



INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

AERONAUTICAL ENGINEERING

TUTORIAL QUESTION BANK

Course Title	HEAT TRANSFER				
Course Code	AAE515				
Programme	B. Tech				
Semester	V	AE			
Course Type	Professional Elective				
Regulation	IARE - R16				
Course Structure	Theory			Practical	
	Lectures	Tutorials	Credits	Laboratory	Credits
	3	1	4	-	-
Chief Coordinator	Dr. P Srinivasa Rao, Professor				
Course Faculty	Dr. P Srinivasa Rao, Professor				

COURSE OBJECTIVES

The course should enable the students to:	
I	Understand the basic modes of heat transfer like conduction, convection and radiation with and without phase change in solid liquids and gases.
II	Design and analyze thermal fluidic components in engineering systems to energy mechanisms (in the form of heat transfer) for steady and unsteady state.
III	Conduct experiments in laboratories and analyze the results with theoretical ones to evolve research oriented projects in the field of heat transfer as well as propulsion.
IV	Apply the concepts of heat transfer with convective mode in internal and external flows involved in engineering components and work in real time problems in Industry.

COURSE OUTCOMES (COs)

The course should enable the students to:	
CO1	Describe the basic concept of the mechanism of heat transfer and understand the law of energy exchange in heat transfer mechanisms. (Problem solving)
CO2	Derive and formulate the mathematical models for steady state heat transfer phenomenon and comprehend the applicability to different surfaces and geometries. (Problem solving)
CO3	Understand the concept heat convection and its forms like free and forced convection. (Problem solving)

CO4	Explore the concept of Boundary layer and derivation of empirical relations; also understand the concept of condensation and boiling. (Problem solving)
CO5	Understand the concept of Radiation heat transfer. Introduction to the methods of solving real time problems.

COURSE LEARNING OUTCOMES

Students, who complete the course, will have demonstrated the ability to do the following:

AAE016.01	Understand basic concepts of heat transfer modes, Fourier Law and First law of thermodynamics.
AAE016.02	Remember the basic laws of energy involved in the heat transfer mechanisms.
AAE016.03	Understand the physical system to convert into mathematical model depending upon the mode of Heat Transfer.
AAE016.04	Understand the thermal response of engineering systems for application of Heat Transfer mechanism in both steady and unsteady state problems.
AAE016.05	Understand heat transfer process and systems by applying conservation of mass and energy into a system.
AAE016.06	Understand the steady state condition and mathematically correlate different forms of heat transfer
AAE016.07	Analyse finned surfaces, and assess how fins can enhance heat transfer
AAE016.08	Remember dimensionless numbers which are used for forced and free convection phenomena.
AAE016.09	Understand the applications of Buckingham Pi Theorem in deriving various non dimensional numbers and their applications in heat transfer
AAE016.10	Remember and use the methodology presented in tutorial to solve a convective heat transfer problems
AAE016.11	Understand the various forms of free and forced convection and the application of the sAAE in day to day problems
AAE016.12	Calculate local and global convective heat fluxes using Nusselt's Theory.
AAE013.13	Understand the method to evolve hydrodynamic and thermal boundary layers applied mathematically to vertical plates and Tubes
AAE016.14	Understand the physical mechanisms of phase change involving pool, nucleate and film boiling processes
AAE016.15	Understand Nusselt's theory of condensation for the application in film and dropwise condensation
AAE016.16	Correlate the empirical relations in terms of vertical and horizontal cylinders during film condensation
AAE016.17	Understand the concepts of black and gray body radiation heat transfer.
AAE016.18	Understand the concept of shape factor and evolve a mechanism for conductive radiation shields
AAE016.19	Understand the various classifications of heat exchangers based on arrangement and correlate the effects of fouling
AAE016.20	Understand the LMTD and NTU methods and apply the sAAE for solving real time problems in heat exchangers

TUTORIAL QUESTION BANK

S. No	Question	Blooms Taxonomy Level	Course Outcome	Course Learning Outcome
UNIT-I				
BASIC CONCEPTS				
Part - A (Short Answer Questions)				
1	How does the science of heat transfer differ from the science of Thermodynamics?	Understand	CO 1	AAE016.01
2	What are the different modes of heat transfer?	Remember	CO 1	AAE016.02
3	What is heat flux? How is it related to the heat transfer rate?	Remember	CO 1	AAE016.02
4	Define Fourier's law of heat conduction?	Understand	CO 1	AAE016.01
5	How are heat, internal energy, and thermal energy related to each other?	Remember	CO 1	AAE016.03
6	Define thermal conductivity and explain its significance in heat transfer?	Understand	CO 1	AAE016.01
7	What are the factors affecting the thermal conductivity?	Remember	CO 1	AAE016.02
8	How does heat conduction differ from convection?	Remember	CO 1	AAE016.02
9	How does forced convection differ from natural convection?	Remember	CO 1	AAE016.02
10	Which is a better heat conductor, diamond or silver? Support your answer.	Remember	CO 1	AAE016.01
11	State the laws of heat transfer?	Understand	CO 1	AAE016.01
12	What is thermal diffusivity and explain its significance?	Understand	CO 1	AAE016.01
13	Define the thermal conductance and thermal resistance of a given system?	Remember	CO 1	AAE016.02
14	Define thermal conductivity. How can it be determined experimentally?	Remember	CO 1	AAE016.01
15	Why are metals good thermal conductors, while non metals are poor conductors of heat?	Understand	CO 1	AAE016.01
16	Explain the initial and boundary conditions?	Remember	CO 1	AAE016.02
17	Write the three dimensional heat conduction equations in Cartesian coordinates?	Understand	CO 1	AAE016.01
18	What is Newton's law of cooling?	Remember	CO 1	AAE016.02
19	Define Stefan Boltzmann Law?	Remember	CO 1	AAE016.02
20	What is meant by one dimensional heat conduction?	Remember	CO 1	AAE016.02
Part - B (Long Answer Questions)				
1	Describe different types of boundary conditions applied to heat conduction problem?	Understand	CO 1	AAE016.03
2	How many boundary conditions are needed to solve a second-order differential equation of heat conduction?	Remember	CO 1	AAE016.04
3	Does any of the energy of the sun reach the earth by conduction or convection? Explain.	Remember	CO 1	AAE016.05
4	Derive general conduction equation in Cartesian coordinates and cylindrical coordinates.	Remember	CO 1	AAE016.04
5	Draw the temperature profile for steady-state conduction through a material with constant thermal conductivity?	Understand	CO 1	AAE016.04
6	The surface temperature of the sun is approximately 5500°C. Assuming the sun to be perfect radiator, estimate the radiation heat flux from the sun?	Understand	CO 1	AAE016.05
7	List out some examples for natural convection and forced convection?	Understand	CO 1	AAE016.05
8	Briefly explain the laws of heat transfer and give the importance in the quantitative analysis of problems?	Understand	CO 1	AAE016.03
9	Explain the concept of thermal resistance. On what parameters thermal resistance depend upon?	Remember	CO 1	AAE016.05
10	Why metals are good thermal conductors, while non-metals are poor conductors of heat? Explain with an example.	Understand	CO 1	AAE016.03

11	Explain the concept of overall heat transfer coefficient. Represent a thermal circuit with conduction and convection.	Understand	CO 1	AAE016.04
12	Differentiate between steady and transient heat conduction?	Remember	CO 1	AAE016.03
13	List out the special forms of the heat conduction equation?	Understand	CO 1	AAE016.03
14	Differentiate between diffusion and mass transfer?	Understand	CO 1	AAE016.04
15	Explain the heat transfer process for practical interest which involves change of phase?	Remember	CO 1	AAE016.02
16	Explain about the combined mechanism of heat transfer?	Understand	CO 1	AAE016.01
17	Write a brief note on concept of driving potential?	Remember	CO 1	AAE016.02
18	Write some of the typical values of convective heat transfer coefficients?	Understand	CO 1	AAE016.02
19	What are super conductors and explain them with examples?	Understand	CO 1	AAE016.04
20	What is thermal radiation and explain different types of thermal radiation?	Remember	CO 1	AAE016.05

Part - C (Problem Solving and Critical Thinking Questions)

1	A stainless steel plate 2cm thick is maintained at a temperature of 550°C at one face and 50°C on the other. The thermal conductivity of stainless steel at 300°C is 19.1 W/mK. Compute the heat transferred through the material per unit area.	Understand	CO 1	AAE016.03
2.	A flat plate of length 1m and width 0.5m is placed in an air stream at 30°C blowing parallel to it. The convective heat transfer coefficient is 30 W/m ² K. Calculate the heat transfer if the plate is maintained at a temperature of 300°C.	Understand	CO 1	AAE016.05
3	A radiator in a domestic heating system operates at a surface temperature of 55°C. Determine the rate at which it emits radiant heat per unit area if it behaves as a black body.	Understand	CO 1	AAE016.05
4	If the combustion chamber wall is made up of Firebrick (k=0.145W/mK, ε=0.85) and is 1.45 cm thickness, Compute the overall heat transfer coefficient for the following data. Gas temperature 800 ⁰ C, Wall temperature on gas side =798 ⁰ C, Film conductance on gas side 40W /m ² K, Film conductance on coolant side 10 W/m ² K, Radiation shape factor between wall and gas is 1.	Remember	CO 1	AAE016.04
5	An insulated pipe of 50mm outside diameter (ε=0.8) is laid in a room at 30°C. If the surface temperature is 250°C and the convective heat transfer coefficient is 10 W/m ² K, calculate the heat loss per unit length of pipe.	Remember	CO 1	AAE016.04
6	An immersion water heater of surface area 0.1m ² and rating 1kW is designed to operate fully submerged in water. Estimate the surface temperature of the heater when the water is at 40°C and the heat transfer coefficient is 300 W/ m ² K. If this heater is by mistake used in air at 40°C with h=9 W/ m ² K, what will be its surface temperature?	Understand	CO 1	AAE016.03
7	Derive the general differential equation for heat conduction in Cartesian coordinate system with neat sketch?	Understand	CO 1	AAE016.03
8	Derive the heat conduction equation in cylindrical coordinate system with neat sketch?	Understand	CO 1	AAE016.03
9	Derive the heat conduction equation in spherical coordinate system with neat sketch?	Remember	CO 1	AAE016.04
10	Explain about the initial and boundary conditions with the different types of boundary conditions?	Understand	CO 1	AAE016.05

**UNIT-II
ONE DIMENSIONAL STEADY STATE AND TRANSIENT CONDUCTION**

Part - A (Short Answer Questions)

1	Define overall heat transfer coefficient?	Understand	CO 2	AAE016.06
2	What is critical radius of insulation or critical thickness?	Understand	CO 2	AAE016.06
3	Explain about Stefan Boltzmann constant?	Understand	CO 2	AAE016.05
4	Explain about moist heating method?	Remember	CO 2	AAE016.07

5	What are extended surfaces and what is the other nAAE for them?	Remember	CO 2	AAE016.07
6	Define fin efficiency and effectiveness?	Understand	CO 2	AAE016.07
7	What is meant by steady state heat conduction?	Remember	CO 2	AAE016.06
8	What is meant by transient heat conduction or unsteady state conduction?	Remember	CO 2	AAE016.06
9	What is a composite system?	Remember	CO 2	AAE016.06
10	Give the significance of Newtonian heating or cooling process?	Remember	CO 2	AAE016.06
11	Explain about multi-dimensional conduction?	Understand	CO 2	AAE016.06
12	Define Biot number?	Remember	CO 2	AAE016.06
13	Explain the significance of Fourier number?	Understand	CO 2	AAE016.06
14	What is non periodic heat flow?	Understand	CO 2	AAE016.06
15	What is meant by lumped heat analysis?	Remember	CO 2	AAE016.06
16	What is a semi-infinite solid?	Remember	CO 2	AAE016.06
17	What is an infinite solid?	Remember	CO 2	AAE016.06
18	What are heisler charts	Remember	CO 2	AAE016.06
19	What is critical thickness of insulation on a small diameter wire or pipe?	Understand	CO 2	AAE016.06
20	What is meant by heat balance integral?	Remember	CO 2	AAE016.06
Part - B (Long Answer Questions)				
1	Derive one dimensional steady state conduction equation in case of slab	Understand	CO 2	AAE016.06
2	Define the overall heat transfer coefficient? Obtain the expression for composite wall with three layers with convective conditions over the wall.	Remember	CO 2	AAE016.06
3	Distinguish between steady state conduction and unsteady state conduction.	Remember	CO 2	AAE016.06
4	Develop an expression for temperature distribution in a slab made of single material.	Remember	CO 2	AAE016.06
5	Describe the temperature distribution along the length of a fin for four various boundary conditions at tip.	Remember	CO 2	AAE016.06
6	Explain the heat transfer analysis in composite wall.		CO 2	AAE016.06
7	Explain briefly (i)Fin effectiveness (ii) Fin efficiency	Remember	CO 2	AAE016.07
8	Derive the expression for heat transfer in fins in case of Rectangular plate fin of uniform cross section.	Understand	CO 2	AAE016.07
9	Derive the expression for heat transfer in fins in case of insulated end.	Remember	CO 2	AAE016.07
10	Derive the equation for steady-state heat transfer through a spherical shell of inner radius r_1 and outer radius r_2 and compare the result with the solution obtained for a thick walled cylinder.	Remember	CO 2	AAE016.07
11	Derive an expression for the heat loss per square metre of the surface area for a furnace wall when the thermal conductivity varies with temperature according to the relation, $K = a + bT^2$	Remember	CO 2	AAE016.06
12	What is critical thickness of insulation on a small diameter wire or pipe. Explain its physical significance?	Understand	CO 2	AAE016.05
13	Define Biot number and Fourier number .What is their importance in heat transfer. Explain.	Remember	CO 2	AAE016.05
14	What are Heisler charts? Explain their significance in solving transient conduction problem.	Remember	CO 2	AAE016.06
15	Derive an expression for the heat flow rate through a hollow sphere of ID d_1 and OD d_2 whose internal and external surfaces are maintained at temperatures T_1 and T_2 respectively. The thermal conductivity varies linearly with temperature from k_1 at T_1 to k_2 at T_2 .	Remember	CO 2	AAE016.06
16	“It is true that insulation is provided to reduce heat transfer rate but due to insulation heat transfer rate is not reduced always” Justify the statement analytically.	Remember	CO 2	AAE016.06
17	Enumerate steps for solving long cylinders using heislier charts	Remember	CO 2	AAE016.04

18	Enumerate steps for heat transfer analysis in slabs using heisler charts.	Understand	CO 2	AAE016.05
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.	Remember	CO 2	AAE016.06
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 vapour 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	Remember	CO 2	AAE016.06

Part – C (Problem Solving and Critical Thinking Questions)

1	A Hollow heat cylinder with $r_1=30$ mm and $r_2=50$ 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.	Remember	CO 2	AAE016.06
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 .	Remember	CO 2	AAE016.05
3	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 10 W/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	Remember	CO 2	AAE016.05
4	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	CO 2	AAE016.06
5	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	CO 2	AAE515.06
6	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 150 W/Mk . The base temperature is 100°C and the fluid is 20°C .	Understand	CO 2	AAE016.07

	The heat transfer coefficient between the fin and the fluid is $30\text{W/m}^2\text{K}$			
7	A copper fin ($k=396\text{ W/Mk}$) 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	CO 2	AAE016.07
8	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 40 W/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	CO 2	AAE016.07
9	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 first immersed in oil and when they reach 200°C .	Understand	CO 2	AAE016.07
10	A large steel ingot, which has been uniformly heated to 750 degree Celsius, is hardened by quenching it in an oil bath that is maintained at 25 degree Celsius. What length of time is required for the temperature to reach 600 degree Celsius at a depth of 1 cm ? Thermal diffusivity for the steel ingot is $1.21 \times 10^{-5}\text{ m}^2/\text{s}$. The ingot may be approximated as a flat plate	Understand	CO 2	AAE016.07

UNIT-III
CONVECTIVE HEAT TRANSFER

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?	Understand	CO 3	AAE016.10
2	What is the physical significance of the Nusselt number? How is it defined	Understand	CO 3	AAE016.12
3	Define incompressible flow and incompressible fluid. Must the flow of a compressible fluid necessarily be treated as compressible?	Remember	CO 3	AAE016.08
4	How does turbulent flow differ from laminar flow? For which flow is the heat transfer coefficient higher?	Remember	CO 3	AAE016.10
5	What is the physical significance of the Reynolds number? How is it defined for external flow over a plate of length L ?	Understand	CO 3	AAE016.11
6	What is turbulent thermal conductivity? What is it caused by?	Understand	CO 3	AAE016.10
7	State Newton's law of cooling Is the acceleration of a fluid particle necessarily zero in steady flow? Explain.	Understand	CO 3	AAE016.10
8	What are the advantages of non-dimensionalizing the convection equations?	Remember	CO 3	AAE016.10
9	How is Reynolds analogy expressed? What is the value of it? What are its limitations?	Understand	CO 3	AAE016.12
10	What is drag? What causes it? Why do we usually try to minimize it?	Remember	CO 3	AAE016.10
11	What is natural convection? How does it differ from forced convection? What force causes natural convection currents?	Remember	CO 3	AAE016.10
12	In which mode of heat transfer is the convection heat transfer Coefficient usually higher, natural convection or forced convection? Why?	Remember	CO 3	AAE016.10
13	How does the Rayleigh number differ from the Grashoff number?	Remember	CO 3	AAE016.12

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	CO 3	AAE016.12
15	Show that the volume expansion coefficient of an ideal gas is $1/T$, where T is the absolute temperature.	Understand	CO 3	AAE016.10
16	Why are finned surfaces frequently used in practice? Why are the finned surfaces referred to as heat sinks in the electronics industry?	Understand	CO 3	AAE016.10
17	When is natural convection negligible and when is it not negligible in forced convection heat transfer?	Understand	CO 3	AAE016.09
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?	Remember	CO 3	AAE016.09
19	Under what conditions does natural convection enhance forced convection, and under what conditions does it hurt forced convection?	Understand	CO 3	AAE016.10
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	CO 3	AAE016.10
Part – B (Long Answer Questions)				
1	Differentiate between Newtonian and Non Newtonian fluids. Give examples.	Understand	CO 3	AAE016.08
2	What is boundary layer thickness what do you mean by laminar and turbulent boundary layers.	Remember	CO 3	AAE016.09
3	What is critical Reynolds number for flow over flat plate? Explain.	Remember	CO 3	AAE016.12
4	Define local and mean heat transfer coefficient. On what factors 'h' value depends on?	Understand	CO 3	AAE016.10
5	A metal plate 0.609m in height forms the vertical wall of an oven and is at a temperature of 171°C . Within the oven is air at a temperature of 93.4°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°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	CO 3	AAE016.11
6	A 0.15m outer diameter steel pipe lies 2m vertically and 8m horizontally in a large room with an ambient temperature of 30°C . The pipe surface is at 250°C and has an emissivity of 0.60. Estimate The total rate of heat loss from the pipe to the atmosphere.	Understand	CO 3	AAE016.11
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°C for bismuth are: $\rho=104\text{kg/m}^3$, $c_p=150.7\text{J/kgK}$, $k=13.02\text{W/Mk}$.	Understand	CO 3	AAE016.11
8	Explain the concept of Nusselt's theory of laminar flow.	Understand	CO 3	AAE016.12
9	Explain the conditions for which Dittus-Boelter equation can be used to determine heat transfer coefficient	Remember	CO 3	AAE016.12
10	What is Rayleigh number? Discuss the nature of flow with respect to it.	Understand	CO 3	AAE016.12
11	What do you mean by hydrodynamic entry length?	Remember	CO 3	AAE016.10
12	Give the steps to find heat transfer in natural convection.	Remember	CO 3	AAE016.10
13	Air at 1atm and 30 C is forced through a horizontal 30mm diameter 0.5m Long at an average velocity of 0.25m/s. The tube	Understand	CO 3	AAE016.11

	wall is maintained at 1370C. Calculate (a) the heat transfer coefficient and (b) percentage error if the calculation is made strictly on the basis of laminar forced convection.			
14	Engine oil at 60°C flows over the upper surface of a 5-m-long flat plate whose temperature is 20°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	CO 3	AAE016.11
15	A square plate 0.4mx0.4m maintained at a uniform temperature of $T_w = 400K$ 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 $x=0.4m$),(b)the average heat coefficient over the entire length by using theoretical analysis .Properties of air at 350 K are $\nu=2.075 \times 10^{-6} m^2/s$, $Pr=0.697$ and $k= 0.03W/Mk$.	Understand	CO 3	AAE016.11
16	A 2.2cmouterdiameter pipe is to cross a river at a 30mwide section while being completely immersed in water The average flow velocity of water is 4 m/s and the water temperature is 150C. Determine the drag force exerted on the pipe by the river.	Understand	CO 3	AAE016.11
17	Give the steps to find heat transfer in natural convection.	Understand	CO 3	AAE016.11
18	Air at 1atm and 30 ⁰ C is forced through a horizontal 30mm diameter0.5m 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	CO 3	AAE016.11
19	Engine oil at 60°C flows over the upper surface of a 5-m-long flat plate whose temperature is 20°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	CO 3	AAE016.11
20	A square plate 0.4mx0.4m maintained at a uniform temperature of $T_w= 400K$ 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 $x=0.4m$),(b)the average heat coefficient over the entire length by using theoretical analysis .Properties of air at 35 ⁰ K are $\nu=2.075 \times 10^{-6} m^2/s$, $Pr=0.697$ and $k= 0.03W/mK$.	Understand	CO 3	AAE016.11
Part - C (Problem Solving and Critical Thinking Questions)				
1	Nitrogen gas at 0 ⁰ C is flowing over a 1. 2m long,2m wide plate maintained at 80 ⁰ C with a velocity of 2.5m/s., $\rho=1.142kg/m^3$, $c_p=1.04kJ/kgK$, $\nu=15.63 \times 10^{-6} m^2/s$ and $k=0.0262W/mK$. Find (a) The average coefficient and (b) the total heat transfer from the plate.	Understand	CO 3	AAE016.11
2	Water at 10 ⁰ C flows over a flat plate (at 90 ⁰ C) measuring 1mx1m, with a velocity of 2m/s. properties of water at 50 ⁰ C are $\rho =988.1^{0}C$, $\nu=0.556 \times 10^{-6} m^2/s$, $Pr=3.54$ and $k=0.648W/mK$. Find: (a) The length of plate over which the flow is laminar, (b) the rate of heat transfer from the entire plate.	Understand	CO 3	AAE016.11
3	Water flows through a 20mm ID at a rate of 0.01kg/s entering at10 ⁰ 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 ⁰ 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	Understand	CO 3	AAE016.11

	25 ⁰ C are: $\rho=997\text{kg/m}^3$, $c_p=4180\text{J/kgK}$, $\nu=910\times 10^{-6}\text{Ns/m}^2$ and $k=0.608\text{W/mK}$.			
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 $c_p=4.187\text{kJ/kgK}$	Remember	CO 3	AAE016.11
5	Atmospheric pressure air at 100 ⁰ centers a 0.04m dia 2m long tube with 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.	Remember	CO 3	AAE016.11
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 ⁰ C enters a 1cm dia tube with a velocity of 3.5m/s. $T_w=30^0\text{C}$, constant. Find The tube length required to cool the oil to 45 ⁰ C.	Remember	CO 3	AAE016.11
7	For the flow system in which air at 27 ⁰ C and 1atm flows over a flat 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.	Understand	CO 3	AAE016.11
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 $Pr=0.681$, $\mu=2.57\times 10^{-5}\text{kg/ms}$, $k=0.0386\text{W/mK}$ and $c_p=1.025\text{kJ/kgK}$.	Understand	CO 3	AAE016.13
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.	Remember	CO 3	AAE016.11
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 $\rho=995.7\text{kg/m}^3$, $c_p=4.174\text{kJ/kgK}$, $k=61.718\times 10^{-2}\text{W/mK}$, $\nu=0.805\times 10^{-6}\text{m}^2/\text{s}$ 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.	Remember	CO 3	AAE016.11

UNIT-IV
HEAT TRANSFER WITH PHASE CHANGE

Part - A (Short Answer Questions)

1	What is the difference between evaporation and boiling?	Understand	CO 4	AAE016.14
2	What is the difference between sub cooled and saturated boiling?	Understand	CO 4	AAE016.14
3	NAAE the different boiling regimes in the order they occur in a vertical tube during flow boiling.	Understand	CO 4	AAE016.14
4	Why drop wise condensation is preferred to film wise condensation?	Remember	CO 4	AAE016.15

5	In condensate flow, how is the wetted perimeter defined? How does wetted perimeter differ from ordinary perimeter	Understand	CO 4	AAE016.15
6	What are the differences between drop wise and film wise condensation?	Remember	CO 4	AAE016.15
7	What is condensation? How does it occur?	Remember	CO 4	AAE016.15
8	How does the presence of a non-condensable gas in a vapour influence the condensation heat transfer?	Remember	CO 4	AAE016.16
9	What are the types of condensation processes? Explain.	Remember	CO 4	AAE016.15
10	Discuss some methods of enhancing pool boiling heat transfer permanently.	Remember	CO 4	AAE016.14
11	What is an electromagnetic wave? How does it differ from a sound wave?	Understand	CO 4	AAE016.14
12	Define irradiation and radiosity.	Understand	CO 4	AAE016.17
13	What are the various radiation properties?	Remember	CO 4	AAE016.17
14	Define radiation shape factor	Understand	CO 4	AAE016.18
15	Discuss some methods of enhancing pool boiling heat transfer permanently.	Understand	CO 4	AAE016.14
16	Define the properties emissivity and absorptivity. When are these two properties equal to each other?	Remember	CO 4	AAE016.17
17	What is a gray body? How does it differ from a blackbody? What is a diffuse gray surface?	Remember	CO 4	AAE016.17
18	What does the view factor represent? When is the view factor from a surface to itself not zero?	Understand	CO 4	AAE016.18
19	What are the summation rule and the superposition rule for view factors?	Remember	CO 4	AAE016.17
20	What are the two methods used in radiation analysis? How do these two methods differ?	Remember	CO 4	AAE016.17
Part – B (Long Answer Questions)				
1	What are the assumptions to be considered for analysis of laminar film condensation?	Understand	CO 4	AAE016.15
2	Why the condenser tubes are horizontal	Understand	CO 4	AAE016.15
3	What is nucleate boiling explain	Understand	CO 4	AAE016.16
4	Derive the expression for condensation heat transfer.	Understand	CO 4	AAE016.16
5	Explain different regimes of boiling heat transfer phenomena.	Understand	CO 4	AAE016.15
6	Sketch the film wise condensation on a vertical wall showing film thickness, velocity and temperature profiles	Understand	CO 4	AAE016.15
7	Why the condenser tubes are horizontal?	Remember	CO 4	AAE016.15
8	What is nucleate boiling? Explain.	Understand	CO 4	AAE016.16
9	Explain the term film boiling. Write in detail about Film boiling.	Understand	CO 4	AAE016.16
10	Write the correlations for boiling heat transfer in case of nucleate boiling.	Remember	CO 4	AAE016.15
11	Differentiate between different types of condensers.	Understand	CO 4	AAE016.16
12	Write correlations for condensation heat transfer.	Understand	CO 4	AAE016.16
13	Explain what do you mean by absorptivity, reflectivity and transmissivity	Understand	CO 4	AAE016.17
14	Write expression for blackbody radiation	Understand	CO 4	AAE016.17
15	What is the Stefan-Boltzmann Law? Explain the concept of total emissive power of a surface?	Understand	CO 4	AAE016.17
16	Explain in brief the concept of a black body.	Understand	CO 4	AAE016.17
17	State the Planck's law. Write down the expression for the radiation intensity.	Remember	CO 4	AAE016.18
18	Distinguish between film wise and drop wise condensation. Which of the two does give a higher heat transfer coefficient? Why?	Remember	CO 4	AAE016.16
19	Derive expression for radiant energy between two small gray surfaces	Understand	CO 4	AAE016.17
20	Write expression for monochromatic emissive power	Remember	CO 4	AAE016.18

Part - C (Problem Solving and Critical Thinking Questions)				
1	A cylindrical cement tube of radii 0.05 cm and 1.0 cm has a wire embedded into it along its axis. To maintain a steady temperature difference of 120 degree Celsius between the inner and outer surfaces, a current of 5 ampere is made to flow in the wire. Find the amount of heat generated per meter length. Take resistance of wire equal to 0.1 ohm per cm of length	Understand	CO 4	AAE016.16
2	An electric cable of aluminum ($k = 240 \text{ W/m degree}$) is to be insulated with rubber ($k = 6 \text{ W/square meter degree}$). If the cable is in air ($h = 6 \text{ W/square meter degree}$). Find the critical radius?	Understand	CO 4	AAE016.16
3	A Vertical plate 300mm wide and 1.2m high is maintained at 7°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	CO 4	AAE016.15
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	Remember	CO 4	AAE016.16
5	A spherical vessel of 0.5 m outside diameter is insulated with 0.2 m thickness of insulation of thermal conductivity 0.04 W/m degree . The surface temperature of the vessel is -195°C and outside air is at 10°C . Determine heat flow per m^2 based on inside area	Remember	CO 4	AAE016.16
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 30 cm, determine (a) the rate of heat transfer to the water and (b) the rate of evaporation of water	Remember	CO 4	AAE016.15
7	A black body emits radiation at 200°K . 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	CO 4	AAE016.17
8	A pipe of outside diameter 20 mm is to be insulated with asbestos which has a mean thermal conductivity of 0.1 W/m degree . The local coefficient of convective heat to the surroundings is $5 \text{ W/square meter degree}$. Find the critical radius of insulation for optimum heat transfer from pipe?	Understand	CO 4	AAE016.14
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	CO 4	AAE016.17
10	Two black discs 1m in diameter are placed directly opposite to each A cable of 10 mm outside is to be laid in an atmosphere of 25°C ($h = 12.5 \text{ W/m}^2 \text{ degree}$) and its surface temperature is likely to be 75°C due to heat generated within it. How would the heat flow from the cable be affected if it is insulated with rubber having thermal conductivity $k = 0.15 \text{ W/m degree}$?	Understand	CO 4	AAE016.17

**UNIT- V
HEAT EXCHANGERS**

Part - A (Short Answer Questions)

1	What is a heat exchanger?	Understand	CO 5	AAE016.19
2	Define effectiveness of heat exchanger.	Understand	CO 5	AAE016.19
3	Describe the selection criteria of heat exchanger.	Understand	CO 5	AAE016.19
4	What is the range of effectiveness of a heat exchanger?	Remember	CO 5	AAE016.19
5	What is a heat exchanger? What are its applications?	Understand	CO 5	AAE016.19

6	Discuss the advantage of NTU method over the LMTD method.	Remember	CO 5	AAE016.20
7	What is LMTD correction factor?	Remember	CO 5	AAE016.19
8	How are heat exchangers classified?	Remember	CO 5	AAE016.19
9	What is meant by open and closed heat exchanger?	Remember	CO 5	AAE016.19
10	What is meant by Regenerators?	Remember	CO 5	AAE016.19
11	What are the types of heat exchangers according to flow	Understand	CO 5	AAE016.19
12	What is meant by parallel flow heat exchangers?	Understand	CO 5	AAE016.19
13	What is meant by counter flow heat exchangers?	Remember	CO 5	AAE016.19
14	What is meant by cross flow heat exchangers?	Understand	CO 5	AAE016.19
15	What is meant by NTU?	Understand	CO 5	AAE016.20
16	What is effectiveness?	Understand	CO 5	AAE016.20
17	What is the purpose of a shell and tube heat exchanger?	Remember	CO 5	AAE016.19
18	What do you understand by mixed flow and unmixed flow?	Remember	CO 5	AAE016.19
19	What is a multi-pass heat exchanger? Where are they used?	Remember	CO 5	AAE016.19
20	Explain about storage type heat exchanger? What are its applications?	Remember	CO 5	AAE016.19
Part - B (Long Answer Questions)				
1	Derive an expression for LMTD in case of a counter – current flow double pipe heat exchanger.	Remember	CO 5	AAE016.19
2	Derive the equation for parallel flow heat exchanger using NTU method.	Remember	CO 5	AAE016.20
3	Describe the process followed in the design of a simple shell and tube heat exchanger.	Remember	CO 5	AAE016.19
4	Derive NTU of parallel flow and counter flow heat exchangers	Remember	CO 5	AAE016.20
5	Derive an expression for effectiveness of counter flow heat exchanger	Remember	CO 5	AAE016.19
6	How are heat exchangers classified? Why is a counter flow heat exchanger more efficient than a parallel flow exchanger?	Understand	CO 5	AAE016.19
7	Explain how heat exchangers are classified.	Understand	CO 5	AAE016.19
8	Discuss the general arrangement of parallel flow, counter flow and cross flow heat exchangers? And why is a counter flow heat exchanger more effective than a parallel flow exchanger?	Understand	CO 5	AAE016.19
9	Discuss the advantages of NTU method over the LMTD method of heat exchanger design.	Remember	CO 5	AAE016.20
10	Derive NTU of parallel flow and counter flow heat exchangers...	Understand	CO 5	AAE016.20
11	In the definition of effectiveness, explain why the minimum heat capacity value (C_{\min}) is used for the maximum possible rate of heat transfer.	Remember	CO 5	AAE016.19
12	Show that for parallel flow heat exchanger $\epsilon = [1 - \exp(-NTU(1+R))] / [1+R]$	Remember	CO 5	AAE016.20
13	Show that for parallel flow heat exchanger $\epsilon = [1 - \exp(-NTU(1-R))] / [1 - R \exp(-NTU(1-R))]$	Remember	CO 5	AAE016.20
14	How are exit fluid temperatures determined with the help of ϵ -NTU method?	Understand	CO 5	AAE016.20
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	CO 5	AAE016.20
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 flow 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	CO 5	AAE016.19
17	In an open heart surgery under hypothermic conditions, the patient's blood is cooled before the surgery and re-warmed	Understand	CO 5	AAE016.19

	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 ⁰ 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 .			
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 for air, Which is 1000J/kgK .	Understand	CO 5	AAE016.19
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	CO 5	AAE016.19
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	CO 5	AAE016.19
Part - C (Problem Solving and Critical Thinking Questions)				
1	A hot fluid enters a heat exchanger at a temperature of 200 ⁰ C at a flow rate of 2.8 kg/sec (sp. heat 2.0 kJ/kg-K) it is cooled by another fluid with a mass flow rate of 0.7 kg/sec (Sp. heat 0.4 kJ/kg-K). The overall heat transfer coefficient based on outside area of 20 m ² is 250 W/m ² -K. Calculate the exit temperature of hot fluid when fluids are in parallel flow.	Understand	CO 5	AAE016.19
2	It is required to design a shell and tube heat exchanger for heating 9000 kg/hr of water from 15 ⁰ C to 88 ⁰ C by hot engine oil ($C_p = 2.35\text{kJ/kg-K}$) flowing through the shell of the heat exchanger. The oil makes a single pass, entering at 150 ⁰ C and leaving at 95 ⁰ C with an average heat transfer coefficient of 400 W/m ² -K, the water flow through 10 thin walled tubes of 25mm diameter with each tube making 8 passes through the shell. The heat transfer efficient on the water side is 3000 W/m ² -K. Find the length of the tube required for the heat exchanger.	Understand	CO 5	AAE016.19
3	In a counter flow double pipe heat exchanger, water is heated from 25 ⁰ C to 65 ⁰ C by oil with a specific heat of 1.45kJ/kg-K and mass flow rate of 0.9kg/s. the oil is cooled from 230 ⁰ C to 160 ⁰ C. If overall heat transfer coefficient is $420\text{W/m}^2\text{-K}$. Calculate the rate of heat transfer, mass flow rate of water and surface area of heat exchanger.	Understand	CO 5	AAE016.19
4	In a food processing plant, a brine solution is heated from 8 ⁰ C to 14 ⁰ C in a double pipe heat exchanger by water entering at 55 ⁰ C and leaving at 40 ⁰ C at the rate of 0.18kg/s. if the overall heat transfer coefficient is $800\text{W/m}^2\text{K}$, determine the area of heat exchanger required a) For a parallel flow arrangement, and b) For counter flow arrangement. Take c_p for water = 4.18kJ/kgK .	Understand	CO 5	AAE016.19

5	In a Double pipe counter flow heat exchanger 10000 kg/h of oil having a specific heat of 2095 J/kgK is cooled from 80 ⁰ C to 50 ⁰ C by 8000 kg/h of water entering at 25 ⁰ C. Determine the heat exchanger area for an overall heat transfer coefficient of 300 W/m ² K. Take C _p for water as 4180 J/kgK.	Understand	CO 5	AAE016.19
6	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 3.33 m ² and the design value of the overall heat transfer coefficient is 930 W/m ² K, how much has it been reduced by fouling? C _p of oil as 2330 J/kg K and c _p of water as 4174 J/kgK.	Understand	CO 5	AAE016.19
7	Calculate the heat transfer area required for a 1-1 shell and tube heat exchanger which is used to cool 55000 kg/hr of alcohol from 66 ⁰ C to 40 ⁰ C using 40,000 kg/hr of water entering at 5 ⁰ C. U = 580 W/m ² K, consider a) counter flow b) parallel flow. CP water = 4.18 × 10 ³ J/kg K Cp alcohol = 3.76 × 10 ³ J/kg K	Remember	CO 5	AAE016.19
8	Hot oil with a capacity rate of 2500 W/K flows through a double pipe heat exchanger. It enters at 360 ⁰ C and leaves at 300 ⁰ C. Cold fluid enters at 30 ⁰ C and leaves at 200 ⁰ C. If the overall heat transfer coefficient is 800 W/m ² K, determine the heat exchanger area required for (i) Parallel flow and (ii) Counter flow.	Understand	CO 5	AAE016.20
9	Saturated steam at 100 ⁰ C is condensing on the shell side of a shell-and-tube heat exchanger. The cooling water enters the tubes at 30 ⁰ C and leaves at 70 ⁰ C. Calculate the effective log mean temperature difference if the arrangement is (i) counter flow, (ii) parallel flow and (iii) cross flow.	Understand	CO 5	AAE016.20
10	Water enters a counter flow, double pipe heat exchanges at 15 ⁰ C, flowing at the rate of 1300 kg/h. It is heated by oil (C _p = 2 J/kg.K) flowing at the rate of 550 kg/h from the inlet temperature of 94 ⁰ C. For an area of 1 m ² an overall heat transfer coefficient of 1075 W/m ² K, determine the total heat transfer and the outlet temperatures of water and oil?	Understand	CO 5	AAE016.20
11	Water at the rate of 4080kg/h is heated from 35 ⁰ C to 75 ⁰ C by oil having a specific heat of 1900J/Kg K. The exchanger is of a counter flow double pipe design. The oil enters at 110 ⁰ C and leaves at 75 ⁰ C. Determine the area of the heat exchanger necessary to handle this load if the overall heat transfer coefficient is 320W/m ² K.	Understand	CO 5	AAE016.19
12	Hot coil having a specific heat of 2.09kJ/kgK flows through a counter flow heat exchanger at the rate of 2268kg/h with an inlet temperature of 93 ⁰ C and an outlet temperature of 65 ⁰ C. Cold oil having a specific heat of 1.67kJ/kg K flows in at a rate of 3600kg/h and leaves at 149 ⁰ C.What area is required to handle this load if the overall heat transfer coefficient based on the inside area is 0.7 kW/m ² K.	Understand	CO 5	AAE016.20

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