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

PCCME301 : Heat Transfer

P. Pages : 3 **GUG/W/22/14068**

Time : Three Hours * 3 2 9 7 * Max. Marks : 80

Notes :
1. All questions carry equal marks.
2. Due credit will be given to neatness and adequate dimensions.
3. Assume suitable data wherever necessary.
4. Illustrate your answer wherever necessary with the help of neat sketches.
5. Use of slide rule, Logarithmic Tables, Steam Tables, Molder's Chart, Drawing instruments Thermodynamic tables for moist air, Psychometric Chart and Refrigeration charts is permitted.
6. Solve Q1 or Q2, Q3 or Q4, Q5 or Q6, Q7 or Q8, Q9 or Q10.

1. a) Derive the general heat conduction equation in Cartesian co-ordinate system? **8**

b) The interior of a refrigerator having inside dimensions 0.5 m x 0.5 m base area and height 1 m, is to be maintained at 6ºC. Refrigerator walls are made of 2 mild steel sheet 3 mm thick (k = 46 W/mK) with 50 mm glass wool insulation between them (k = 0.05 W/mK). If average heat transfer coefficients at outer and inner surface are 11.6 and 14.5 W/m^2 K respectively. Calculate:- **8**

i) The rate at which heat is removed from interior to keep specified temperature in the kitchen at 25ºC.

ii) Temperature on the outer surface of the metal sheet.

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 = 0.17 W/mºC) and second layer of insulating material 50 mm thick (k = 0.093 W/mºC). The temperature of steam passing through the pipe is 300 ºC and the ambient air temperature surrounding the pipe is 30 ºC. Taking inner and outer heat transfer coefficients 30 and 5.8 W/m^2 ºC respectively, find the heat lost per meter length of pipe? **12**

b) Obtain the relation that represents the condition for minimum resistance and consequently maximum heat flow rate for cylinder? **4**

3. a) The rate of heat generation in a slab of thickness 160 mm (k = 180 W/m) is 1.2x10^6 W/m^3. If the temperature of each of the surface of solid is 120ºC. Determine temperature and the heat flow rate at the mid plane? **6**

b) An electric motor drives a centrifugal pump which circulates a hot liquid metal at 480ºC. The motor is coupled to the pump impeller by horizontal steel shaft (k = 32 W/m ºC) 25 mm in diameter. If the ambient air temperature is 20 ºC. The temperature of the motor is limited to a maximum value of 55ºC and heat transfer coefficient between the steel shaft and the ambient air is 14.8 W/m^2 ºC, what length of the shaft should be specified between the motor and the pump? **10**

OR

4. a) Obtain the temperature distribution equation in the body/solid for Newtonian heating or cooling? **6**

b) A copper slab (density = 9000 kg/m^3, c = 380 J/kg. ºC, k = 370 W/m ºC) measuring 400 mm x 400 mm x 5 mm has a uniform temperature of 250ºC. its temperature is suddenly lowered to 30 ºC. Calculate the time required for the plate to reach the temperature of 90 ºC. Assume convective heat transfer coefficient as 90 W/m^2 ºC. **10**

5. a) Air at 20 ºC and atmospheric pressure flows at a velocity of 4.5 m/s past a flat plate with a sharp edge. The entire plate surface is maintained at a temperature of 60ºC. Assuming that the transition occurs at critical Reynolds number of $5x10^5$, find the distance from the leading edge at which the flow in the boundary layer changes from laminar to turbulent. At the location calculate the following:-
i) Thickness of hydrodynamic boundary layer,
ii) Thickness of thermal boundary layer,
iii) Local and Avg. convective heat transfer coefficients,
iv) Heat transfer rate from both sides for unit width of the plate? **8**

b) Nuclear reactor with its core constructed of parallel vertical plates 2.25 m high and 1.5 m wide has been designed on free convection heating of liquid bismuth. Metallurgical considerations limit the maximum surface temperature of the plate to 975 ºC. Estimate the maximum possible heat dissipation from both sides of each plate.
The appropriate correlation for the convection coefficient is Nu = 0.13 $(Gr. Pr)^{1/3}$ **8**

OR

6. a) Explain with boiling curve, various regimes of saturated pool boiling? **8**

b) Steam condenser consisting of square array of 625 horizontal tubes, each 6 mm in diameter installed at the exhaust hood of steam turbine and are exposed to saturated steam at a pressure of 15 kPa. If tube surface is maintained at 25ºC. Calculate :- i) Heat transfer coefficient, ii) Rate at which steam is condensed per unit length of the tube. **8**
Corresponding to 15 kPa pressure, the properties of vapour (from the table) are:

$$t_{sat} = 54^{o}C,\ \rho_v = 0.098\ kg/m^3,\ h_{fg} = 2373\ kJ/kg.$$

$$\rho_\ell = 992\ kg/m^3;\ \mu = 663x10^{-6}\ Ns/m^2;\ k = 0.631\ W/m^{o}C$$

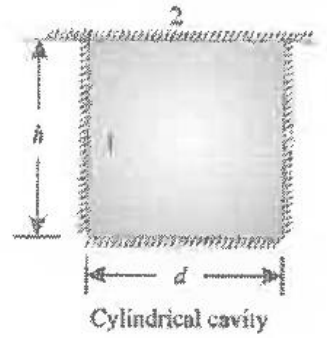
7. a) Define the following terms- **6**
i) Total emissive power,
ii) Monochromatic emissive power,
iii) Emissivity.

b) State and prove Kirchoff's law of radiation? **4**

c) What is black body how does it differ from gray body? What are the properties of black body? **6**

OR

8. a) Define shape factor in relation to radiation heat exchange by radiation? Derive the expression for shape factor of cavities enclosed on its surface by flat surface. Also calculate net radiative heat transfer from the cavities as shown in fig. if h = 20 cm, d = 15 cm, temperature of surface inside cavity = 400 ºC, and emissivity of each cavity surface = 0.8 **8**



Cylindrical cavity

b) Consider 2 large parallel plates one at temperature 727ºC with emissivity 0.8 and other at temperature 227ºC with emissivity 0.4. An aluminum radiation shield with an emissivity of 0.05 on both sides placed between the plates. Calculate the percentage reduction in heat transfer rate between 2 plates as a result of the shield. **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 through the heat exchangers are 600 kg/h and 500 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 heat exchanger. **8**

OR

10. a) Write a note on compact heat exchanger? **4**

b) A counter flow heat exchanger is employed to cool 0.55 kg/sec $\left(c_p = 2.4 \text{ kJ/kg } ^\circ\text{C}\right)$ of oil from 115ºC to 40ºC by water. The inlet and outlet temperatures of cooling water are 15ºC and 75ºC respectively. Overall heat transfer coefficient is expected to be 1450 W/m^2 ºC. Using NTU method calculate the following:- **12**

i) Mass flow rate of water,
ii) Effectiveness of heat exchanger,
iii) Surface area required.

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