

JK LAKSHMIPAT UNIVERSITY, JAIPUR

INSTITUTE OF ENGINEERING AND TECHNOLOGY

End Term Examination (Regular/ Backlog), Nov.-Dec. 2015

B. Tech in Mechanical Engineering, Semester VII

Roll No.....

ME 729: Heat and Mass Transfer

Time: 3 hours

Max. Marks: 100

Instructions to students:

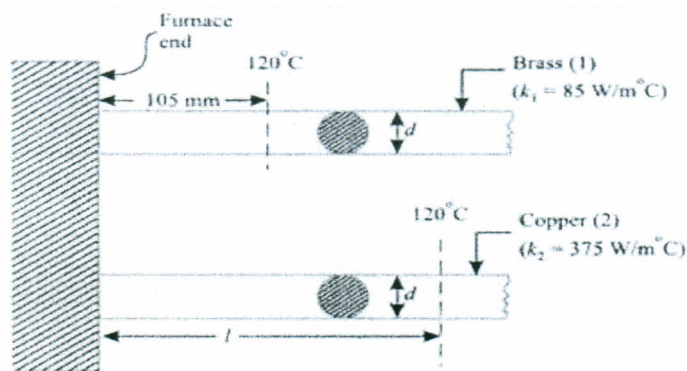
1. Do not write anything other than your roll number on question paper.
2. Assume suitable data wherever required and mention it clearly.
3. Writing appropriate units, nomenclature, and drawing neat sketches/schematics/ flow chart wherever, required are an integral part of the answer.

Q.1A Objective type multiple choice questions (10 questions @ 1 mark) 10

- i. A Plane wall is 25 cm thick with an area of 1 m^2 , and has a thermal conductivity of 0.5 W/mK . If a temperature difference of 60°C is imposed across it, what is the heat flow?
(a) 120 W (b) 140 W (c) 160 W (d) 180 W
- ii. A composite wall having three layers of thickness 0.3m, 0.2m and 0.1m and of thermal conductivities 0.6, 0.4 and 0.1 W/mK , respectively, is having surface area 1 m^2 . If the inner and outer temperatures of the composite wall are 1840K and 340K, respectively, what is the rate of heat transfer?
(a) 150 W (b) 1500 W (c) 75W (d) 750W
- iii. Stanton number is the ratio of nusselt number to
(a) Reynolds number (b) Prandlt number
(c) product of reynolds and prandlt number (d) none of these
- iv. Calculate the prandlt number for engine oil at 60°C with $\mu = 8.36 \times 10^{-2} \text{ kg/ms}$, $C_p = 2035 \frac{\text{J}}{\text{kg K}}$, $k = 0.141 \frac{\text{W}}{\text{mK}}$.
(a) 1150 (b) 1007 (c) 1207 (d) 1250
- v. In pool boiling, the highest heat transfer coefficient occurs in
(a) Subcooled boiling zone (b) nucleate boiling zone
(c) Partial film boiling zone (d) film boiling zone
- vi. Nucleation or bubble formation in nucleate boiling requires liquid to be
(a) superheated (b) saturated (c) subcooled (d) in the boiling regime
- vii. Two spheres A and B of same material have radii 1m and 4m and temperature 4000K and 2000K respectively, which one of the following statement is correct?
The energy radiated by sphere A is
(a) greater than that of sphere B
(b) less than that of sphere B
(c) equal to that of sphere B
(d) equal to double that of sphere B

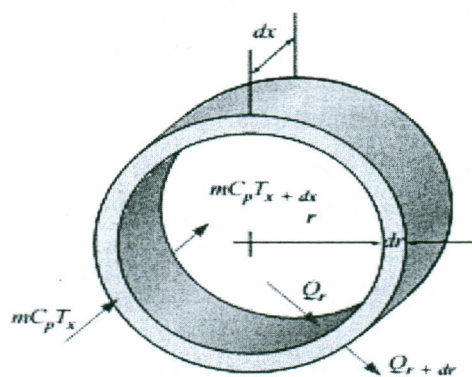
- viii. An outer wall of a furnace is at T_w kelvins and it faces an environment at T_e , the wall's average convective heat transfer coefficient h is $4 \text{ W/m}^2 \text{ K}$. for radiative heat transfer the walls emissivity is equals 0.8. The ratio of net heat loss by radiation to heat loss by convection from the wall is closet to
- (a) $5\sigma \frac{T_w^4 - T_e^4}{T_w - T_e}$ (b) $2.5\sigma \frac{T_w^4 - T_e^4}{T_w - T_e}$ (c) $0.5\sigma \frac{T_w^4 - T_e^4}{T_w - T_e}$ (d) $0.2\sigma \frac{T_w^4 - T_e^4}{T_w - T_e}$
- ix. In a counter flow heat exchanger,
For the hot fluid
 Heat capacity = 2 kJ/kg K ; mass flow rate = 5 kg/sec ; Inlet temperature = 150°C ; Outlet temperature = 100°C ;
For the cold fluid
 Heat capacity = 4 kJ/kg K ; mass flow rate = 10 kg/sec ; Inlet temperature = 20°C ;
 Neglecting heat transfer to the surrounding, find outlet temperature of the cold fluid in $^\circ\text{C}$.
 (a) 7.5 (b) 32.5 (c) 45.5 (d) 70
- x. In a condenser water enters at 30°C and flows at the rate 1500 kg/hr . The condensing steam is at a temperature of 120°C and cooling water leaves the condenser at 80°C . Specific heat of water is 4.187 kJ/kg K . If the overall heat transfer coefficient is $2000 \text{ W/m}^2\text{K}$, then the heat transfer area is
 (a) 0.707 m^2 (b) 7.07 m^2 (c) 70.7 m^2 (d) 141.4 m^2

Q.2	Short answer type questions (4 questions @ 2.5 marks)	10
(a)	The surface of a blackbody is at 500 K temperature. Obtain the total emissive power, the wavelength of the maximum monochromatic emissive power.	
(b)	Differentiate between film condensation and dropwise condensation.	
(c)	A bulb of diameter 10 cm (d) is heated internally with an electric heater of 100 W (Q). The bulb dissipates the heat to the atmosphere by convection. The convection heat transfer coefficient between the air and the bulb (h) is $65 \text{ W/m}^2\text{C}$. If the atmosphere is at 35°C (T_a), determine the bulb surface temperature (T_s).	
(d)	Define Stefan-boltzmann law and emissivity.	
Q.3A	Write the significance of the following: (a) Reynolds number (b) Nusselt number (c) Prandlt number (d) Rayleigh number	05
Q.3B	What is boiling? Differentiate between pool boiling and forced boiling? Explain pool boiling curve with neat sketch.	05
Q.4A	Derive the expression for temperature distribution, under one dimensional steady state heat conduction for the Composite plane wall consisting of three layers.	05
Q.4B	Two long rods of the same diameter, one made of brass ($k = 85 \text{ W/m}^\circ\text{C}$) and other made of copper ($k=375 \text{ W/m}^\circ\text{C}$) have one of their ends inserted into the furnace. Both of the rods are exposed to the same environment. At a distance 105mm away from the furnace end, the temperature of the brass rod is 120°C . At what distance from the furnace end the same temperature would be reached in the copper rod?	05



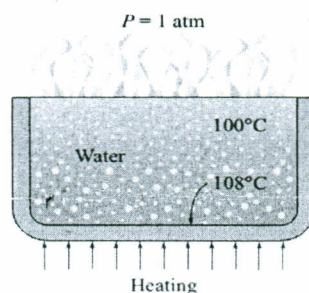
Q.5A Consider Forced convection steady laminar flow of a fluid in a circular tube of radius R . The fluid properties ρ , k , and C_p are constant, and the work done by viscous stresses is negligible. The fluid flows along the x -axis with velocity V . The flow is fully developed so that is independent of x and thus $V = V(r)$. Derive an energy equation for a differential volume element.

05



Q.5B 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.

05



Q.6A A room is heated by initiating fire at the fireplace. The exfiltration of room air through a chimney is reduced by the use of a glass door fire screen of height 0.8m and width of 1.1m. If the ambient air temperature is 25°C and the surface temperature attained by the glass is 175°C , calculate the free convection heat transfer rate from the fire place to the room. For this room following correlation given by Churchill and Chu is valid:

10

$$Nu = \left[0.825 + \frac{0.387 (Gr.Pr)^{1/6}}{[1 + (0.492/Pr)^{9/16}]^{8/27}} \right]^2$$

The thermo-physical properties of air at 100°C are:

$$k = 3.208 \times 10^{-2} \text{ W/m}^2\text{°C}, \nu = 23.13 \times 10^{-6} \text{ m}^2/\text{s}, Pr = 0.688$$

Q.7A In a concentric counter flow heat exchanger, water flows through the inner tube at 25°C and leaves at 42°C. The engine oil enters at 100°C and flows in the annular flow passage. The exit temperature of the engine oil is 50°C. Mass flow rate of water and the engine oil are 1.5 kg/s and 1 kg/s, respectively. The specific heat of water and oil are 4.178 J/Kg K and 2130 J/kgK, respectively. Calculate the effectiveness of the heat exchanger. 05

Q.7B Calculate the rate of heat loss from a human body which may be considered as a vertical cylinder 30 cm in diameter, and 175 cm high while standing in a 30 km/hr wind at 15°C. The surface temperature of the human is 35°C. At the mean film temperature ($t_f = 25^\circ\text{C}$), thermophysical properties of air are: 05

$$\nu = 15.33 \times 10^{-6} \frac{\text{m}^2}{\text{s}}; k = 0.0263 \text{ W/m-deg}; Pr = 0.7$$

OR

Q.7B A wire of radius 3mm and 1.25m length is to be maintained at 60°C by insulating it by a material of thermal conductivity 0.175 W/mK. The temperature of surrounding air is 20°C with heat transfer coefficient 8.5 W/m²K. For maximum heat dissipation, determine the minimum thickness of insulation and the heat loss. 05

Q.8A Write the importance of heat exchangers in the industry. How they are classified? Derive an expression for log mean temperature difference (LMTD) for parallel flow in double pipe heat exchanger. 10

Q.9A A vertical flat plate in the form of fin is 600 m in height and is exposed to steam at atmospheric pressure. If the surface of the plate is maintained at 60°C, calculate the following: 10

- The film thickness at the trailing edge of the film
- The overall heat transfer coefficient
- The heat transfer rate
- The condensate mass flow rate

Assume laminar flow conditions and unit width of the plate.

{ Given data:

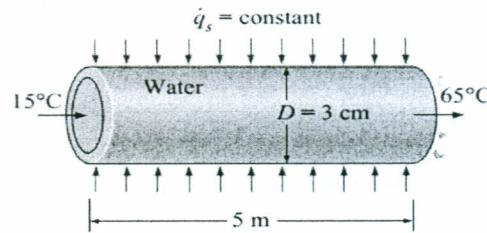
The properties of vapour at atmospheric pressure are:

$$t_{sat} = 100^\circ\text{C}, h_{fg} = 2257 \text{ kJ/kg}; \rho_v = 0.596 \text{ kg/m}^3.$$

The properties of saturated vapour at the mean film temperature $t_f = \frac{100 + 60}{2} = 80^\circ\text{C}$ are:

$$\rho_l = 971.8 \text{ kg/m}^3, k = 67.413 \times 10^{-2} \text{ W/m}^2\text{°C}, \mu = 355.3 \times 10^{-6} \text{ Ns/m}^2 \text{ or kg/ms}$$

- Q.9B Water is to be heated from 15 °C to 65°C as it flows through a 3 cm internal diameter and 5 m long tube. The tube is equipped with an electric resistance heater that provides uniform heating throughout the surface of the tube. The outer surface of the heater is well insulated, so that in steady operation all the heat generated in the heater is transferred to the water in the tube. If the system is to provide hot water at a rate of 10 L/min, determine the power rating of the resistance heater. Also estimate the inner surface temperature of the tube at the exit. 10



OR

- Q.9B (a) Define intensity of radiation and prove that the intensity of normal radiation is $1/\pi$ times the total emissive power. 07 + 03 = 10
 (b) A black body of 0.2 m² area has an effective temperature of 800 K. Calculate
 (i) The total rate of energy emission
 (ii) The intensity of the normal radiation
 (iii) The wavelength of maximum monochromatic emissive power.

----- GOOD LUCK -----