



INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

MECHANICAL ENGINEERING

TUTORIAL QUESTION BANK

2017 - 2018

Course Name	: HEAT TRANSFER
Course Code	: A60331
Class	: III B. Tech II Semester
Branch	: Mechanical Engineering
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COURSE OVERVIEW:

Heat transfer is the flow of thermal energy driven by thermal non-equilibrium, commonly measured as a heat flux, i.e the heat flow per unit time at a control surface. This course focuses on the problems and complexities of heat transfer and emphasizes on analysis using correlations. The course assumes basic understanding of thermodynamic and fluid mechanics and exposure to differential equations and methods of solutions. Topics include modes of heat transfer and their laws, boundary conditions, conduction heat transfer –three dimensional, one dimensional steady and unsteady without heat generation, variable thermal conductivity, fin analysis, lumped heat capacity systems, free and forced convection with dimensional analysis, laminar boundary layer theory, heat exchangers, heat transfer with phase change and radiation heat transfer.

S. No	Question	Blooms Taxonomy Level	Course Outcome
UNIT – I			
PART – A (SHORT ANSWER QUESTIONS)			
1	How does the science of heat transfer differ from the science of thermodynamics?	Understand	1
2	What is the driving force for (a) heat transfer, (b) electric current flow, (c) fluid flow?	Understand	1
3	What is heat flux? How is it related to the heat transfer rate?	Remember	1
4	What are the mechanisms of energy transfer to a closed system? How is heat transfer distinguished from the other forms of energy transfer?	Remember	1
5	How are heat, internal energy, and thermal energy related to each other?	Understand	2
6	Define thermal conductivity and explain its significance in heat transfer	Remember	2
7	What are the mechanisms of heat transfer? How are they distinguished from each other?	Understand	2
8	How does heat conduction differ from convection?	Remember	3
9	How does forced convection differ from natural convection?	Remember	5

S. No	Question	Blooms Taxonomy Level	Course Outcome
10	Which is a better heat conductor, diamond or silver?	Understand	5
11	What are the three modes of Heat Transfer? Explain their differences?	Understand	5
12	What does conduction refer to? State Fourier's law of heat transfer?	Understand	1
13	How does the temperature in a cylindrical wall vary?	Remember	2
14	Define thermal conductivity. How can it be determined experimentally?	Remember	1
15	Why are metals good thermal conductors, while non metals are poor conductors of heat?	Understand	2
16	State Fourier's law of heat conduction? why is the negative sign used?	Remember	1
17	What is temperature gradient? Where it was used?	Understand	2
18	Explain the mechanism of heat conduction in glass, liquids and gasses?	Remember	3
19	How are Fourier's law and Ohm's law similar?	Remember	5
20	Explain the resistance concept to illustrate the analogy of heat flow and flow of electricity?	Remember	5
PART – B (LONGANSWER QUESTIONS)			
1	Distinguish between the basic laws of heat transfer with examples?	Understand	1
2	Discuss basic laws of 3 modes of heat transfer?	Remember	1
3	Derive general conduction equation in Cartesian coordinates?	Remember	1
4	Derive conduction equation in cylindrical coordinates?	Remember	1
5	Derive conduction equation in spherical coordinate systems?	Remember	1
6	What are the applications of heat transfer?	Understand	1
7	What are the different forms of heat transfer?	Remember	3
8	Describe different types of boundary conditions apply to heat conduction problem?	Understand	2
9	Explain the concept of thermal diffusivity.	Remember	2
10	Explain the concept of convective mode of heat transfer	Remember	3
11	Explain the concept of radiation mode of heat transfer	Remember	3
12	What are the physical mechanisms of heat conduction in solid, liquid and gases?	Remember	2
13	Does any of the energy of the sun reach the earth by conduction or convection? Explain.	Remember	3
14	Consider heat transfer through a windowless wall of a house in a winter day. Discuss the parameters that affect the rate of heat conduction Through the wall.	Remember	3
15	How the thermal conductivity of liquids and gases vary with temperature. Explain.	Remember	3
16	Consider a person standing in a breezy room at 20°C. Determine the total rate of heat transfer from this person if the exposed surface area and the average outer surface temperature of the person are 1.6 m ² and 29°C, respectively, and the convection heat transfer coefficient is 6 W/m ² ·°C	Understand	4
17	Consider an alloy of two metals whose thermal conductivities are k ₁ and k ₂ . will the thermal conductivity of the alloy be less than k ₁ , greater than k ₂ , or between k ₁ and k ₂ . Explain.	Remember	3
18	Explain the concept of thermal resistance. On what parameters resistance depend upon.	Understand	7
19	Why metals are good thermal conductors, while non-metals are poor conductors of heat? Explain with an example.	Remember	2

S. No	Question	Blooms Taxonomy Level	Course Outcome
20	Explain the concept of overall heat transfer coefficient. Represent a thermal circuit with conduction and convection.	Remember	2
PART – C (ANALYTICAL QUESTIONS)			
1	An insulated pipe of 50 mm outside diameter ($\epsilon=0.8$) is laid in a room at 30°C . If the surface temperatures is 250°C and the convective heat transfer coefficient is $10\text{ W/m}^2\text{K}$. Calculate the heat loss per unit length of pipe.	Understand	1
2	Sheets of brass and steel each 1 cm thickness is in contact. The outer surface of brass is at 100°C . And that of steel is at 0°C . and $K_b/K_s=2$. Determine Interface temperature of sheets	Understand	1
3	A steam pipe of ($\epsilon=0.9$) of 0.4 m diameter has a surface temperature of 500°C . and is located in a large room at 25°C where $h=25\text{ W/m}^2\text{K}$. Find (i) Combined heat transfer coefficient (ii) The rate of heat loss per unit length	Understand	1
4	If the combustion chamber wall is made up of Firebrick ($k=0.145\text{ W/mK}$, ($\epsilon=0.85$) and is 1.45 cm thickness, Compute the overall heat transfer coefficient for the following data. Gas temperature 800°C Wall temperature on gas side $=798^{\circ}\text{C}$ film conductance on gas side $40\text{ W/m}^2\text{K}$ Film conductance on coolant side $10\text{ W/m}^2\text{K}$	Understand	1
5	The convective heat transfer coefficient $h=2.512(\Delta T)^{0.25}\text{ W/m}^2\text{K}$. A hot plate of $A=0.2\text{ m}^2$ at 59°C losses heat to a room temperature 20°C . Find the fraction of heat lost by natural convection when heat is transferred from the plate steadily at the rate of 100W .	Understand	1
6	The roof of an electrically heated home is 6 m long, 8 m wide, and 0.25 m thick, and is made of a flat layer of concrete whose thermal conductivity is $k=0.8\text{ W/m}\cdot^{\circ}\text{C}$ The temperatures of the inner and the outer surfaces of the roof one night are measured to be 15°C and 4°C , respectively, for a period of 10 hours. Determine (a) the rate of heat loss through the roof that night and (b) the cost of that heat loss to the home owner if the cost of electricity is $\$0.08/\text{kWh}$.	Understand	1
7	Consider a person standing in a breezy room at 20°C . Determine the total rate of heat transfer from this person if the exposed surface area and the average outer surface temperature of the person are 1.6 m^2 and 29°C , respectively, and the convection heat transfer coefficient is $6\text{ W/m}^2\cdot^{\circ}\text{C}$	Understand	2
8	The ratio of radius of the earth's orbit to that of sun is 216. The solar insolation on the earth is $1.4\text{ W/m}^2\text{K}$. Find the surface temperature of the sun if it is assumed to be an ideal radiator (Blackbody).	Understand	7
9	A brick ($k=1.2\text{ W/mK}$) wall 0.15m thick separates combustion gases in a furnace from the atmospheric air at 30°C . The outer surface temperature is 100°C while its emissivity is 0.8 and $h=20\text{ W/m}^2\text{K}$. Determine the inner surface temperature of the brick wall.	Understand	7
10.	A pipe 2 cm in diameter at 30°C is placed in (i) an air flow at 50°C with $h=20\text{ W/m}^2\text{K}$ and in (ii) water at 30°C with $h=70\text{ W/m}^2\text{K}$. Find the heat transfer rate per unit length of the pipe.	Understand	7

S. No	Question	Blooms Taxonomy Level	Course Outcome
UNIT – II			
PART – A (SHORT ANSWER QUESTIONS)			
1	How does transient heat transfer differ from steady heat transfer? How does one-dimensional heat transfer differ from two-dimensional heat transfer?	Understand	1
2	From a heat transfer point of view, what is the difference between isotropic and anisotropic materials?	Understand	5
3	What is heat generation in a solid? Give examples.	Remember	5
4	What is a thermal symmetry boundary condition?	Understand	5
5	A container consists of two spherical layers, A and B, that are in perfect contact. If the radius of the interface is r_0 , express the boundary conditions at the interface.	Understand	6
6	Does heat generation in a solid violate the first law of thermodynamics, which states that energy cannot be created or destroyed? Explain	Understand	6
7	Is the thermal conductivity of a medium, in general, constant or does it varies with temperature?	Understand	7
8	How is the combined heat transfer coefficient defined? What convenience does it offer in heat transfer calculations?	Understand	7
9	What is thermal contact resistance? How is it related to thermal contact conductance?	Remember	5
10	What is the difference between the fin effectiveness and the fin efficiency	Remember	5
11	What is lumped system analysis?	Remember	1
12	When is lumped system analysis it applicable?	Understand	1
13	In what medium is the lumped system analysis more likely to be applicable: in water or in air? Why?	Understand	1
14	Obtain relations for the characteristic lengths of a large plane wall of thickness $2L$, a very long cylinder of radius r_0 , and a sphere of radius r_0 .	Understand	3
15	What is an infinitely long cylinder?	Remember	6
16	Define Biot number.	Remember	6
17	What is the physical significance of the Fourier number?	Understand	6
18	Why are the transient temperature charts prepared using non dimensionalized quantities such as the Biot and Fourier numbers instead of the actual variables such as thermal conductivity and time?	Understand	6
19	What is a semi-infinite medium? Give examples of solid bodies that can be treated as semi-infinite mediums for heat transfer purposes?	Understand	6
20	Under what conditions can a plane wall be treated as a semi-infinite medium?	Understand	6
PART – B (LONG ANSWER QUESTIONS)			
1	Derive one dimensional steady state conduction equation in case of slab	Remember	E
2	Explain the following (i) Log mean area (ii)geometric mean area	Remember	7
3	What is critical thickness of insulation? Explain.	Remember	5

S. No	Question	Blooms Taxonomy Level	Course Outcome
4	Derive the conduction in one-dimensional case for a cylinder	Remember	6
5	What are the assumptions for heat transfer analysis in case of fins	Understand	5
6	Derive the expression for heat transfer in fins in case of (i) Rectangular plate fin of uniform cross section (ii) insulated end.	Remember	5
7	Define fin and explain different types of fins.	Understand	6
8	Explain briefly (i) Fin effectiveness (ii) Fin efficiency	Remember	5
9	Explain the heat transfer analysis in composite wall.	Understand	5
10	Derive expression for critical thickness of insulation for a cylinder.	Remember	6
11	Under what conditions the systems are said to be lumped heat systems. Explain	Understand	1
12	Explain the concept of lumped analysis.	Remember	1
13	Derive the expression for heat transfer under transient mode	Remember	7
14	Define Biot number and Fourier number .What is their importance in heat transfer. Explain.	Remember	6
15	Explain how Biot number help in transient conduction problem	Understand	6
16	What are heisler charts? Under what conditions heisler charts are used in heat transfer problems.	Understand	6
17	Enumerate steps for solving long cylinders using heisler charts.	Understand	1
18	Enumerate steps for heat transfer analysis in slabs using heisler charts.	Understand	2
19	A Thermocouple, the junction of which can be approximated as a 1mm diameter of a gas stream. The properties of the junction are $\rho = 8500\text{kg/m}^3$, $c=320\text{J/kg K}$ and $k=35\text{W/m K}$. The heat transfer coefficient between the junction and the gas is $210\text{W/m}^2\text{K}$. Determine how long it will take for the thermocouple to read 99% of the initial temperature difference.	Understand	2
20	A Steel tube of length 20cm with internal and external diameters of 10 and 12cm is quenched from 500°C to 30°C in a large reservoir of water at 10°C it is less owing to a film of vapor being produced at the surface, and an effective mean value between 500°C and 100°C is 0.5kW/m^2 . The density of steel is 7800kg/m^3 and the specific heat is 0.47kJ/kg K . neglecting internal thermal resistance of the steel tube, determine the quenching time	Understand	2
PART – C (ANALYTICAL QUESTIONS)			
1	A Hollow heat cylinder with $r_1=30\text{ mm}$ and $r_2=50\text{ mm}$, $k=15\text{W/mK}$ is heated on the inner surface at a rate of 10^5 W/m^2 and dissipates heat by conduction from the outer surface to a fluid at 100°C with $h=400\text{ W/m}^2\text{K}$. Find the temperature inside and outside surfaces of the cylinder. and also find rate of heat transfer through the wall	Understand	5
2	A tube 2 cm. O.D maintained at uniform temperature of T_i is covered with insulation ($k=0.20\text{ W/mK}$) to reduce heat loss to the ambient air T_a with $h_a=15\text{W/m}^2\text{K}$. Find i) the critical thickness r_c of insulation (ii)the ratio of heat loss from the tube with insulation to that without insulation, (a) if the thickness of insulation is equal to r_c	Understand	5
3	Three 10cm dia rods A,B and C protrude from a steam bath at 100°C to a length of 25cm into an atmosphere at 20°C . The temperature at	Understand	6

S. No	Question	Blooms Taxonomy Level	Course Outcome
	the other end are $T_a=26.76^{\circ}\text{C}$, $T_b=32^{\circ}\text{C}$ and $T_c=36.93^{\circ}\text{C}$. Find the thermal conductivities of the rod A, B and C, if $h=23\text{W/m}^2\text{K}$ in each case.		
4	A stainless steel fin ($k=20\text{W/mK}$) having a diameter of 20 mm and a length of 0.1 m is attached to a wall at 300°C . The ambient temperature is 50°C and the heat transfer coefficient is 10W/mK . The fin tip is insulated. Determine (a) the rate of heat dissipation from the fin, (b) the temperature at the fin tip, (c) the rate of heat transfer from the wall area covered by the fin was not used and (d) the heat transfer rate from the same fin geometry if the stainless steel fin is replaced by a fictitious fin with infinite thermal conductivity	Understand	6
5	Two large steel plates at temperatures of 120°C and 80°C are separated by a steel rod 300 mm long and 25mm in diameter. The rod is welded to each plate. The space between the plates is filled with insulation, which also insulates the circumference of the rod. Because of a voltage difference between the two plates, current flows through the rod, dissipating electrical energy at a rate of 150W. Find out the maximum temperature in the rod and the heat flux. Take k for the rod as 47W/mK .	Understand	6
6	A cylinder steel ingot (diameter 100mm, length 300mm, $k=40\text{W/mK}$, $\rho=7600\text{kg/m}^3$ and $c=600\text{J/kg K}$) is to be heated in a furnace from 50°C to 850°C . The temperature inside the furnace is 1300°C and the surface heat transfer coefficient is $100\text{W/m}^2\text{K}$. Calculate the time required for heating	Understand	6
7	Determine the heat transfer rate from the rectangular fin of length 20cm, width 40 cm and thickness 2 cm. The tip of the fin is not insulated and the fin has a thermal conductivity of 150W/mK . The base temperature is 100°C and the fluid is 20°C . The heat transfer coefficient between the fin and the fluid is $30\text{W/m}^2\text{K}$	Understand	7
8	A copper fin ($k=396\text{W/m K}$) 0.25 cm in diameter protrudes from a wall at 95°C into ambient air at 25°C . The heat transfer coefficient by free convection is equal to $10\text{W/m}^2\text{K}$. Calculate the heat loss if (a) The fin is infinitely long (b) The fin is 2.5 cm long and the coefficient at the end is same as around the circumference	Understand	7
9	A solid sphere of radius 0.5 m has an internal heat generation rate of $2 \times 10^6\text{W/m}^3$. If the thermal conductivity of material is 40W/mK and the convective heat transfer coefficient at the surface of sphere is $100\text{W/m}^2\text{K}$. Calculate the temperatures at the outer surface and at the center. Take ambient temperature as 30°C .	Understand	7
10	Steel ball bearing ($k=50\text{W/m K}$, $\alpha=1.3 \times 10^{-5}\text{m}^2/\text{s}$) having a diameter of 40mm are heated to a temperature of 650°C and then quenched in a tank of oil 55°C . If the heat transfer coefficient between the ball bearings and oil is $300\text{W/m}^2\text{K}$, determine (a) the duration of time the bearings must remain in oil to reach a temperature of 200°C , (b) the total amount of heat removed from each bearing during this time and (c) the instantaneous heat transfer rate from the bearings when they are	Understand	3

S. No	Question	Blooms Taxonomy Level	Course Outcome
	first immersed in oil and when they reach 200°C .		
UNIT – III			
PART – A (SHORT ANSWER QUESTIONS)			
1	What is forced convection? How does it differ from natural convection? Is convection caused by winds forced or natural convection?	Remember	8
2	What is the physical significance of the Nusselt number? How is it defined	Understand	8
3	Define incompressible flow and incompressible fluid. Must the flow of a compressible fluid necessarily be treated as compressible?	Remember	8
4	How does turbulent flow differ from laminar flow? For which flow is the heat transfer coefficient higher?	Understand	8
5	What is the physical significance of the Reynolds number? How is it defined for external flow over a plate of length L?	Understand	8
6	What is turbulent thermal conductivity? What is it caused by?	Understand	9
7	State Newton's law of cooling Is the acceleration of a fluid particle necessarily zero in steady flow? Explain.	Remember	9
8	What are the advantages of nondimensionalizing the convection equations?	Understand	9
9	How is Reynolds analogy expressed? What is the value of it? What are its limitations?	Understand	8
10	What is drag? What causes it? Why do we usually try to minimize it?	Remember	8
11	What is natural convection? How does it differ from forced convection? What force causes natural convection currents?	Remember	8
12	In which mode of heat transfer is the convection heat transfer coefficient usually higher, natural convection or forced convection? Why	Understand	9
13	How does the Rayleigh number differ from the Grashoff number	Remember	9
14	Consider laminar natural convection from a vertical hot plate. Will the heat flux be higher at the top or at the bottom of the plate? Why?	Understand	8
15	Show that the volume expansion coefficient of an ideal gas is $1/T$, where T is the absolute temperature.	Understand	8
16	Why are finned surfaces frequently used in practice? Why are the finned surfaces referred to as heat sinks in the electronics industry?	Understand	8
17	When is natural convection negligible and when is it not negligible in forced convection heat transfer?	Remember	9
18	When neither natural nor forced convection is negligible, is it correct to calculate each independently and add them to determine the total convection heat transfer?	Understand	9
19	Under what conditions does natural convection enhance forced convection, and under what conditions does it hurt forced convection?	Understand	8
20	Why heat sinks with closely packed fins are not suitable for natural convection heat transfer, although they increase the heat transfer surface area more?	Remember	10
PART – B (LONG ANSWER QUESTIONS)			
1	Differentiate between Newtonian and Non Newtonian fluids. Give examples	Remember	8

S. No	Question	Blooms Taxonomy Level	Course Outcome
2	What is boundary layer thickness what do you mean by laminar and turbulent boundary layers.	Understand	9
3	What is critical Reynolds number for flow over flat plate? Explain.	Understand	8
4	Define local and mean heat transfer coefficient. On what factors 'h' value depends on ?	Understand	8
5	A metal plate 0.609m in height forms the vertical wall of an oven and is at a temperature of 171 ⁰ C. Within the oven is air at a temperature of 93.4 ⁰ C and the atmospheric pressure. Assuming that natural convection conditions hold near the plate, and that for this case $Nu=0.548(GrPr)^{1/4}$ find the mean heat transfer coefficient and the heat taken up by air per second per meter width. For air at 132.2 ⁰ C, take $k=33.2 \times 10^{-6} \text{ kW/m}$, $\mu=0.232 \times 10^{-4} \text{ kg/ms}$, $c_p=1.005 \text{ kJ/kgK}$. Assume air as an ideal gas and $R=0.287 \text{ kJ/kgK}$.	Understand	9
6	A 0.15m outer diameter. steel pipe lies 2m vertically and 8m horizontally in a large room with an ambient temperature of 30 ⁰ C. The pipe surface is at 250 ⁰ C and has an emissivity of 0.60. Estimate The total rate of heat loss from the pipe to the atmosphere	Understand	8
7	A nuclear reactor with its core constructed of parallel vertical plates 2.2m high and 1.45m wide has been designed on free convection heating of liquid bismuth. The maximum possible heat dissipation from both sides of each plate. For the convection coefficient the appropriate correlation is $Nu=0.13(Gr.Pr)^{1/3}$ where the properties evaluated at the mean film temperature of 650 ⁰ C for bismuth are: $\rho=10^4 \text{ kg/m}^3$, $c_p=150.7 \text{ J/kgK}$, $k=13.02 \text{ W/mK}$.	Understand	9
8	State Buckingham pi theorem .What are the merits and demerits.	Remember	8
9	What do you mean by VonKorman's integral method. And derive drag force and heat transfer coefficient for flow over a flat plate.	Understand	10
10	Explain Reynold's analogy. Derive an expression for it.	Understand	10
11	What is physical significance of Grashoff number Derive $\beta=1/T$	Remember	9
12	Explain the concept of Nusselt's theory of laminar flow.	Remember	9
13	Explain the conditions for which Dittus-Boelter equation can be used to determine heat transfer coefficient	Remember	10
14	What is Rayleigh number? Discuss the nature of flow with respect to it.	Remember	9
15	What do you mean by hydrodynamic entry length?	Remember	10
16	Give the steps to find heat transfer in natural convection.	Understand	9
17	Air at 1atm and 30 ⁰ C is forced through a horizontal 30mm diameter 0.5m Long at an average velocity of 0.25m/s. The tube wall is maintained at 137 ⁰ C. Calculate (a) the heat transfer coefficient and (b) percentage error if the calculation is made strictly on the basis of laminar forced convection	Understand	9
18	Engine oil at 60 ⁰ C flows over the upper surface of a 5-m-long flat plate whose temperature is 20 ⁰ C with a velocity of 2 m/s Determine the total drag force and the rate of heat transfer per unit width of the entire plate	Understand	8

S. No	Question	Blooms Taxonomy Level	Course Outcome
19	A square plate 0.4m x 0.4m maintained at a uniform temperature of $T_w = 400\text{K}$ is suspended vertically in quiescent atmospheric air at 27°C . Determine (a) the boundary layer thickness at the trailing edge of the plate (i.e. at $x = 0.4\text{m}$), (b) the average heat coefficient over the entire length by using theoretical analysis. Properties of air at 35°C are $\nu = 2.075 \times 10^{-6} \text{m}^2/\text{s}$, $Pr = 0.697$ and $k = 0.03 \text{W/mK}$.	Understand	8
20	A 2.2cm outer diameter pipe is to cross a river at a 30m wide section while being completely immersed in water. The average flow velocity of water is 4 m/s and the water temperature is 15°C . Determine the drag force exerted on the pipe by the river.	Understand	8
PART – C (ANALYTICAL QUESTIONS)			
1	Nitrogen gas at 0°C is flowing over a 1.2m long, 2m wide plate maintained at 80°C with a velocity of 2.5m/s., $\rho = 1.142 \text{kg/m}^3$, $c_p = 1.04 \text{kJ/kgK}$, $\nu = 15.63 \times 10^{-6} \text{m}^2/\text{s}$ and $k = 0.0262 \text{W/mK}$. Find (a) The average coefficient and (b) the total heat transfer from the plate.	Understand	8
2	Water at 10°C flows over a flat plate (at 90°C) measuring 1m x 1m, with a velocity of 2m/s. properties of water at 50°C are $\rho = 988.1 \text{kg/m}^3$, $\nu = 0.556 \times 10^{-6} \text{m}^2/\text{s}$, $Pr = 3.54$ and $k = 0.648 \text{W/mK}$. Find: (a) The length of plate over which the flow is laminar, (b) the rate of heat transfer from the entire plate..	Understand	8
3	Water flows through a 20mm ID at a rate of 0.01kg/s entering at 10°C . The tube is wrapped from outside by an electric element that produces a uniform flux of 156kW/m^2 . If the exit temperature of water is 40°C , estimate (a) the Reynolds number, (b) the heat transfer coefficient, (c) the length of the pipe needed, (d) the inner tube surface temperature at exit, (e) the friction factor, (f) the pressure drop in the tube, and (g) the pumping power required if the pump efficiency is 60%. Neglect entrance effects. Properties of water at mean temperature of 25°C are: $\rho = 997 \text{kg/m}^3$, $c_p = 4180 \text{J/kgK}$, $\nu = 910 \times 10^{-6} \text{Ns/m}^2$ and $k = 0.608 \text{W/mK}$.	Understand	8
4	It was found during a test in which water flowed with a velocity of 2.44m/s through a tube (2.54cm inner diameter and 6.08m long), that the head lost due to friction was 1.22m of water. Estimate the surface heat transfer coefficient based on Reynolds analogy. Take $\rho = 998 \text{kg/m}^3$ and $c_p = 4.187 \text{kJ/kgK}$	Understand	9
5	Atmospheric pressure air at 100°C enters a 0.04m dia 2m long tube with a velocity of 9m/s. A 1kW electric heater wound on the surface of the outer surface of the tube provides a uniform heat flux to the tube. find (a) The mass flow rate of air, (b) the exit temperature of air, and (c) the wall temperature of tube at outlet.	Understand	9
6	Lubricating oil ($\rho = 865 \text{kg/m}^3$, $k = 0.14 \text{W/mK}$ and $c_p = 1.78 \text{kJ/kgK}$ and $\nu = 9 \times 10^{-6} \text{m}^2/\text{s}$) at 60°C enters a 1cm diameter tube with a velocity of 3.5m/s. $T_w = 30^\circ\text{C}$, constant. Find The tube length required to cool the oil to 45°C .	Understand	9
	For the flow system in which air at 27°C and 1atm flows over a flat	Understand	10

S. No	Question	Blooms Taxonomy Level	Course Outcome
7	plate at a velocity of 3m/s, estimate the drag force exerted on the 45cm of the plate using the analogy between fluid friction and heat transfer.		
8	Air at 2atm and 200 ⁰ C is heated as it flows at a velocity of 12m/s through a tube with a diameter of 3cm. A constant heat flux condition is maintained at the wall and the wall temperature is 20 ⁰ C above the air temperature all along the length of the tube. Calculate (a) the heat transfer per unit length of tube. Properties of air at 200 ⁰ C are Pr=0.681, $\mu=2.57 \times 10^{-5}$ kg/ms, k=0.0386W/mK and $c_p=1.025$ kJ/kgK.	Understand	10
9	Air at 1atm, 27 ⁰ C flow across a sphere of 0.015m diameter at a velocity of 5m/s. A heater inside the sphere maintains the surface temperature at 77 ⁰ C. Find the rate of heat transfer from the sphere.	Understand	10
10	Water flows at a velocity of 12m/s in a straight tube of 60mm diameter. The tube surface temperature is maintained at 70 ⁰ C and the flowing water is heated from the inlet temperature of 15 ⁰ C to an outlet temperature of 45 ⁰ C. Taking the physical properties of water at the bulk temperature of 30 ⁰ C as $\rho=995.7$ kg/m ³ , $c_p=4.174$ kJ/kgK, $k=61.718 \times 10^{-2}$ W/mK, $\nu=0.805 \times 10^{-6}$ m ² /s and Pr=5.42. Calculate (a) the heat surface coefficient from the tube surface to the water, (b) the heat transferred and (c) the length of the tube.	Understand	10

UNIT – IV

PART – A (SHORT ANSWER QUESTIONS)

1	What is the difference between evaporation and boiling?	Understand	9
2	What is the difference between sub cooled and saturated boiling?	Remember	9
3	Name the different boiling regimes in the order they occur in a vertical tube during flow boiling	Remember	10
4	What is the difference between film and drop wise condensation? Which is a more effective mechanism of heat transfer?	Remember	10
5	In condensate flow, how is the wetted perimeter defined? How does wetted perimeter differ from ordinary perimeter	Remember	10
6	What is the modified latent heat of vaporization? For what is it used? How does it differ from the ordinary latent heat of vaporization?	Remember	11
7	What is condensation? How does it occur?	Understand	10
8	How does the presence of a noncondensable gas in a vapor influence the condensation heat transfer?	Understand	10
9	Name the different boiling regimes in the order they occur in a vertical tube during flow boiling	Remember	10
10	Discuss some methods of enhancing pool boiling heat transfer permanently.	Remember	11
11	What is an electromagnetic wave? How does it differ from a sound wave?	Understand	10
12	What is thermal radiation? How does it differ from the other forms of electromagnetic radiation?	Remember	9
13	What is a blackbody? Does a blackbody actually exist?	Remember	9

S. No	Question	Blooms Taxonomy Level	Course Outcome
14	Why did we define the blackbody radiation function? What does it represent? For what is it used?	Understand	9
15	What does a solid angle represent, and how does it differ from a plane angle? What is the value of a solid angle associated with a sphere?	Understand	10
16	Define the properties emissivity and absorptivity. When are these two properties equal to each other?	Remember	11
17	What is a gray body? How does it differ from a blackbody? What is a diffuse gray surface?	Remember	10
18	What does the view factor represent? When is the view factor from a surface to itself not zero?	Understand	10
19	What are the summation rule and the superposition rule for view factors?	Remember	10
20	What are the two methods used in radiation analysis? How do these two methods differ?	Remember	11
PART – B (LONG ANSWER QUESTIONS)			
1	What are the assumptions to be considered for analysis of laminar film condensation	Remember	10
2	Derive the expression for condensation heat transfer.	Remember	10
3	Explain different regimes of boiling heat transfer phenomena	Remember	11
4	Explain drop wise and film wise condensation	Remember	11
5	Why the condenser tubes are horizontal	Understand	10
6	What is nucleate boiling? Explain.	Remember	9
7	Explain film boiling	Remember	9
8	Write the correlations for boiling heat transfer in case of nucleate boiling	Remember	10
9	Differentiate between different types of condensers	Remember	11
10	Write correlations for condensation heat transfer.	Remember	10
11	Explain what do you mean by absorptivity, reflectivity and transmissivity	Understand	9
12	Define Opaque body and blackbody	Remember	9
13	Define monochromatic emissive power and total emissive power	Remember	9
14	What are the basic laws of radiation?	Understand	9
15	What is shape factor obtain the expression for it?	Understand	10
16	Derive expression for radiant energy between two small gray surfaces	Understand	10
17	Explain radiosity	Understand	10
18	Explain irradiation	Remember	11
19	Write expression for monochromatic emissive power	Remember	11
20	Write expression for blackbody radiation	Remember	11
PART – C (ANALYTICAL QUESTIONS)			

S. No	Question	Blooms Taxonomy Level	Course Outcome
1	Saturated steam at 54.5°C condenses on the outside surface of a 25.4mm outer diameter 3.66m long vertical tube maintained at a uniform temperature of 43.3°C . Because of the occurrence of ripples on the surface of the condensate film the actual heat transfer coefficient is 20% higher than the obtained by Nusselt's equation. Determine the average condensation heat transfer coefficient over the entire length of the tube and the rate of condensate flow at the bottom of the tube. Check that the flow is laminar. The properties of condensate at 48.9°C are $h_{fg}=2372.4\text{kJ/kgK}$, $k=0.642\text{W/mK}$, $\rho=988.4\text{kg/m}^3$ and $\mu=0.558\times 10^{-3}\text{kg/ms}$.	Understand	9
2	Saturated steam at 110°C condenses on the outside of a bank of 64 horizontal tubes of 25mm outer diameter; 1m long arranged 8×8 square arrays. Calculate the rate of condensation if the tube surface is maintained at 100°C . The properties of saturated water at 105°C are $\rho=654.7\text{kg/m}^3$, $k=0.684\text{W/m}^2\text{K}$, $\mu=271\times 10^{-6}\text{Kg/mS}$ and $h_{fg}=2243.7\text{kJ/kg}$.	Understand	10
3	A Vertical plate 300mm wide and 1.2m high is maintained at 70°C and is exposed to saturated steam at 1atm pressure. Calculate the heat transfer coefficient and the total mass of steam condensed per hour. What would be the heat coefficient if the plate is inclined at 30°C to the vertical?	Understand	11
4	Estimate the power required to boil water in a copper pan, 0.35m in diameter. The pan is maintained at 120°C by an electric heater. What is the evaporation rate? Estimate the critical heat flux	Understand	11
5	A metal-clad heating element of 8mm diameter and emissivity 0.9 is horizontally immersed in a water bath. The surface temperature of the metal is 260°C under steady-state boiling conditions. Estimate the power dissipation per unit length of heater	Understand	9
6	Water is to be boiled at atmospheric pressure in a mechanically polished stainless steel pan placed on top of a heating unit, The inner surface of the bottom of the pan is maintained at 108°C . If the diameter of the bottom of the pan is 30cm , determine (a) the rate of heat transfer to the water and (b) the rate of evaporation of water	Understand	10
7	A black body emits radiation at 2000K . Calculate (i) the monochromatic emissive power at $1\ \mu\text{m}$ wavelength, (ii) wavelength at which the emission is maintained and (iii) the maximum emissive power	Understand	10
8	The filament of a 75W light bulb may be considered a black body radiating into a black enclosure at 70°C . The filament diameter is 0.10mm and the length is 50mm . Considering the radiation, determine the filament temperature.	Understand	11
9	An enclosure measures $1.5\text{m}\times 1.7\text{m}$ with a height of 2m . The walls and ceiling are maintained at 250°C and the floor at 130°C . The walls and ceiling have an emissivity of 0.82 and the floor 0.7 . Determine the net radiation to the floor.	Understand	11
10	Two black discs 1m in diameter are placed directly opposite to each other at a distance of 0.5m . The discs are maintained at 1000K and 500K respectively. Calculate the heat flow between the discs (a) when no other surfaces are present and (b) when the discs are connected by a cylindrical refractory no-flux surface.	Understand	11

S. No	Question	Blooms Taxonomy Level	Course Outcome
UNIT- V			
PART – A (SHORT ANSWER QUESTIONS)			
1	Classify heat exchangers according to flow type and explain the characteristics of each type.	Remember	11
2	Classify heat exchangers according to construction type and explain the characteristics of each type.	Remember	12
3	What is a regenerative heat exchanger? How does a static type of regenerative heat exchanger differ from a dynamic type?	Remember	12
4	What are the heat transfer mechanisms involved during heat transfer from the hot to the cold fluid?	Understand	13
5	Draw a 2-shell-passes and 8-tube-passes shell-and tube heat exchanger. What is the primary reason for using so many tube passes?	Understand	13
6	What are the common causes of fouling in a heat exchanger? How does fouling affect heat transfer and pressure drop?	Remember	13
7	How is the thermal resistance due to fouling in a heat exchanger accounted for? How do the fluid velocity and temperature affect fouling?	Understand	12
8	Can the logarithmic mean temperature difference of a heat exchanger be a negative quantity? Explain	Understand	13
9	When the outlet temperatures of the fluids in a heat exchanger are not known, is it still practical to use the LMTD method? Explain.	Remember	12
10	What are the common approximations made in the analysis of heat exchangers?	Remember	13
11	What is a heat exchanger? What are its applications?	Understand	12
12	Give the three broad classes of heat exchangers?	Remember	12
13	What is direct contact type heat exchanger? Give examples?	Remember	13
14	What is compact Heat exchanger, what are its applications?	Understand	13
15	What do you understand by mixed flow and unmixed flow?	Understand	13
16	What is multi pass heat exchanger? Where they are used?	Remember	13
17	Explain about storage type heat exchanger? What are its applications?	Understand	12
18	What are the different flow arrangements in recuperative heat exchangers?	Understand	13
19	Explain the operation of a plate heat exchanger? What are its applications?	Understand	13
20	Define effectiveness and NTU of a heat exchanger?	Remember	1 2
PART – B (LONG ANSWER QUESTIONS)			
1	Classify heat exchangers	Remember	12
2	What are the applications of heat exchangers..	Understand	13
3	What do you mean by fouling factor causes of fouling	Remember	13
4	What are shell and tube heat exchangers?	Understand	12
5	Derive LMTD for parallel flow heat exchangers	Remember	13
6	Derive LMTD for counter flow heat exchangers	Remember	12
7	Define effectiveness and NTU mmk of heat exchanger	Remember	13
8	Derive expression for effectiveness of parallel flow heat exchanger	Understand	13

S. No	Question	Blooms Taxonomy Level	Course Outcome
9	Derive expression for effectiveness of counter flow heat exchanger	Understand	12
10	Derive NTU of parallel flow and counter flow heat exchangers...	Understand	12
11	In the definition of effectiveness, explain why minimum heat capacity value (C_{\min}) is used for the maximum possible rate of heat transfer.	Remember	13
12	Show that for parallel flow heat exchanger $\epsilon = [1 - \exp(-NTU(1+R))]/[1+R]$	Remember	13
13	Show that for parallel flow heat exchanger $\epsilon = [1 - \exp(-NTU(1-R))]/[1 - R \exp(-NTU(1-R))]$	Remember	13
14	How are exit fluid temperature determined with the help of ϵ -NTU method?	Understand	12
15	When one of the two fluids undergoes phase change, show that the effectiveness values for both parallel flow and counter flow heat exchangers are equal and given by $\epsilon = 1 - \exp(-NTU)$	Remember	12
16	In an oil cooler, oil enters at 160°C . If the water entering at 35°C flows parallel to oil, the exit temperatures of oil and water are 90°C and 70°C respectively. Determine the exit temperatures of oil and water if the two fluids in opposite directions. Assuming that the flow rates of the two fluids and U_0 remain unaltered. What would be the minimum temperatures to which oil could be cooled in parallel flow and counter flow operations?	Understand	13
17	In an open heart surgery under hypothermic conditions, the patient's blood is cooled before the surgery and re warmed afterwards. It is proposed that a concentric tube counter flow heat exchanger of length 0.5m is to be used for this purpose, with a thin-walled inner tube having a diameter of 55mm. If water at 60°C and 0.1kg/s is used to heat blood entering the exchanger and the heat flow rate. Take $U_0 = 500\text{W/m}^2\text{K}$, c_p of blood = 3.5kJ/kg K and c_p of water 4.183kJ/kgK .	Understand	13
18	A flow of 0.1kg/s of exhaust gases at 700K from a gas turbine is used to preheat the incoming air, which is at the ambient temperature of 300K. It is desired to cool the exhaust to 400K and it is estimated that an overall heat coefficient of $30\text{W/m}^2\text{K}$ can be achieved in an appropriate exchanger. Determine the area required for a counter flow heat exchanger. Take the specific heat of exhaust gasses the same as for air, which is 1000J/kgK .	Understand	13
19	After a long time in service, a counter flow oil cooler is checked to ascertain if its performance has deteriorated due to fouling. In the heat transfer surface is 3.33m^2 and the design value of the overall heat transfer coefficient is $930\text{W/m}^2\text{K}$, how much has it been reduced by fouling? C_p of oil as 2330J/kg K and c_p of water as 4174J/kgK .	Remember	12
20	A brass ($k = 111\text{W/mK}$) condenser tube has a 30mm outer diameter and 2mm wall thickness. sea water enters the tube at 290K and the saturated low pressure steam condenses on the outer side of the tube. The inside and outside heat transfer coefficients are estimated to be 4000 and $8000\text{W/m}^2\text{K}$, respectively and a fouling resistance of $10^{-4}\text{(W/m}^2\text{K)}$ on the water side is expected. Estimate the overall heat transfer coefficient based on inside area.	Understand	12
PART – C (ANALYTICAL QUESTIONS)			
1	A chemical having specific heat of 3.3kJ/kgK flowing at the rate of 20000kg/h enters a parallel flow heat exchanger at 120°C . The flow rate of cooling water is 50000kg/h with an inlet temperature of 20°C . The	Understand	12

S. No	Question	Blooms Taxonomy Level	Course Outcome
	heat transfer area is 10m^2 and the overall heat transfer coefficient is $1050\text{W}/\text{m}^2\text{K}$. Find (i) the effectiveness of the heat exchanger, (ii) the outlet temperatures of water and chemical. Take for water $c_p=4.186\text{kJ}/\text{kgK}$		
2	In a double-pipe counter flow heat exchanger the inner tube has a diameter of 20mm and very little thickness. The inner diameter of the outer tube is 30mm. Water flows through the inner tube at a rate of 0.5kg/s and the oil flows through the shell at a rate of 0.8kg/s. Take the average temperatures of the water and the oil as 47°C and 80°C respectively and assume fully developed flow. Determine the overall heat transfer coefficient. Given for water at 47°C , $\rho=0.637\text{W}/\text{mK}$, $\nu=0.59\times 10^{-6}\text{m}^2/\text{s}$ and $\text{Pr}=3.79$. For oil at 80°C , $\rho=852\text{kg}/\text{m}^3$, $k=0.138\text{W}/\text{mK}$, $\nu=37.5\times 10^{-6}\text{m}^2/\text{s}$ and $\text{Pr}=490$.	Understand	12
3	The condenser of a large steam power plant is a shell-and-tube heat exchanger having a single shell and 30000 tubes, with each tube making two passes. The tubes are thin-walled with 25mm diameter and steam condenses on the outside of the tubes with $h_o=11\text{kW}/\text{m}^2\text{K}$. The cooling water flowing through the tubes is 30000kg/s and the heat transfer rate is 2GW. Water enters at 20°C while steam condenses at 50°C . Find the length of the tubes in one pass. Properties of water at 27°C are $c_p=4.18\text{kJ}/\text{kgK}$, $\mu=855\times 10^{-6}\text{Ns}/\text{m}^2$, $k=0.613\text{W}/\text{mK}$ and $\text{Pr}=5.83$	Understand	13
4	A double-pipe (shell-and-tube) heat exchanger is constructed of a stainless steel ($k= 15.1 \text{ W}/\text{m} \cdot ^\circ\text{C}$) inner tube of inner diameter $D_i = 1.5 \text{ cm}$ and outer diameter $D_o = 1.9 \text{ cm}$ and an outer shell of inner diameter 3.2 cm. The convection heat transfer coefficient is given to be $h_i=800\text{W}/\text{m}^2 \cdot ^\circ\text{C}$ on the inner surface of the tube and $h_o =1200 \text{ W}/\text{m}^2 \cdot ^\circ\text{C}$ on the outer surface. For a fouling factor of $R_{f,i} = 0.0004 \text{ m}^2 \cdot ^\circ\text{C}/ \text{W}$ on the tube side and $R_{f,o} = 0.0001 \text{ m}^2 \cdot ^\circ\text{C}/ \text{W}$ on the shell side, determine (a) the thermal resistance of the heat exchanger per unit length and (b) the overall heat transfer coefficients, U_i and U_o based on the inner and outer surface areas of the tube, respectively	Understand	13
5	Steam in the condenser of a power plant is to be condensed at a temperature of 30°C with cooling water from a nearby lake, which enters the tubes of the condenser at 14°C and leaves at 22°C . The surface area of the tubes is 45 m^2 , and the overall heat transfer coefficient is $2100\text{W}/\text{m}^2 \cdot ^\circ\text{C}$. Determine the mass flow rate of the cooling water needed and the rate of condensation of the steam in the condenser.	Understand	13

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