B.E. (Fire Engineering) Fourth Semester (C.B.S.)

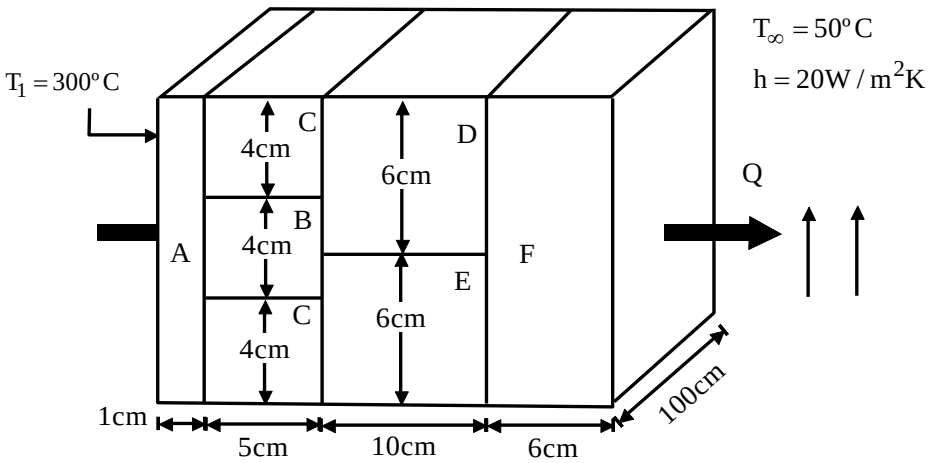
Heat & Mass Transfer

P. Pages : 4 **NIR/KW/18/3952**

Time : Three Hours Max. Marks : 80

Notes :
1. All questions carry marks as indicated.
2. Solve Question 1 OR Questions No. 2.
3. Solve Question 3 OR Questions No. 4.
4. Solve Question 5 OR Questions No. 6.
5. Solve Question 7 OR Questions No. 8.
6. Solve Question 9 OR Questions No. 10.
7. Solve Question 11 OR Questions No. 12.
8. Due credit will be given to neatness and adequate dimensions.
9. Assume suitable data whenever necessary.
10. Diagrams and chemical equations should be given whenever necessary.
11. Illustrate your answers whenever necessary with the help of neat sketches.
12. Use of non programmable calculator is permitted.
13. Use of Heat Transfer Design Data Book and Steam table is permitted.

1. Consider a 5m high and 8m long and 0.22m thick wall whose representation is shown in fig. (1). The thermal conductivity of various materials used are $K_A = K_F = 2, K_B = 8$, $K_C = 20, K_D = 15$ and $K_E = 35\,W/mK$. The left surface of the wall is maintained at uniform temperatures of 300ºC. The right surface is exposed to convection environment at 50ºC with $h = 20\,W/m^2K$. Determine (a) one dimensional heat transfer rate through the wall, (b) temperature at the point where section B, D & E meet, and (c) temperature drop across the section F. **14**



OR

2. a) An aluminum pipe carries steam at 110ºC. The pipe $(K = 185\,W/m^oC)$ has an inner diameter of 100mm and outer diameter of 120mm. The pipe is located in a room where the ambient air temperature is 30ºC and the convective heat transfer coefficient between the pipe and air is $15\,W/m^{2o}C$. Determine the heat transfer rate per unit length of pipe. **8**

To reduce the heat loss from the pipe, it is covered with a 50mm thick layer of insulation $(K = 0.20\,W/m^oC)$. Determine the heat transfer rate per unit length from the insulated pipe. Assume that the convective resistance of the steam is negligible.

b) Explain the concept of overall heat transfer coefficient and thermal conductivity. **6**

3. a) Discuss the concept of critical thickness of insulation for sphere. **5**

b) An electric cable, 8mm in diameter is covered by plastic sheathing $(K = 0.18\,W/mK)$. The surface temperature of cable was observed as 50ºC when it is exposed to air at 20ºC with convective coefficient of $12.0\,W/m^2K$. Calculate **8**

i) the thickness of insulation to keep the wire as cool as possible, and

ii) Surface temperature of insulated cable, if the intensity of current flowing the conductor remains unchanged.

OR

4. a) Explain fin effectiveness and fin efficiency. **6**

b) Superheated steam at 330ºC is flowing at 20 m/s velocity $(h = 110\,W/m^2{}^oC)$ through a pipe 120 mm in diameter. The temperature of steam is to be measured by putting a pocket in the pipe of 15 mm diameter (inside) and 1mm wall thickness. The thermal conductivity of the material of the pocket is $50\,W/m^oC$. **7**

i) Determine the length of insertion so that thermometric error is 0.5 percent. Find also the temperature measured if the pipe wall temperature is 40ºC.

ii) What will be the actual error in temperature measurement in ºC if the depth of immersion is 55 mm only and the pipe wall temperature is 40ºC?

5. a) Explain the significance of Biot and Fourier number. **4**

b) A 6 cm diameter, steel ball is at uniform temperature of 800ºC. It is to be hardened by suddenly dropping it into an oil bath at a temperature of 50ºC with convection coefficient of $500\,W/m^2K$. If the quenching occurs when the ball reaches a temperature of 100ºC, determine how long the ball should be kept in the oil bath. **9**

If 100 balls are to be quenched per minute, determine the rate at which the heat must be removed from the oil bath in order to maintain the bath temperature at 50ºC.

Take thermophysical properties as :

$K = 61\,W/mK,\ \rho = 7850\,kg/m^3,\ C = 460\,J/kg\,K$.

OR

6. a) What do you mean by hydrodynamic and thermal boundary layers? Explain with reference to flow over a flat heated plate. **6**

b) A cylindrical body of 300mm diameter and 1.6m height is maintained at a constant temperature of 36.5ºC. The surrounding temperature is 13.5ºC. Find out the amount of heat to be generated by the body per hour if $\rho = 1.025\,kg/m^3,\ C_p = 0.96\,kJ/kg^oC$, $\nu = 15.06\times10^{-6}\,m^2/s, K = 0.0892\,kJ/m-h-^oC$ and $\beta = \frac{1}{298}K^{-1}$. **7**

Assume $Nu = 0.12\,(Gr.Pr)^{1/3}$.

7. a) Explain the physical significance of Reynolds number and Nusselt number. **6**

b) Air at 20ºC and at atmospheric pressure flows over a flat plate at a velocity of $1.8\,m/s$. If the length of the plate is 2.2 m and is maintained at 100ºC, calculate the heat transfer rate per unit width using (i) exact and (ii) approximate methods. The properties of air at mean bulk temperature of $(100+20)/2 = 60^{o}C$ are : **8**

$\rho = 1.06\,kg/m^3$, $C_p = 1.005\,kJ/kg^{o}C$

$K = 0.02894\,W/m^{o}C$, $Pr = 0.696$

$\nu = 18.97 \times 10^{-6}\,m^2/s$

OR

8. A chemical having specific heat of $3.3\,kJ/kg\,k$ 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 $1050\,W/m^2K$. Find **14**

i) The number of transfer unit
ii) The effectiveness of the heat exchanger.
iii) The outlet temperature of water and chemical.
Take for water, specific heat = 4.186 kJ/kg k.

9. a) Distinguish between filmwise and dropwise condensation with the help of neat sketch. **6**

b) A steam condenser consisting of a square array of 625 horizontal tubes, each 6mm in diameter, is installed at the exhaust hood of a steam turbine. The tubes are exposed to saturated steam at a pressure of 15 kPa. If the tube surface temperature is maintained at 25ºC, Calculate : **7**

i) The heat transfer coefficient, and
ii) The rate at which steam is condensed per unit length of the tubes.
Assume film condensation on the tubes and absence of non – condensable gases.

OR

10. a) Explain Regimes of pool boiling with neat labelled sketch. **5**

b) Vertical flat plate in the form of fin is 600 m in height and is exposed to steam at atmospheric pressure. If surface of the plate is maintained at 60ºC. Calculate the following: **8**

i) The film thickness at the trailing edge of the film.
ii) The overall heat transfer coefficient.
iii) The heat transfer rate and
iv) The condensate mass flow rate.
Assume laminar flow conditions and unit width of the plate.

11. a) Explain the terms : **6**

i) Planck's law

ii) Wein's displacement law

iii) Stefan Boltzmann law

b) Assuming the sun (diameter = $1.4\times10^{9}\,m$) as a black body having a surface temperature of 5750 K and at a mean distance of $15\times10^{10}\,m$ from the earth (diameter = $12.8\times10^{6}\,m$), estimate the following : **7**

i) The total energy emitted by the sun,

ii) The emission received per m^2 just outside the atmosphere of the earth.

iii) The total energy received by the earth if no radiation is blocked by the atmosphere of the earth, and

iv) The energy received by a $1.6\,m\times1.6\,m$ solar collector whose normal is inclined at 50º to the sun. The energy loss through the atmosphere is 42 percent & diffuse radiation is 22 percent of direct radiation.

OR

12. a) Write short note on **any three.** **6**

i) Radiation Shields

ii) Absorptivity, Reflectivity and Transmissivity

iii) Configuration Factor

iv) Concept of a Black Body.

b) An electric heating system is installed in the ceiling of a room 5m (length) x 5m (width) x 2.5m (height). The temperature of the ceiling is 315 K, whereas under equilibrium conditions the walls are at 295k. If the floor is non – sensitive to radiations and the emissivities of the ceiling and wall are 0.75 and 0.65 respectively, Calculate the radiant heat loss from the ceiling to the walls. **7**

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