B.E. Mechanical Engineering (Model Curriculum) Semester-V

PCCME301 - Heat Transfer

P. Pages : 3 **GUG/W/23/14068**

Time : Three Hours Max. Marks : 80

Notes : 1. All questions carry marks as indicated.
2. Assume suitable data wherever necessary.
3. Illustrate your answers wherever necessary with the help of neat sketches.
4. Use of slide rule, Steam tables, Drawing instruments, Thermodynamic tables for moist air and non-programmable Electronic calculator and Heat transfer data book is allowed.
5. Q. 1 or Q. 2, Q. 3 or Q. 4, Q. 5 or Q. 6, Q. 7 or Q. 8, Q. 9 or Q. 10.

1. a) State Fourier's law of heat conduction? Derive expression for temperature distribution under 1-dimensional steady state heat conduction for plane wall? **6**

b) A flat wall of a furnace is made up of fire brick, insulating brick and building brick of thicknesses 25 cm. 12.5 cm and 25 cm respectively. The inside wall is at a temperature of 600ºC and the atmospheric temperature is 20ºC. If the heat transfer coefficient for the outside surface is $10\,W/m^{2}{}^{o}C$, calculate: **10**

i) That loss per m^2 of wall area;
ii) Temperature of the outside wall surface of the furnace.

Take : $k_{fire\,brick} = 1.4\,W/m^{o}C$; $k_{insulating\,brick} = 0.2W/m^{o}C$.

$k_{building\,brick} = 0.8W/m^{o}C$

OR

2. a) A steam pipe of 160 mm inside diameter and 5 mm thick (k = 58 W/mºC) is covered with first layer of insulating material 30 mm thick $(k = 0.17W/m^{o}C)$ and second layer of insulating material 50 mm thick (k = 0.093 W/mºC). The temperature of steam passing through the pipe is 300ºC and ambient air temperature surrounding the pipe is 30ºC. Taking inner and outer heat transfer coefficients 30 and 5.8 W/m^2 ºC respectively. Find the heat lost per metre length of pipe. **10**

b) Define critical thickness of insulation and Obtain the condition for critical thickness of radius in case of cylinder? **6**

3. a) A plane wall (k = 15 W/mºC) 100 mm thick generate heat at the rate of $4\times10^{4}\,W/m^{3}$ when an electric current is passed through it. The convective heat transfer coefficient between each face of the wall and the ambient air is 50 W/m^2 ºC. If the ambient air temperature is 20ºC. Determine the surface temperature and maximum temperature in the wall. **8**

b) It is required to heat oil to about 350ºC for frying purpose. A laddel is used in the frying. The section of the handle is $4mm\times15\,mm$. The surroundings are at 35ºC. The conductivity of the material is 210 W/mºC. If the temperature at a distance of 400 mm from the oil should not reach 45ºC, determine the convective heat transfer coefficient. **8**

OR

4. a) The temperature of the air stream in a tube is measured with the help of a thermometer placed into a protective well filled with oil. The thermometer well is made of a steel tube (k = 55.8 W/m°C). 120 mm long and 1.5 mm thick. The surface heat transfer coefficient from the air to the protective well is 23.3 W/m^2 °C and the temperature recorded by the thermometer is 84°C. It the temperature at the base of the well is 40°C, what is the measurement error? **8**

b) A solid copper sphere of 10 cm diameter $\left[\rho = 8954\,\text{kg/m}^3, c_p = 383\,\text{J/kg K}, k = 386\,\text{W/m K}\right]$, initially at a uniform temperature $t_i = 250^\circ\text{C}$, is suddenly immersed in a well-stirred fluid which is maintained at a uniform temperature $t_a = 50^\circ\text{C}$. The heat transfer coefficient between the sphere and the fluid is $h = 200\,\text{W/m}^2\text{K}$. Determine the temperature of the copper block at $\tau = 5\,\text{min}$ after the immersion. **8**

5. a) A horizontal pipe of 10 cm outside diameter carrying steam is exposed to air at 25°C. The outside surface temperature of steam pipe is 155°C and emissivity is 0.8. Estimate the heat loss from pipe per unit length by convection and radiation mode of heat transfer? Use the Nusselt number relation given below. $\left(R_a = G_r.P_r\right)$. **8**

$$\overline{Nu} = \left[0.6 + \frac{0.387\left(Ra\right)^{1/6}}{\left\{1+\left(\frac{0.559}{Pr}\right)^{9/16}\right\}^{8/27}}\right]^2$$

b) Air is flowing over a plate $4\text{m} \times 2\text{m}$ with a velocity of 5 m/s at 15°C. IF $\rho = 1.208\ \text{kg/m}^3$ and $\nu = 1.47 \times 10^{-5}\,\text{m}^2/\text{s}$, calculate: **8**

i) Length of plate over which the boundary layer is laminar and thickness of the laminar boundary layer.
ii) Shear stress at the location where boundary layer ceases to be laminar and
iii) Total force and both sides on that portion of plate where boundary layer is laminar.

OR

6. a) Define and explain the significance of following dimensionless numbers: **4**
i) Reynolds Number.
ii) Pradtl Number
iii) Grashoff Number

b) Explain with boiling curve, various regimes of saturated pool boiling? **6**

c) A horizontal tube of outer diameter 20 mm is exposed to dry steam at 100°C. The tube surface temperature is maintained at 84°C by circulating water through it. Calculate the rate of formation of condensate per metre length of the tube. **6**

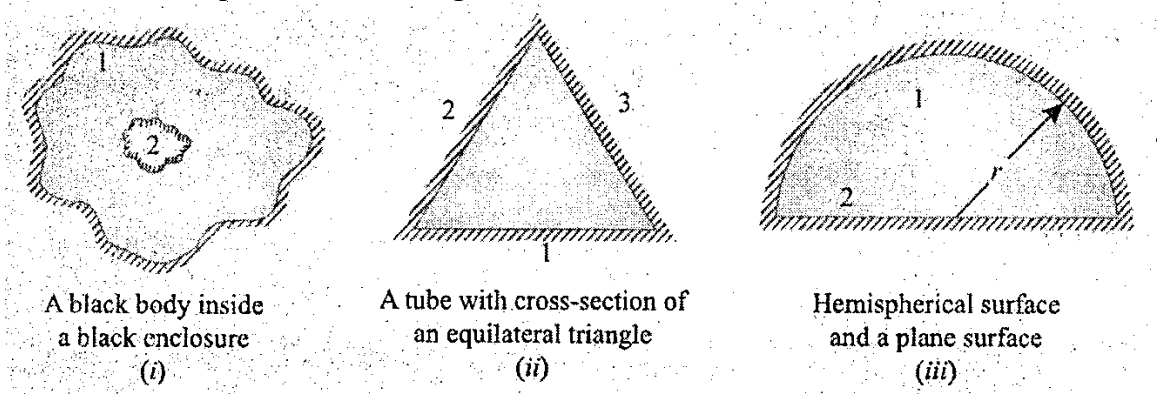
7. a) Define Radiation mode of heat transfer and state Stefan Boltzmann law? **4**

b) What is black body? State the properties of black body? **6**

c) State Plank's and Wien's displacement law? **6**

OR

8. a) Calculate the shape factor for configuration shown below? **8**



A black body inside a black enclosure (*i*)

A tube with cross-section of an equilateral triangle (*ii*)

Hemispherical surface and a plane surface (*iii*)

b) Two large parallel plates with $\varepsilon = 0.5$ each, are maintained at different temperatures and are exchanging heat only by radiation. Two equally large radiation shields with surface emissivity 0.05 are introduced in parallel to the plates. Find the percentage reduction in net radiative heat transfer. **8**

9. a) Derive an expression for LMTD in case of parallel flow heat exchangers? **8**

b) The flow rates of hot and cold water streams running parallel through a heat exchanger are 600 kg/h and 1500 kg/h respectively. The inlet temperatures on the hot and cold sides are 70ºC and 25ºC respectively. The exit temperature of hot water is 50ºC. If the individual heat transfer coefficients on both sides are $700\,W/m^2{}^oC$, calculate the area of the heat exchanger. **8**

Take cp of water = 4.2 kJ/kg ºC

OR

10. a) Write a short note on. **6**

a) Compact heat exchanger

b) Fouling in a heat exchanger

b) A chemical having specific heat of 3.3 kJ/kg flowing at the rate of 20000 kg/h enters a parallel flow heat exchanger at 120ºC. The flow rate of cooling water is 50000 kg/h with an inlet temperature of 20ºC. The heat transfer area is $10\,m^2$ and the overall heat transfer coefficient is $1050\,W/m^2K$. **10**

Find:

i) The effectiveness of the heat exchanger.

ii) The outlet temperature of water and chemical.

Take specific heat of water as 4.2 kJ/kgºC

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