, you need to restrict yourself between Blooms Level 1 to Level 5.
4. Only for Mini-project and Main project, you may extend up to Blooms Level 6 while composing COs.
5. For a given course, the course in-charge has to involve all the other Professors who teach that course and ask them to come up with the CO-PO mapping. The course in-charge has to take the average value of all of these CO-PO mappings and finalize the values or the course in-charge can go with what the majority of the faculty members prefer for. Ensure that none of the Professors who are handling the particular course discuss with each other while marking the CO-PO values.
6. If you want to match your COs with non-technical POs, then correlate the action verbs used in the course COs with the thumb rule given in the table and map the values. (Applies only for mapping COs to non-technical POs).

**8.7 Tips for Assigning the values while mapping COs to POs.**

1. Select action verbs for a CO from different Bloom's levels based on the importance of the particular CO for the given course.
2. Stick on to single action verbs while composing COs but you may go for multiple action verbs if the need arises.
3. You need to justify for marking of the values in CO-PO articulation matrix. Use a combination of words found in the COs, POs and your course syllabus for writing the justification. Restrict yourself to one or two lines.
4. Values to CO-PO (technical POs in particular) matrix can be assigned by
  - (a) Judging the importance of the particular CO in relation to the POs. If the CO matches strongly with a particular PO criterion then assign 3, if it matches moderately then assign 2 or if the match is low then assign 1 else mark with “ - ” symbol.
  - (b) If an action verb used in a CO is repeated at multiple Bloom's levels, then you need to

judge which Bloom's level is the best fit for that action verb.

## 8.8 Method for Articulation

1. Identify the key competencies of POs/PSOs to each CO and make a corresponding mapping table with assigning ✓ mark at the corresponding cell. One observation to be noted is that the first five POs are purely of technical in nature, while the other POs are non-technical.
2. Justify each CO - PO/PSO mapping with a justification statement and recognize the number of vital features mentioned in the justification statement that are matching with the given Key Attributes for Assessing Program Outcomes. Use a combination of words found in the COs, POs//PSOs and your course syllabus for writing the justification.
3. Make a table with number of key competencies for CO – PO/PSO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
4. Make a table with percentage of key competencies for CO – PO/PSO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
5. Finally, Course Articulation Matrix (CO - PO / PSO Mapping) is prepared with COs and POs and COs and PSOs on the scale of 0 to 3, 0 being no correlation (marked with “ - ”), 1 being the low/slight correlation, 2 being medium/moderate correlation and 3 being substantial/high correlation based on the following strategy

$0-0 \leq C \leq 5\%$  - No correlation.

$1 - 5 < C \leq 40\%$  - Low / Slight.  $2 - 40\% < C < 60\%$  - Moderate  $3 - 60\% \leq C < 100\%$  - Substantial / High

## 9 Key Competencies for Assessing Program Outcomes:

| PO  | NBA statement / Vital features   | No. of vital features |
|-----|--|-----------------------|
| PO1 | <p><b>Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems (Engineering Knowledge). Knowledge, understanding and application of</b></p> <ol style="list-style-type: none"> <li>1. Scientific principles and methodology</li> <li>2. Mathematical principles</li> <li>3. Own and / or other engineering disciplines to integrate / support study of their own engineering discipline</li> </ol> | 3                     |

| PO  | NBA statement / Vital features  | No. of vital features |
|-----|---|-----------------------|
| PO2 | <p><b>Identify, formulate, review research literature, and analyse complex Engineering problems reaching substantiated conclusions using first principles of mathematics natural sciences, and Engineering sciences (Problem Analysis).</b></p> <ol style="list-style-type: none"> <li>1. Problem or opportunity identification</li> <li>2. Problem statement and system definition</li> <li>3. Problem formulation and abstraction</li> <li>4. Information and data collection</li> <li>5. Model translation</li> <li>6. Validation</li> <li>7. Experimental design</li> <li>8. Solution development or experimentation / Implementation</li> <li>9. Interpretation of results</li> <li>10. Documentation</li> </ol>   | 3                     |
| PO3 | <p><b>Design solutions for complex Engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and Environmental considerations (Design/Development of Solutions).</b></p> <ol style="list-style-type: none"> <li>1. Investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues</li> <li>2. Understand customer and user needs and the importance of considerations such as aesthetics</li> <li>3. Identify and manage cost drivers</li> <li>4. Use creativity to establish innovative solutions</li> <li>5. Ensure fitness for purpose for all aspects of the problem including production, operation, maintenance and disposal</li> <li>6. Manage the design process and evaluate outcomes</li> <li>7. Knowledge and understanding of commercial and economic context of engineering processes</li> <li>8. Knowledge of management techniques which may be used to achieve engineering objectives within that context</li> <li>9. Understanding of the requirement for engineering activities to promote sustainable development</li> <li>10. Awareness of the framework of relevant legal requirements governing engineering activities, including personnel, health, safety, and risk issues</li> </ol> | 10                    |

| PO  | NBA statement / Vital features   | No. of vital features |
|-----|--|-----------------------|
| PO4 | <p><b>Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions (Conduct Investigations of Complex Problems).</b></p> <ol style="list-style-type: none"> <li>1. Knowledge of characteristics of particular materials, equipment, processes, or product</li> <li>2. Workshop and laboratory skills</li> <li>3. Understanding of contexts in which engineering knowledge can be applied (example, operations and management, technology development, etc.)</li> <li>4. Understanding use of technical literature and other information sources Awareness of nature of intellectual property and contractual issues</li> <li>5. Understanding of appropriate codes of practice and industry standards</li> <li>6. Awareness of quality issues</li> <li>7. Ability to work with technical uncertainty.</li> <li>8. Understanding of engineering principles and the ability to apply them to analyse key engineering processes</li> <li>9. Ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modeling techniques</li> <li>10. Ability to apply quantitative methods and computer software relevant to their engineering discipline, in order to solve engineering problems</li> <li>11. Understanding of and ability to apply a systems approach to engineering problems.</li> </ol> | 11                    |
| PO5 | <p><b>Create, select, and apply appropriate techniques, resources, and modern Engineering and IT tools including prediction and modelling to complex Engineering activities with an understanding of the limitations (Modern Tool Usage).</b></p> <ol style="list-style-type: none"> <li>1. Computer software / simulation packages / diagnostic equipment / technical library resources / literature search tools.</li> </ol>   | 1                     |

| PO  | NBA statement / Vital features  | No. of vital features |
|-----|---|-----------------------|
| PO6 | <p><b>Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice (The Engineer and Society).</b></p> <ol style="list-style-type: none"> <li>1. Knowledge and understanding of commercial and economic context of engineering processes</li> <li>2. Knowledge of management techniques which may be used to achieve engineering objectives within that context</li> <li>3. Understanding of the requirement for engineering activities to promote sustainable development</li> <li>4. Awareness of the framework of relevant legal requirements governing engineering activities, including personnel, health, safety, and risk (including environmental risk) issues</li> <li>5. Understanding of the need for a high level of professional and ethical conduct in engineering</li> </ol> | 5                     |
| PO7 | <p><b>Understand the impact of the professional Engineering solutions in societal and Environmental contexts, and demonstrate the knowledge of, and need for sustainable development (Environment and Sustainability). Impact of the professional Engineering solutions (Not technical)</b></p> <ol style="list-style-type: none"> <li>1. Socio economic</li> <li>2. Political and</li> <li>3. Environmental</li> </ol>   | 3                     |
| PO8 | <p><b>Apply ethical principles and commit to professional ethics and responsibilities and norms of the Engineering practice (Ethics).</b></p> <ol style="list-style-type: none"> <li>1. Comprises four components:ability to make informed ethical choices, knowledge of professional codes of ethics, evaluates the ethical dimensions of professional practice, and demonstrates ethical behavior.</li> <li>2. Stood up for what they believed in</li> <li>3. High degree of trust and integrity</li> </ol>   | 3                     |

| PO   | NBA statement / Vital features  | No. of vital features |
|------|---|-----------------------|
| PO9  | <p><b>Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings (Individual and Team-work).</b></p> <ol style="list-style-type: none"> <li>1. Independence</li> <li>2. Maturity – requiring only the achievement of goals to drive their performance</li> <li>3. Self-direction (take a vaguely defined problem and systematically work to resolution)</li> <li>4. Teams are used during the classroom periods, in the hands-on labs, and in the design projects.</li> <li>5. Some teams change for eight-week industry oriented Mini-Project, and for the seventeen - week design project.</li> <li>6. Instruction on effective teamwork and project management is provided along with an appropriate textbook for reference.</li> <li>7. Teamwork is important not only for helping the students know their classmates but also in completing assignments.</li> <li>8. Students also are responsible for evaluating each other’s performance, which is then reflected in the final grade.</li> <li>9. Ability to work with all levels of people in an organization</li> <li>10. Ability to get along with others</li> <li>11. Demonstrated ability to work well with a team</li> <li>12. Subjective evidence from senior students shows that the friendships and teamwork extend into the Junior years, and for some of those students, the friendships continue into the workplace after graduation.</li> </ol> | 12                    |
| PO10 | <p><b>Communicate effectively on complex Engineering activities with the Engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions (Communication). ”Students should demonstrate the ability to communicate effectively in writing / Orally.”</b></p> <ol style="list-style-type: none"> <li>1. Clarity (Writing)</li> <li>2. Grammar/Punctuation (Writing)</li> <li>3. References (Writing)</li> <li>4. Speaking Style (Oral)</li> <li>5. Subject Matter (Oral)</li> </ol>  | 5                     |



| PO   | NBA statement / Vital features   | No. of vital features |
|------|--|-----------------------|
| PO11 | <p><b>Demonstrate knowledge and understanding of the Engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary Environments (Project Management and Finance).</b></p> <ol style="list-style-type: none"> <li>1. Scope Statement</li> <li>2. Critical Success Factors</li> <li>3. Deliverables</li> <li>4. Work Breakdown Structure</li> <li>5. Schedule</li> <li>6. Budget</li> <li>7. Quality</li> <li>8. Human Resources Plan</li> <li>9. Stakeholder List</li> <li>10. Communication</li> <li>11. Risk Register</li> <li>12. Procurement Plan</li> </ol>   | 12                    |
| PO12 | <p><b>Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change (Life - Long Learning).</b></p> <ol style="list-style-type: none"> <li>1. Project management professional certification / MBA</li> <li>2. Begin work on advanced degree</li> <li>3. Keeping current in CSE and advanced engineering concepts</li> <li>4. Personal continuing education efforts</li> <li>5. Ongoing learning – stays up with industry trends/ new technology</li> <li>6. Continued personal development</li> <li>7. Have learned at least 2-3 new significant skills</li> <li>8. Have taken up to 80 hours (2 weeks) training per year</li> </ol> | 8                     |

## 10 Key Competencies for Assessing Program Specific Outcomes:

| PSO  | NBA statement / Vital features   | No. of vital features |
|------|--|-----------------------|
| PSO1 | <p><b>Build suitable statistical models, tools and techniques to analyse large data sets for visualization and interpretation.</b></p> <ol style="list-style-type: none"> <li>1. Programming Skills..</li> <li>2. Apply various data access methods.</li> <li>3. Data Analysis and Exploration.</li> <li>4. Statistical Programming and Analysis.</li> </ol>   | 4                     |
| PSO2 | <p><b>Focus on improving software reliability, network security or information retrieval systems.</b></p> <ol style="list-style-type: none"> <li>1. Design and Develop Software Applications with a focus on high security and reliability.</li> <li>2. Design and Develop information retrieval systems for specific applications.</li> </ol>   | 2                     |
| PSO3 | <p><b>Make use of computing theory, mathematics, statistical methods and the principles of optimization techniques in data analytics for providing solutions.</b></p> <ol style="list-style-type: none"> <li>1. Identity and formulate the Data Science application.</li> <li>2. Use of complex computing algorithms.</li> <li>3. Data Preprocessing.</li> <li>4. Optimized solutions for complex problems.</li> </ol> | 4                     |

## 11 Program Outcomes and Program Specific outcomes Attained through course modules:

Courses offered in Electronics and Communication Engineering Curriculum (IARE-R20) and POs/P-SOs attained through course modules for I, II, III, IV V VI VII and VIII semesters.

| Code                      | Subject                      | PO |   |   |   |   |   |   |   |   |    |    |    | PSO |   |   |  |
|---------------------------|------------------------------|----|---|---|---|---|---|---|---|---|----|----|----|-----|---|---|--|
|                           |                              | 1  | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1   | 2 | 3 |  |
| <b>I Semester B. Tech</b> |                              |    |   |   |   |   |   |   |   |   |    |    |    |     |   |   |  |
| AHSC02                    | Linear Algebra and Calculus  | ✓  | ✓ |   |   |   |   |   |   |   |    |    |    |     |   |   |  |
| AHSC06                    | Chemistry                    | ✓  | ✓ |   |   |   |   | ✓ |   |   |    |    |    |     |   |   |  |
| AEEC01                    | Basic Electrical Engineering | ✓  | ✓ |   |   |   |   |   |   |   |    |    |    |     | ✓ |   |  |

| Code                | Subject  | PO |   |   |   |   |   |   |   |   |    |    |    | PSO |   |   |
|---------------------|--|----|---|---|---|---|---|---|---|---|----|----|----|-----|---|---|
|                     |  | 1  | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1   | 2 | 3 |
| ACSC01              | Python Programming                                   | ✓  | ✓ | ✓ |   | ✓ |   |   |   |   | ✓  |    | ✓  | ✓   |   | ✓ |
| AEEC04              | Basic Electrical Engineering Laboratory              | ✓  |   |   |   |   |   |   | ✓ | ✓ | ✓  |    | ✓  | ✓   |   |   |
| ACSC02              | Python Programming Laboratory                        | ✓  | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  |    | ✓  | ✓   | ✓ | ✓ |
| AMEC04              | Engineering Workshop Practice                        | ✓  |   | ✓ |   |   | ✓ | ✓ |   | ✓ |    | ✓  |    |     |   | ✓ |
| <b>II SEMESTER</b>  |  |    |   |   |   |   |   |   |   |   |    |    |    |     |   |   |
| AHSC01              | English  |    |   |   |   |   |   |   |   |   | ✓  |    |    |     |   |   |
| AHSC08              | Probability and Statistics                           | ✓  | ✓ |   | ✓ | ✓ |   |   |   |   |    |    |    |     |   |   |
| AHSC09              | Applied Physics                                      | ✓  | ✓ |   | ✓ |   |   |   |   |   |    |    |    |     |   |   |
| ACSC04              | Programming for Problem Solving using C              | ✓  | ✓ | ✓ |   | ✓ |   |   |   |   | ✓  |    | ✓  | ✓   |   | ✓ |
| AHSC04              | English Language and communication Skills Laboratory |    |   |   |   |   |   |   |   | ✓ | ✓  |    |    |     |   |   |
| AHSC05              | Physics Laboratory                                   | ✓  | ✓ |   | ✓ |   |   |   |   |   |    |    |    |     |   |   |
| ACSC05              | Programming for Problem Solving using C Laboratory   | ✓  | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  | ✓  |    | ✓   | ✓ | ✓ |
| <b>III SEMESTER</b> |  |    |   |   |   |   |   |   |   |   |    |    |    |     |   |   |
| AITC01              | Discrete Mathematical Structures                     | ✓  | ✓ | ✓ |   |   |   |   |   |   |    |    |    | ✓   |   |   |
| ACSC07              | Computer Organization and Architecture               | ✓  | ✓ | ✓ | ✓ |   |   |   |   |   | ✓  |    | ✓  | ✓   |   | ✓ |
| ACSC08              | Data Structures                                      | ✓  | ✓ | ✓ | ✓ | ✓ |   |   |   |   | ✓  |    | ✓  | ✓   | ✓ | ✓ |
| AITC02              | Programming with Objects                             | ✓  | ✓ |   | ✓ | ✓ |   |   |   |   |    |    | ✓  | ✓   |   | ✓ |
| AECC08              | Analog and Digital Electronics                       | ✓  | ✓ | ✓ |   |   |   |   |   |   | ✓  |    | ✓  | ✓   |   |   |

| Code               | Subject   | PO |   |   |   |   |   |   |   |   |    |    |    | PSO |   |   |
|--------------------|---|----|---|---|---|---|---|---|---|---|----|----|----|-----|---|---|
|                    |   | 1  | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1   | 2 | 3 |
| ACSC09             | ExEEEd-<br>Prototype/Design<br>Building               |    |   |   |   |   |   |   |   |   | ✓  |    |    | ✓   | ✓ | ✓ |
| AITC03             | Programming with<br>Objects Laboratory                |    |   | ✓ |   | ✓ | ✓ |   |   |   | ✓  |    | ✓  | ✓   | ✓ | ✓ |
| ACSC11             | Advanced Python<br>Programming<br>Laboratory          | ✓  | ✓ | ✓ | ✓ | ✓ |   |   |   |   | ✓  | ✓  |    |     | ✓ |   |
| ACSC10             | Data Structures<br>Laboratory                         | ✓  | ✓ | ✓ |   | ✓ | ✓ |   |   |   | ✓  |    | ✓  | ✓   | ✓ | ✓ |
| <b>IV SEMESTER</b> |   |    |   |   |   |   |   |   |   |   |    |    |    |     |   |   |
| AITC04             | Theory of<br>Computation                              | ✓  | ✓ | ✓ | ✓ |   |   |   |   |   |    |    |    | ✓   |   | ✓ |
| ACSC12             | Operating Systems                                     | ✓  | ✓ | ✓ | ✓ |   |   |   |   |   | ✓  |    | ✓  | ✓   | ✓ | ✓ |
| AITC05             | Database<br>Management<br>Systems                     | ✓  | ✓ | ✓ | ✓ |   |   |   |   |   | ✓  |    |    | ✓   | ✓ | ✓ |
| ACSC13             | Design and<br>Analysis of<br>Algorithms               | ✓  | ✓ | ✓ | ✓ |   |   |   |   |   |    |    | ✓  | ✓   |   |   |
| AHSC13             | Business<br>Economics and<br>Financial Analysis       | ✓  | ✓ |   |   |   |   |   | ✓ | ✓ |    | ✓  |    |     |   | ✓ |
| ACSC14             | ExEEEd<br>-Fabrication/Model<br>Development           |    | ✓ | ✓ |   |   |   |   |   |   | ✓  |    |    | ✓   | ✓ | ✓ |
| AITC07             | Database<br>Management<br>Systems<br>Laboratory       | ✓  | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  | ✓  | ✓  | ✓   | ✓ |   |
| ACSC15             | Design and<br>Analysis of<br>algorithms<br>Laboratory |    | ✓ | ✓ | ✓ | ✓ | ✓ |   | ✓ | ✓ |    | ✓  | ✓  | ✓   | ✓ | ✓ |
| ACSC16             | Linux<br>Programming<br>Laboratory                    | ✓  | ✓ |   | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  |    | ✓  | ✓   | ✓ | ✓ |

## 12 Methods for measuring Learning Outcomes and Value Addition:

There are many different ways to assess student learning. In this section, we present the different types of assessment approaches available and the different frame works to interpret the results.

- i) Continuous Internal Assessment (CIA)
- ii) Alternate Assessment Tools (AAT)
- iii) Semester end examination (SEE)
- iv) Laboratory and project work
- v) Course exit survey
- vi) Program exit survey
- vii) Alumni survey
- viii) Employer survey
- ix) Course expert committee
- x) Program Assessment and Quality Improvement Committee (PAQIC)
- xi) Department Advisory Board (DAB)
- xii) Faculty meetings
- xiii) Professional societies

**The above assessment indicators are detailed below.**

### 12.1 Continuous Internal Assessment (CIA)

Two Continuous Internal Examinations (CIEs) are conducted for all courses by the department. All students must participate in this evaluation process. These evaluations are critically reviewed by HOD and senior faculty and the essence is communicated to the faculty concerned to analyze, improve and practice so as to improve the performance of the student.

### 12.2 Alternate Assessment Tools (AAT)

This AAT enables faculty to design own assessment patterns during the CIA. The AAT converts the classroom into an effective learning center. The AAT may include tutorial hours/classes, seminars, assignments, term paper, open ended experiments, METE (Modeling and Experimental Tools in Engineering), five minutes video, MOOCs etc. The AAT chosen for this course is given in table.

### 12.3 Semester End Examination (SEE)

The semester end examination is conducted for all the courses in the department. Before the Semester end examinations course reviews are conducted, feedback taken from students and remedial measures will be taken up such that the student gets benefited before going for end exams. The positive and negative comments made by the students about the course are recorded and submitted to the departmental academic council (DAC) and to the principal for taking necessary actions to better the course for subsequent semesters.

### 12.4 Laboratory and Project Works

The laboratory work is continuously monitored and assessed to suit the present demands of the industry. Students are advised and guided to do project works giving solutions to research / industrial problems to the extent possible by the capabilities and limitations of the student. The results of the assessment of the individual projects and laboratory work can easily be conflated in order to provide the students with periodic reviews of their overall progress and to produce terminal marks and grading.

## **12.5 Course Exit Surveys**

Students are encouraged to fill-out a brief survey on the fulfillment of course objectives. The data is reviewed by the concerned course faculty and the results are kept open for the entire faculty. Based on this, alterations or changes to the course objectives are undertaken by thorough discussions in faculty and DAC meetings.

## **12.6 Programme Exit Survey**

The programme exit questionnaire form is to be filled by all the students leaving the institution. The questionnaire is designed in such a way to gather information from the students regarding the program educational objectives, solicit about program experiences, carrier choices, as well as any suggestions and comments for the improvement of the program. The opinions expressed in exit interview forms are reviewed by the DAC for implementation purposes.

## **12.7 Alumni Survey**

The survey asks former students of the department about the status of their employment and further education, perceptions of institutional emphasis, estimated gains in knowledge and skills, involvement as a graduate student, and continuing involvement with Institute of Aeronautical Engineering. This survey is administered every three years. The data obtained will be analyzed and used in continuous improvement.

## **12.8 Employer Survey**

The main purpose of this employer questionnaire is to know employer's views about the skills they require of employees compared to the skills actually possessed by them. The purpose is also to identify gaps in technical and vocational skills, need for required training practices to fill these gaps and criteria for hiring new employees. These employer surveys are reviewed by the College Academic Council (CAC) to affect the present curriculum to suit the requirement so the employer.

## **12.9 Course Expert Committee**

The course expert team is responsible in exercising the central domain of expertise in developing and renewing the curriculum and assessing its quality and effectiveness to the highest of professional standards. Inform the Academic Committee the 'day-to-day' matters as are relevant to the offered courses. This committee will consider the student and staff feedback on the efficient and effective development of the relevant courses. The committee also review the course full stack content developed by the respective course coordinator.

## **12.10 Programme Assessment and Quality Improvement Committee (PAQIC)**

PAC Monitors the achievements of Program Outcomes (POs), Program Specific Outcomes (PSOs) and Program Educational Objectives (PEOs). It will evaluate the program effectiveness and proposes the necessary changes. It also prepares the periodic reports on program activities, progress, status or other special reports for management. It also motivates the faculty and students towards attending workshops, developing projects, working models, paper publications and engaging in research activities.

## **12.11 Department Advisory Board (DAB)**

Departmental Advisory Board plays an important role in the development of the department. Department level Advisory Board will be established for providing guidance and direction for qualitative

growth of the department. The Board interacts and maintains liaison with key stakeholders. DAB will Monitor the progress of the program and develop or recommend the new or revised goals and objectives for the program. Also, the DAB will review and analyze the gaps between curriculum and Industry requirement and gives necessary feedback or advices to be taken to improve the curriculum.

### 12.12 Faculty Meetings

The DAC meets bi-annually for every academic year to review the strategic planning and modification of PEOs. Faculty meetings are conducted at least once in fortnight for ensuring the implementation of DAC's suggestions and guidelines. All these proceedings are recorded and kept for the availability of all faculties.

### 12.13 Professional Societies

The importance of professional societies like IEEE, IETE, ISTE, IE (I) etc., are explained to the students and they are encouraged to become members of the above to carry out their continuous search for knowledge. Student and faculty chapters of the above societies are constituted for a better technical and entrepreneurial environment. These professional societies promote excellence in instruction, research, public service and practice.

## 13 CO - Assessment processes and tools:

Course outcomes are evaluated based on two approaches namely direct and indirect assessment methods. The direct assessment methods are based on the Continuous Internal Assessment (CIA) and Semester End Examination (SEE) whereas the indirect assessment methods are based on the course end survey and program exit survey provided by the students, Alumni and Employer. The weightage in CO attainment of Direct and Indirect assessments are illustrated in Table.

| Assessment Method   | Assessment Tool                            | Weightage in CO attainment |
|---------------------|--|----------------------------|
| Direct Assessment   | Continuous Internal Assessment (CIE & AAT) | 80%                        |
|                     | Semester End Examination                   |                            |
| Indirect Assessment | Course End Survey                          | 20%                        |

### 13.1 Direct Assessment:

Direct assessment methods are based on the student's knowledge and performance in the various assessments and examinations. These assessment methods provide evidence that a student has command over a specific course, content, or skill, or that the students work demonstrates a specific quality such as creativity, analysis, or synthesis.

The various direct assessment tools used to assess the impact of delivery of course content is listed in Table.

- Continuous internal examination, semester end examinations, AAT (includes assignment, 5 minutes videos, seminars etc.) are used for CO calculation.
- The attainment values are calculated for individual courses and are formulated and summed for assessing the POs.



- Performance in AAT is indicative of the student's communication skills.

| S No | Courses                   | Components                           | Frequency           | Max. Marks | Evidence                  |
|------|---------------------------|--------------------------------------|---------------------|------------|---------------------------|
| 1    | Core / Elective           | Continuous Internal Examination      | Twice in a semester | 25         | Answer script             |
|      |                           | Alternative Assessment Tools (AAT)   | Twice in a semester | 5          | Video / Quiz / assignment |
|      |                           | Semester End Examination             | Once in a semester  | 70         | Answer script             |
| 2    | Laboratory                | Conduction of experiment             | Once in a week      | 4          | Work sheets               |
|      |                           | Observation                          | Once in a week      | 4          | Work sheets               |
|      |                           | Result                               | Once in a week      | 4          | Work sheets               |
|      |                           | Record                               | Once in a week      | 4          | Work sheets               |
|      |                           | Viva                                 | Once in a week      | 4          | Work sheets               |
|      |                           | Internal laboratory assessment       | Once in a semester  | 10         | Answer script             |
|      |                           | Semester End Examination             | Once in a semester  | 70         | Answer script             |
| 3    | Project Work              | Presentation                         | Twice in a semester | 30         | Presentation              |
|      |                           | Semester End Examination             | Once in a semester  | 70         | Thesis report             |
| 4    | Comprehensive Examination | Written examination (objective type) | Once in a semester  | 50         | Online assessment         |
|      |                           | Oral examination                     | Once in a Semester  | 50         | Viva                      |

### 13.2 Indirect Assessment:

Course End Survey - In this survey, questionnaires are prepared based on the level of understanding of the course and the questions are mapped to Course Outcomes. The tools and processes used in indirect assessment are shown in Table.

TABLE 15: Tools used in Indirect assessment

| Tools             | Process   | Frequency          |
|-------------------|---|--------------------|
| Course end survey | <ul style="list-style-type: none"> <li>• Taken for every course at the end of the semester</li> <li>• Gives an overall view that helps to assess the extent of coverage/ compliance of COs</li> <li>• Helps the faculty to improve upon the various teaching methodologies</li> </ul> | Once in a semester |

**Direct Tools:** (Measurable in terms of marks and w.r.t. CO) Assessment done by faculty at department level

**Indirect Tools:** (Non measurable (surveys) in terms of marks and w.r.t. CO) Assessment done at institute level.

## 14 PO/PSO - Assessment tools and Processes

The institute has the following methods for assessing attainment of POs/PSOs.

1. Direct method
2. Indirect method

The attainment levels of course outcomes help in computing the PO/PSO based upon the mapping done.

TABLE 16: Attainment of PO/PSOs

|                            | Assessment          | Tools                    | Weight |
|----------------------------|---------------------|--------------------------|--------|
| <b>POs/PSOs Attainment</b> | Direct Assessment   | CO attainment of courses | 80%    |
|                            | Indirect Assessment | Student exit survey      | 20%    |
|                            |                     | Alumni survey            |        |
|                            |                     | Employer survey          |        |

The CO values of both theory and laboratory courses with appropriate weightage as per CO-PO mapping, as per Program Articulation Matrix are considered for calculation of direct attainment of PO/PSOs.

### 14.1 PO Direct Attainment is calculated using the following rubric:

PO Direct Attainment = (Strength of CO-PO)\*CO attainment / Sum of CO-PO strength.

The below figure represents the evaluation process of POs/PSOs attainment through course outcome attainment.

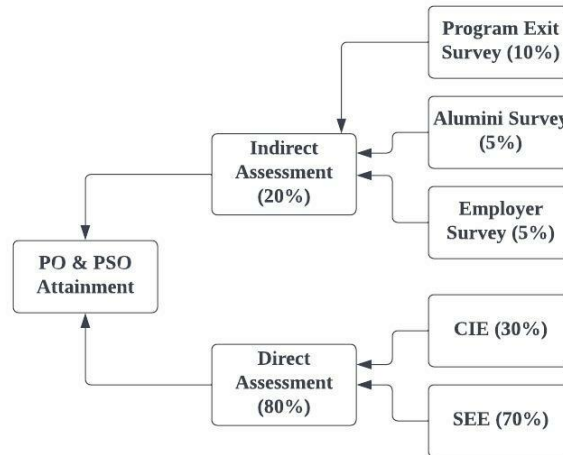


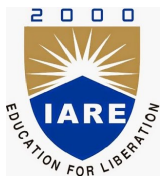
FIGURE 4: Evaluation process of POs/PSOs attainment

## 15 Course Description:

The “Course Description” provides general information regarding the topics and content addressed in the course. A sample course description is given in Annexure – A for the reference.

**The “Course Description” contains the following contents:**

- Course Overview
- Prerequisite(s)
- Marks Distribution
- Content delivery / Instructional methodologies
- Evaluation Methodology
- Course Objectives
- Course Outcomes
- Program Outcomes
- Program Specific Outcomes
- How Program Outcomes are assessed
- How Program Specific Outcomes are assessed
- Mapping of each CO with PO(s), PSO(s)
- Justification for CO – PO / PSO mapping- direct
- Total count of key competencies for CO – PO/ PSO mapping
- Percentage of key competencies for CO – PO/ PSO
- Course articulation matrix (PO / PSO mapping)
- Assessment methodology-direct
- Assessment methodology-indirect
- Syllabus
- List of Text Books / References / Websites
- Course Plan



# INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

## COURSE DESCRIPTION

|                    |  |                    |         |            |         |
|--------------------|--|--------------------|---------|------------|---------|
| Department         | <b>COMPUTER SCIENCE &amp; ENGINEERING (DS)</b> |                    |         |            |         |
| Course Title       | <b>FOUNDATIONS OF MACHINE LEARNING</b>         |                    |         |            |         |
| Course Code        | ACAC03   |                    |         |            |         |
| Program            | B.Tech   |                    |         |            |         |
| Semester           | VI   | CSE( Data science) |         |            |         |
| Course Type        | Core   |                    |         |            |         |
| Regulation         | IARE - UG20                                    |                    |         |            |         |
| Course Structure   | Theory   |                    |         | Practical  |         |
|                    | Lecture  | Tutorials          | Credits | Laboratory | Credits |
|                    | 3  | -                  | 3       | 2          | 2       |
| Course Coordinator | Dr G.Sucharitha Reddy, Associate Professor     |                    |         |            |         |

### I COURSE PRE-REQUISITES:

| Level  | Course Code | Semester | Prerequisites                                 |
|--------|-------------|----------|---|
| B.Tech | AHSC08      | II       | Basic knowledge of Probability and Statistics |

### II COURSE OVERVIEW:

The main emphasis of this course is to provide systems the ability to automatically learn and improve from experience without being explicitly programmed. The course includes the fundamental concepts to build, train, and predict data models using machine learning (ML) algorithms. This course provides a clear understanding on concepts of supervised learning through decision trees, advanced techniques like neural networks, Naive Bayes and k-nearest neighbor algorithm and introduction to unsupervised and reinforcement learning. Machine Learning has revolutionized industries like medicine, healthcare, manufacturing, banking, and several other industries

### III MARKS DISTRIBUTION:

| Subject                         | SEE Examination | CIE Examination | Total Marks |
|---------------------------------|-----------------|-----------------|-------------|
| Foundations of Machine Learning | 70 Marks        | 30 Marks        | 100         |

### IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

|   |                        |   |              |   |              |   |        |
|---|------------------------|---|--------------|---|--------------|---|--------|
| ✓ | PPT                    | ✓ | Chalk & Talk | x | Assignments  | x | MOOC   |
| ✓ | Open Ended Experiments | x | Seminars     | x | Mini Project | ✓ | Videos |
| x | Others                 |   |              |   |              |   |        |

## V EVALUATION METHODOLOGY:

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). CIA is conducted for a total of 30 marks, with 20 marks for Continuous Internal Examination (CIE), and 10 marks for Alternative Assessment Tool (AAT).

**Semester End Examination (SEE):** The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into FIVE modules and each module carries equal weightage in terms of marks distribution. The question paper pattern is as follows. Two full questions with "either" or "choice" will be drawn from each module. Each question carries 14 marks. There could be a maximum of two sub divisions in a question.

The expected percentage of cognitive level of the questions is broadly based on the criteria given in below Table.

| Percentage of Cognitive Level | Blooms Taxonomy Level |
|-------------------------------|-----------------------|
| 10%                           | Remember              |
| 10 %                          | Understand            |
| 80 %                          | Apply                 |
| 0 %                           | Analyze               |

### Continuous Internal Assessment (CIA):

CIA is conducted for a total of 30 marks, with 20 marks for continuous internal examination (CIE) and 10 marks for Alternative Assessment Tool (AAT).

| Component   |  | Marks | Total Marks |
|-------------|--|-------|-------------|
| CIA         | Continuous Internal Examination – 1 (Mid-term) | 10    | 30          |
|             | Continuous Internal Examination – 2 (Mid-term) | 10    |             |
|             | AAT-1  | 5     |             |
|             | AAT-2  | 5     |             |
| SEE         | Semester End Examination (SEE)                 | 70    | 70          |
| Total Marks |  |       | 100         |

### Continuous Internal Examination (CIE):

Two CIE exams shall be conducted at the end of the 8<sup>th</sup> and 16<sup>th</sup> week of the semester respectively for 10 marks each of 2 hours duration consisting of five descriptive type questions out of which four questions have to be answered.

### Alternative Assessment Tool (AAT)

This AAT enables faculty to design own assessment patterns during the CIA. The AAT converts the classroom into an effective learning center. The AAT may include tutorial hours/classes, seminars, assignments, term paper, open ended experiments, METE (Modeling and Experimental Tools in Engineering), five minutes video, MOOCs etc. The AAT chosen for this course is given in table

| Concept Video | Tech-talk | Complex Problem Solving |
|---------------|-----------|-------------------------|
| 40%           | 40%       | 20%                     |

## VI COURSE OBJECTIVES:

The students will try to learn:

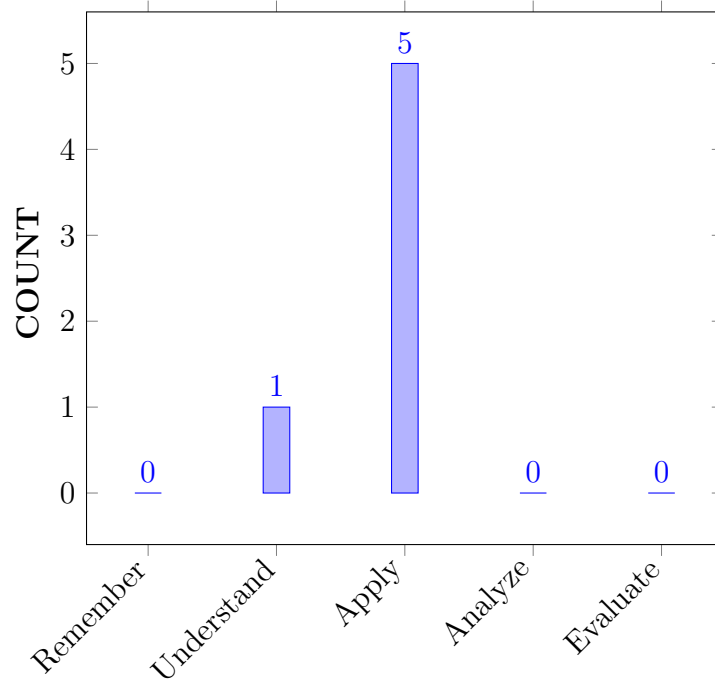
|     |  |
|-----|--|
| I   | The fundamental concepts and techniques of machine learning.   |
| II  | The underlying mathematical relationships within and across machine learning algorithms and the paradigms of supervised and unsupervised learning. |
| III | The skills of using machine learning software for solving practical problems.  |
| IV  | To choose suitable machine learning algorithms and evaluate the performance of algorithms to provide solutions for various real-world problems.    |

## VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

|      |  |            |
|------|--|------------|
| CO 1 | <b>Demonstrate</b> the characteristics of Machine Learning that make it useful to solve real-world problems  | Understand |
| CO 2 | <b>Make use of</b> Supervised Learning Algorithms and Decision Learning Algorithms for Data Classification.  | Apply      |
| CO 3 | <b>Build</b> the Linear Regression Techniques and Ensemble Techniques to predict output.   | Apply      |
| CO 4 | <b>Make use of</b> Bayesian Learning for Classification Model and outline Unsupervised learning Algorithms for determining hidden patterns in data | Apply      |
| CO 5 | <b>Discuss</b> the methodology of Neural Networks and Support Vector Machines to classify the Linear and Non-Linear data                           | Apply      |
| CO 6 | <b>Identify</b> appropriate Machine Learning Algorithms depending on the nature of the Learning System   | Apply      |

## COURSE KNOWLEDGE COMPETENCY LEVEL



**BLOOMS TAXONOMY**

## VIII PROGRAM OUTCOMES:

| Program Outcomes |   |
|------------------|---|
| PO 1             | <b>Engineering knowledge:</b> Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.   |
| PO 2             | <b>Problem analysis:</b> Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.  |
| PO 3             | <b>Design/Development of Solutions:</b> Design solutions for complex Engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and Environmental considerations |
| PO 4             | <b>Conduct Investigations of Complex Problems:</b> Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.   |
| PO 5             | <b>Modern Tool Usage:</b> Create, select, and apply appropriate techniques, resources, and modern Engineering and IT tools including prediction and modelling to complex Engineering activities with an understanding of the limitations  |
| PO 6             | <b>The engineer and society:</b> Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.  |

|       |  |
|-------|--|
| PO 7  | <b>Environment and sustainability:</b> Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.   |
| PO 8  | <b>Ethics:</b> Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.  |
| PO 9  | <b>Communication:</b> Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions. |
| PO 10 | <b>Project management and finance:</b> Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.   |
| PO 12 | <b>Life-Long Learning:</b> Recognize the need for and having the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.  |

## IX HOW PROGRAM OUTCOMES ARE ASSESSED:

| Program |   | Strength | Proficiency Assessed by |
|---------|---|----------|-------------------------|
| PO 1    | <b>Engineering knowledge:</b> Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.   | 3        | CIE/Quiz/AAT            |
| PO 2    | <b>Problem analysis:</b> Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.  | 2.6      | CIE/Quiz/AAT            |
| PO 3    | <b>Design/Development of Solutions:</b> Design solutions for complex Engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and Environmental considerations | 2        | CIE/Quiz/AAT            |
| PO 4    | <b>Conduct Investigations of Complex Problems:</b> Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.   | 1        | CIE / Quiz / AAT        |
| PO 5    | <b>Modern Tool Usage:</b> Create, select, and apply appropriate techniques, resources, and modern Engineering and IT tools including prediction and modelling to complex Engineering activities with an understanding of the limitations  | 3        | CIE / Quiz / AAT        |



|       |   |     |                  |
|-------|---|-----|------------------|
| PO 12 | <b>Life-Long Learning:</b> Recognize the need for and having the preparation and ability to engage in independent and life-long learning in the broadest context of technological change. | 1.5 | CIE / Quiz / AAT |
|-------|---|-----|------------------|

3 = High; 2 = Medium; 1 = Low

## X HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

| Program |  | Strength | Proficiency Assessed by |
|---------|--|----------|-------------------------|
| PSO 1   | Build suitable statistical models, tools and techniques to analyse large data sets for visualization and interpretation.                               | 2        | CIE / Quiz / AAT        |
| PSO 3   | Make use of computing theory, mathematics, statistical methods and the principles of optimization techniques in data analytics for providing solutions | 2.2      | CIE / Quiz / AAT        |

3 = High; 2 = Medium; 1 = Low

## XI MAPPING OF EACH CO WITH PO(s),PSO(s):

| COURSE OUTCOMES | PROGRAM OUTCOMES |      |      |      |      |      |      |      |      |       |       |       | PSO'S |   |   |   |
|-----------------|------------------|------|------|------|------|------|------|------|------|-------|-------|-------|-------|---|---|---|
|                 | PO 1             | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 | PO 11 | PO 12 | 1     | 2 | 3 |   |
| CO 1            | ✓                | ✓    | -    | ✓    | -    | -    | -    | -    | -    | -     | -     | -     | -     | - | - | - |
| CO 2            | ✓                | ✓    | ✓    | -    | ✓    | -    | -    | -    | -    | -     | -     | ✓     | ✓     | - | ✓ |   |
| CO 3            | ✓                | ✓    | ✓    | ✓    | ✓    | -    | -    | -    | -    | -     | -     | ✓     | ✓     | - | ✓ |   |
| CO 4            | ✓                | ✓    | ✓    | ✓    | ✓    | -    | -    | -    | -    | -     | -     | ✓     | ✓     | - | ✓ |   |
| CO 5            | ✓                | ✓    | ✓    | ✓    | ✓    | -    | -    | -    | -    | -     | -     | -     | ✓     | - | ✓ |   |
| CO 6            | ✓                | ✓    | ✓    | ✓    | ✓    | -    | -    | -    | -    | -     | -     | ✓     | ✓     | - | ✓ |   |

## XII JUSTIFICATIONS FOR CO – (PO, PSO) MAPPING -DIRECT:

| COURSE OUTCOMES | PO'S<br>PSO'S | Justification for mapping (Students will be able to)   | No. of Key Competencies |
|-----------------|---------------|--|-------------------------|
| CO 1            | PO 1          | Trying to define and identify <b>the characteristics required to design a learning system</b>                    | 2                       |
|                 | PO 2          | With the knowledge of Machine Learning trying to apply <b>to real-world problems to design a Learning System</b> | 4                       |
|                 | PO 4          | Applying Machine Learning Algorithms <b>to solve real world problems</b>   | 4                       |
| CO 2            | PO 1          | Understand the mathematical principles involved in Supervised Learning Algorithms.                               | 3                       |
|                 | PO2           | Identify the suitable supervised learning algorithms for solution development and experimentation.               | 6                       |
|                 | PO 3          | Use of different classification algorithms to establish innovative solutions                                     | 4                       |

|      |       |  |   |
|------|-------|--|---|
|      | PO 5  | Make use of modern tools for development of algorithms.  | 1 |
|      | PO 12 | Ability to relate Hypothesis space search for an Application using Decision Tree Learning  | 3 |
|      | PSO 1 | Identify the appropriate statistical models and tools to analyse the large datasets.   | 2 |
|      | PSO 3 | Use of complex computing algorithms to provide the solutions for different applications.   | 2 |
| CO 3 | PO 1  | Use the engineering fundamentals and mathematical principles to apply the suitable regression models to predict the output from the database.                              | 3 |
|      | PO 2  | Design and evaluate the regression models on different types datasets.   | 6 |
|      | PO 3  | Use of different linear regression algorithms to establish innovative solutions for different types of datasets.   | 4 |
|      | PO 4  | Understanding of engineering principles and apply them to analyse the complex data for classification and regression   | 3 |
|      | PO 5  | Make use of modern tools to produce solution for different problems.   | 1 |
|      | PO 12 | Ability to relate Hypothesis space search for an Application using various regression techniques   | 4 |
|      | PSO 1 | Identify the appropriate statistical models and tools to analyse the large datasets for suitable regression algorithm.   | 2 |
|      | PSO 3 | Use of complex computing algorithms to provide the solutions for different applications.   | 2 |
| CO 4 | PO 1  | Use the engineering fundamentals and mathematical principles to apply the suitable unsupervised machine learning models to develop the output for the unlabelled database. | 3 |
|      | PO 2  | Using Bayesian Learning for Classification model and outlining Unsupervised Learning Algorithm for experimental design   | 5 |
|      | PO3   | Understand the datasets and user needs and the importance of considerations in applying the suitable machine learning model.   | 4 |
|      | PO 4  | Using Bayesian Learning for Classification model and outlining Unsupervised Learning Algorithm for determining hidden patterns of data                                     | 3 |
|      | PO 5  | Trying to determine hidden patterns of data using modern tools for Unsupervised Learning Algorithms  | 1 |
|      | PO12  | Study the advance topics of machine learning applications for different types of datasets.   | 3 |
|      | PSO1  | Identify the appropriate statistical models and tools to analyse the large datasets for suitable unsupervised algorithms.  | 2 |
|      | PSO3  | Use of complex computing algorithms to provide the solutions for different applications.   | 2 |

|      |      |   |   |
|------|------|---|---|
| CO 5 | PO 1 | Use the suitable mathematical principles to apply Neural network models to develop the output for linear and non linear data. | 3 |
|      | PO 2 | Using different machine learning algorithms for experimental design on linear and non linear data                             | 6 |
|      | PO3  | Understand the datasets and user needs and the importance of considerations in applying the suitable machine learning model.  | 4 |
|      | PO 4 | Use the appropriate codes of practice for industry solutions using suitable machine learning model.                           | 3 |
|      | PO 5 | Trying to determine hidden patterns of data using moern tools on Linear and Non Linear data.                                  | 1 |
|      | PSO1 | Identify the appropriate statistical models and tools to analyse the large datasets for suitable machine learning algorithms. | 2 |
|      | PSO3 | Use of complex computing algorithms to provide the solutions for different applications.                                      | 2 |
| CO 6 | PO 1 | Identify the appropriate machine learning model based on the fundamental engineering and mathematical princiles               | 3 |
|      | PO 2 | Using different machine learning algorithms for experimental design based on the type of data.                                | 6 |
|      | PO3  | Understand the datasets and user needs and the importance of considerations in applying the suitable machine learning model.  | 4 |
|      | PO 4 | Use the appropriate codes of practice for industry solutions using suitable machine learning model.                           | 3 |
|      | PO 5 | Trying to determine hidden patterns of data using moern tools on data.  | 1 |
|      | PO12 | Study the advance topics of machine learning applications for different types of datasets.                                    | 4 |
|      | PSO1 | Identify the appropriate statistical models and tools to analyse the large datasets for suitable machine learning algorithms. | 2 |
|      | PSO3 | Use of complex computing algorithms to provide the solutions for different applications.                                      | 3 |

### XIII TOTAL COUNT OF KEY COMPETENCIES FOR CO – (PO, PSO) MAPPING:

| COURSE<br>OUTCOMES | Program Outcomes/ No. of Key Competencies Matched |         |         |         |         |         |         |         |         |          |          |          | PSO'S    |          |          |
|--------------------|---|---------|---------|---------|---------|---------|---------|---------|---------|----------|----------|----------|----------|----------|----------|
|                    | PO<br>1   | PO<br>2 | PO<br>3 | PO<br>4 | PO<br>5 | PO<br>6 | PO<br>7 | PO<br>8 | PO<br>9 | PO<br>10 | PO<br>11 | PO<br>12 | PSO<br>1 | PSO<br>2 | PSO<br>3 |
| CO 1               | 2   | 4       | -       | 4       | -       | -       | -       | -       | -       | -        | -        | -        | -        | -        | -        |
| CO 2               | 3   | 6       | 4       | -       | 1       | -       | -       | -       | -       | -        | -        | 3        | 2        | -        | 2        |
| CO 3               | 3   | 6       | 4       | 3       | 1       | -       | -       | -       | -       | -        | -        | 4        | 2        | -        | 2        |
| CO 4               | 3   | 5       | 4       | 3       | 1       | -       | -       | -       | -       | -        | -        | 3        | 2        | -        | 2        |
| CO 5               | 3   | 6       | 4       | 3       | 1       | -       | -       | -       | -       | -        | -        | -        | 2        | -        | 2        |

|      |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO 6 | 3 | 6 | 4 | 3 | 1 | - | - | - | - | - | - | 4 | 2 | - | 3 |
|------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

#### XIV PERCENTAGE OF KEY COMPETENCIES FOR CO – (PO, PSO):

| COURSE<br>OUTCOMES | PROGRAM OUTCOMES |         |         |         |         |         |         |         |         |          |          |          | PSO'S    |          |          |
|--------------------|------------------|---------|---------|---------|---------|---------|---------|---------|---------|----------|----------|----------|----------|----------|----------|
|                    | PO<br>1          | PO<br>2 | PO<br>3 | PO<br>4 | PO<br>5 | PO<br>6 | PO<br>7 | PO<br>8 | PO<br>9 | PO<br>10 | PO<br>11 | PO<br>12 | PSO<br>1 | PSO<br>2 | PSO<br>3 |
| CO 1               | 66.7             | 40      | -       | 36      | -       | -       | -       | -       | -       | -        | -        | -        | -        | -        | -        |
| CO 2               | 100              | 60      | 40      | -       | 100     | -       | -       | -       | -       | -        | -        | 37       | 50       | -        | 50       |
| CO 3               | 100              | 60      | 40      | 27      | 100     | -       | -       | -       | -       | -        | -        | 50       | 50       | -        | 50       |
| CO 4               | 100              | 50      | 40      | 27      | 100     | -       | -       | -       | -       | -        | -        | 37       | 50       | -        | 50       |
| CO 5               | 100              | 60      | 40      | 27      | 100     | -       | -       | -       | -       | -        | -        | -        | 50       | -        | 50       |
| CO 6               | 100              | 60      | 40      | 27      | 100     | -       | -       | -       | -       | -        | -        | 50       | 50       | -        | 75       |

#### XV COURSE ARTICULATION MATRIX (PO – PSO MAPPING):

CO'S and PO'S and CO'S and PSO'S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

**0** -  $0 \leq C \leq 5\%$  – No correlation

**2** -  $40\% < C < 60\%$  – Moderate

**1-5**  $< C \leq 40\%$  – Low/ Slight

**3** -  $60\% \leq C < 100\%$  – Substantial /High

| COURSE<br>OUTCOMES | PROGRAM OUTCOMES |         |         |         |         |         |         |         |         |          |          |          | PSO'S    |          |          |
|--------------------|------------------|---------|---------|---------|---------|---------|---------|---------|---------|----------|----------|----------|----------|----------|----------|
|                    | PO<br>1          | PO<br>2 | PO<br>3 | PO<br>4 | PO<br>5 | PO<br>6 | PO<br>7 | PO<br>8 | PO<br>9 | PO<br>10 | PO<br>11 | PO<br>12 | PSO<br>1 | PSO<br>2 | PSO<br>3 |
| CO 1               | 3                | 2       | -       | 1       | -       | -       | -       | -       | -       | -        | -        | -        | -        | -        | -        |
| CO 2               | 3                | 3       | 2       | -       | 3       | -       | -       | -       | -       | -        | -        | 1        | 2        | -        | 2        |
| CO 3               | 3                | 3       | 2       | 1       | 3       | -       | -       | -       | -       | -        | -        | 2        | 2        | -        | 2        |
| CO 4               | 3                | 2       | 2       | 1       | 3       | -       | -       | -       | -       | -        | -        | 1        | 2        | -        | 2        |
| CO 5               | 3                | 3       | 2       | 1       | 3       | -       | -       | -       | -       | -        | -        | -        | 2        | -        | 2        |
| CO 6               | 3                | 3       | 2       | 1       | 3       | -       | -       | -       | -       | -        | -        | 2        | 2        | -        | 3        |
| <b>TOTAL</b>       | 18               | 16      | 10      | 5       | 15      | -       | -       | -       | -       | -        | -        | 6        | 10       | -        | 11       |
| <b>AVERAGE</b>     | 3                | 2.6     | 2       | 1       | 3       | -       | -       | -       | -       | -        | -        | 1.5      | 2        | -        | 2.2      |

#### XVI ASSESSMENT METHODOLOGY DIRECT:

|                      |   |                 |   |                        |   |
|----------------------|---|-----------------|---|------------------------|---|
| CIE Exams            | ✓ | SEE Exams       | ✓ | Seminars               | - |
| Laboratory Practices | - | Student Viva    | - | Certification          | - |
| Term Paper           | - | 5 Minutes Video | ✓ | Open Ended Experiments | - |
| Assignments          | ✓ |                 |   |                        |   |

#### XVII ASSESSMENT METHODOLOGY INDIRECT:

|   |  |   |                           |
|---|--|---|---------------------------|
| ✓ | Early Semester Feedback                | ✓ | End Semester OBE Feedback |
| X | Assessment of Mini Projects by Experts |   |                           |

## XVIII SYLLABUS:

|            |   |
|------------|---|
| MODULE I   | <b>INTRODUCTION TO MACHINE LEARNING</b>   |
|            | Machine Learning Foundations: Introduction to machine learning, learning problems and scenarios, need for machine learning, types of learning, standard learning tasks, the Statistical Learning Framework, Probably Approximately Correct (PAC) learning.              |
| MODULE II  | <b>SUPERVISED LEARNING ALGORITHMS</b>   |
|            | Learning a Class from Examples, Linear, Non-linear, Multi-class and Multi-label classification, Decision Trees: ID3, Classification and Regression Trees (CART), Regression: Linear Regression, Multiple Linear Regression, Logistic Regression                         |
| MODULE III | <b>ENSEMBLE AND PROBABILISTIC LEARNING</b>  |
|            | Ensemble Learning Model Combination Schemes, Voting, Error-Correcting Output Codes, Bagging: Random Forest Trees, Boosting: Adaboost, Stacking Bayesian Learning, Bayes Optimal Classifier, Naïve Bayes Classifier, Bayesian Belief Networks, Mining Frequent Patterns  |
| MODULE IV  | <b>UNSUPERVISED LEARNING</b>  |
|            | Introduction to clustering, Hierarchical: AGNES, DIANA, Partitional: K-means clustering, K-Mode Clustering, Self-Organizing Map, Expectation Maximization, Gaussian Mixture Models, Principal Component Analysis (PCA), Locally Linear Embedding (LLE), Factor Analysis |
| MODULE V   | <b>ADVANCED SUPERVISED LEARNING</b>   |
|            | Neural Networks: Introduction, Perceptron, Multilayer Perceptron, Support vector machines: Linear and NonLinear, Kernel Functions, K-Nearest Neighbors.   |

## TEXTBOOKS

1. Ethem Alpaydin, "Introduction to Machine Learning", MIT Press, PHI, 3rd Edition, 2014.
2. Mehryar Mohri, Afshin Rostamizadeh, Ameet Talwalkar, "Foundations of Machine Learning", MIT Press, 2nd Edition, 2018.

## REFERENCE BOOKS:

1. Tom M. Mitchell, "Machine Learning", McGraw Hill, Indian Edition, 2017.
2. Sahi Shalev-Shwartz, Shai Ben-David, "Understanding Machine Learning: From Theory to Algorithms", Cambridge University Press, 2014.
3. Christopher M. Bishop, "Pattern Recognition and Machine Learning", Springer, 2010
4. Trevor Hastie, Robert Tibshirani, Jerome Friedman, "The Elements of Statistical Learning: Data Mining, Inference, and Prediction", Springer, 2nd Edition, 2009.
5. Avrim Blum, John Hopcroft, Ravindran Kannan, "Foundations of Data Science", Cambridge University Press, 2020
6. Gareth James, Daniela Witten, Trevor Hastie and Rob Tibshirani, "An Introduction to Statistical Learning: with applications in R", Springer Texts in Statistics, 2017.

## WEB REFERENCES:

1. <https://nptel.ac.in/courses/112105171/1>

## COURSE WEB PAGE:

1. lms.iare.ac.in

## XIX COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

| S.No                             | Topics to be covered  | CO's | Reference   |
|----------------------------------|---|------|-------------|
| <b>OBE DISCUSSION</b>            |   |      |             |
| 1                                | Institutions adopting OBE try to bring changes to the curriculum by dynamically adapting to the requirements of the different stakeholders like Students, Parents, Industry Personnel and Recruiters. OBE is all about feedback and outcomes. In this we will discuss about the course outcomes and program outcomes and their attainment |      |             |
| <b>CONTENT DELIVERY (THEORY)</b> |   |      |             |
| 1                                | Machine Learning Foundations: Introduction to Machine Learning, types of learning   | CO1  | T2: 1       |
| 2                                | Types of learning   | CO1  | T2: 1       |
| 3                                | Learning problems and scenarios, need for machine learning  | CO1  | T2: 2-6     |
| 4                                | Need for machine learning   | CO1  | T2: 2-6     |
| 5                                | Types of Machine Learning   | CO1  | R2:-21-22   |
| 6                                | Standard learning tasks   | CO1  | T2:3        |
| 7                                | The Statistical Learning Framework,   | CO1  | R2:33-37    |
| 8                                | Probability.  | CO1  | R2:43       |
| 9                                | Probably Approximately Correct (PAC) learning.  | CO1  | R2:43       |
| 10                               | Probably Approximately Correct (PAC) learning.  | CO1  | R2:43       |
| 11                               | Learning a Class from Examples,   | CO2  | T1: 21      |
| 12                               | Decision Trees:   | CO2  | T1: 191     |
| 13                               | Examples for Decision Trees:  | CO2  | T1: 191     |
| 14                               | ID3 Algorithm   | CO2  | T1: 191     |
| 15                               | Classification and Regression Trees (CART),   | CO2  | T1: 191     |
| 16                               | Introduction to Regression  | CO2  | R2:123-126  |
| 17                               | Linear Regression   | CO2  | R2:123-126  |
| 18                               | Multiple Linear Regression  | CO2  | R2:123-126  |
| 19                               | Logistic Regression   | CO2  | R2:123-126  |
| 20                               | Ensemble Learning Model   | CO3  | T1: 423-424 |
| 21                               | Ensemble Learning Model Combination Schemes   | CO3  | T1: 423-424 |
| 22                               | Ensemble Learning Model Combination Schemes and Voting  | CO3  | T1: 423-424 |
| 23                               | Error-Correcting Output Codes,  | CO3  | T1:427      |
| 24                               | Error-Correcting Output Codes,  | CO3  | T1:427      |

|                     |   |      |                       |
|---------------------|---|------|-----------------------|
| 25                  | Bagging: Random Forest Trees  | CO3  | T1:62-69              |
| 26                  | Boosting: Adaboost  | CO3  | T1:62-69              |
| 27                  | Stacking  | CO3  | T1:62-69              |
| 28                  | Bayesian Learning   | CO3  | R1:154-171,R1:174-190 |
| 29                  | Bayes Optimal Classifier  | CO3  | R1:154-171,R1:174-190 |
| 30                  | Naïve Bayes Classifier  | CO3  | R1:154-171,R1:174-190 |
| 31                  | Bayesian Belief Networks, Mining Frequent Patterns  | CO3  | R1:154-171,R1:174-190 |
| 32                  | Introduction to Clustering  | CO4  | T1:143-145            |
| 33                  | Partitional: K-means clustering   | CO4  | T1:144-145            |
| 34                  | Expectation Maximization, Gaussian Mixture Models,Hierarchical: AGNES, DIANA,   | CO4  | T1:149,157            |
| 35                  | Self-Organizing Map   | CO4  | T1:113-120,286        |
| 36                  | Principal Component Analysis(PCA)   | CO4  | T1:113-120,286        |
| 37                  | Locally Linear Embedding (LLE), Factor Analysis   | CO4  | T1:113-120,286        |
| 38                  | Neural Networks: Introduction   | CO5  | T1:233-245            |
| 39                  | Perceptron, Multilayer Perceptron   | CO5  | T1:233-245            |
| 40                  | Multilayer Perceptron   | CO5  | T1:233-245            |
| 41                  | Support vector machines: Linear and NonLinear, Kernel Functions   | CO5  | T1:309-313            |
| 42                  | K-Nearest Neighbors.  | CO5  | T1:168-170            |
| <b>CASE STUDIES</b> |   |      |                       |
| 1                   | Let us say our hypothesis class is a circle instead of a rectangle. What are the parameters? How can the parameters of a circle hypothesis be calculated in such a case? What if it is an ellipse? Why does it make more sense to use an ellipse instead of a circle? How can you generalize your code to K greater than 2 classes? | CO 6 | T1:43                 |
| 2                   | Imagine our hypothesis is not one rectangle but a union of two (or m greater than 1) rectangles. What is the advantage of such a hypothesis class? Show that any class can be represented by such a hypothesis class with large enough m.   | CO 6 | T1:43                 |

|    |   |      |        |
|----|---|------|--------|
| 3  | The complexity of most learning algorithms is a function of the training set. Can you propose a filtering algorithm that finds redundant instances?   | CO 6 | T1:43  |
| 4  | For a two-class problem, generate normal samples for two classes with different variances, then use parametric classification to estimate the discriminant points. Compare these with the theoretical values  | CO 6 | T1:84  |
| 5  | Assume a linear model and then add 0-mean Gaussian noise to generate a sample. Divide your sample into two as training and validation sets. Use linear regression using the training half. Compute error on the validation set. Do the same for polynomials of degrees 2 and 3 as well            | CO 6 | T1:85  |
| 6  | In document clustering, ambiguity of words can be decreased by taking the context into account, for example, by considering pairs of words, as in cock tail party vs. party elections. Discuss how this can be implemented.   | CO 6 | T1:107 |
| 7  | If we have a supervisor who can provide us with the label for any $x$ , where should we choose $x$ to learn with fewer queries?   | CO 6 | T1:43  |
| 8  | One source of noise is error in the labels. Can you propose a method to find data points that are highly likely to be mislabeled  | CO 6 | T1:44  |
| 9  | Take a word, for example, "machine." Write it ten times. Also ask a friend to write it ten times. Analyzing these twenty images, try to find features, types of strokes, curvatures, loops, how you make the dots, and so on, that discriminate your handwriting from your friend's               | CO 6 | T1:19  |
| 10 | In basket analysis, we want to find the dependence between two items $X$ and $Y$ . Given a database of customer transactions, how can you find these dependencies? How would you generalize this to more than two items   | CO 6 | T1:18  |
| 11 | Let us say we are building an OCR and for each character, we store the bitmap of that character as a template that we match with the read character pixel by pixel. Explain when such a system would fail. Why are barcode readers still used?  | CO 6 | T1:18  |
| 12 | Imagine you have two possibilities: You can fax a document, that is, send the image, or you can use an optical character reader (OCR) and send the text file. Discuss the advantage and disadvantages of the two approaches in a comparative manner. When would one be preferable over the other? | CO 6 | T1:18  |
| 13 | Let us say you are given the task of building an automated taxi. Define the constraints. What are the inputs? What is the output? How can you communicate with the passenger? Do you need to communicate with the other automated taxis, that is, do you need a "language"?                       | CO 6 | T1:18  |



|   |  |      |            |
|---|--|------|------------|
| 14  | In your everyday newspaper, find five sample news reports for each category of politics, sports, and the arts. Go over these reports and find words that are used frequently for each category, which may help us discriminate between different categories. For example, a news report on politics is likely to include words such as “government,” “recession,” “congress,” and so forth, whereas a news report on the arts may include “album,” “canvas,” or “theater.” There are also words such as “goal” that are ambiguous. | CO 6 | T1:18      |
| 15  | Assume we are given the task to build a system that can distinguish junk email. What is in a junk e-mail that lets us know that it is junk? How can the computer detect junk through a syntactic analysis? What would you like the computer to do if it detects a junk e-mail delete it automatically, move it to a different file, or just highlight it on the screen?  | CO 6 | T1:18      |
| <b>DISCUSSION OF DEFINITION AND TERMINOLOGY</b> |  |      |            |
| 1   | Introduction to Machine Learning   | CO 1 | T1:1-13    |
| 2   | Supervised Learning Algorithms   | CO 2 | T1:21-41   |
| 3   | Ensemble and Probabilistic Learning  | CO 3 | T1:47-69   |
| 4   | Unsupervised Learning  | CO 4 | T1:86-123  |
| 5   | Advanced Supervised Learning   | CO 5 | T1:125-158 |
| <b>DISCUSSION OF QUESTION BANK</b>              |  |      |            |
| 1   | Introduction to Machine Learning   | CO 1 | T1:1-13    |
| 2   | Supervised Learning Algorithms   | CO 2 | T1:21-41   |
| 3   | Ensemble and Probabilistic Learning  | CO 3 | T1:47-69   |
| 4   | Unsupervised Learning  | CO 4 | T1:86-123  |
| 5   | Advanced Supervised Learning   | CO 5 | T1:125-158 |

Signature of Course Coordinator  
Dr. G.Sucharitha Reddy, Associate professor

HOD,CSE (DS)