VELAMMAL INSTITUTE OF TECHNOLOGY, PANCHETTI.

DEPARTMENT OF MECHANICAL ENGINEERING

ME6502- HEAT AND MASS TRANSFER

(Question Bank)

Unit-1 Conduction

Part-A

1. **State Fourier's Law of conduction.**
2. **Define Thermal Conductivity.**
3. **Write down the equation for conduction of heat through a slab or plane wall.**
4. **Write down the equation for conduction of heat through a hollow cylinder.**
5. **State Newton's law of cooling or convection law.**
6. **Write down the general equation for one dimensional steady state heat transfer in slab or plane wall with and without heat generation.**
7. **Define overall heat transfer co-efficient.**
8. **Write down the equation for heat transfer through composite pipes or cylinder.**
9. **What is critical radius of insulation (or) critical thickness?**
10. **Define fins (or) extended surfaces.**
11. **State the applications of fins.**
12. **Define Fin efficiency.**
13. **Define Fin effectiveness.**

Part -B

1. A wall is constructed of several layers. The first layer consists of masonry brick 20 cm. thick of thermal conductivity 0.66 W/mK, the second layer consists of 3 cm thick mortar of thermal conductivity 0.6 W/mK, the third layer consists of 8 cm thick lime stone of thermal conductivity 0.58 W/mK and the outer layer consists of 1.2 cm thick plaster of thermal conductivity 0.6 W/mK. The heat transfer coefficient on the interior and exterior of the wall are 5.6 W/m^{2}K and 11 W/m^{2}K respectively. Interior room temperature is 22°C and outside air temperature is -5°C.

Calculate

a) **Overall heat transfer coefficient**
b) **Overall thermal resistance**
c) **The rate of heat transfer**
d) **The temperature at the junction between the mortar and the limestone.**

2. A furnace wall made up of 7.5 cm of fire plate and 0.65 cm of mild steel plate. Inside surface exposed to hot gas at 650°C and outside air temperature 27°C. The convective heat transfer co-efficient for inner side is 60 W/m^{2}K. The convective heat transfer co-

efficient for outer side is 8W/m^{2}K. Calculate the heat lost per square meter area of the furnace wall and also find outside surface temperature.

3. A steel tube (K = 43.26 W/mK) of 5.08 cm inner diameter and 7.62 cm outer diameter is covered with 2.5 cm layer of insulation (K = 0.208 W/mK) the inside surface of the tube receivers heat from a hot gas at the temperature of 316°C with heat transfer co-efficient of 28 W/m^{2}K. While the outer surface exposed to the ambient air at 30°C with heat transfer co-efficient of 17 W/m^{2}K. Calculate heat loss for 3 m length of the tube.

4. **Derive an expression of Critical Radius of Insulation For A Cylinder.**

5. **A wire of 6 mm diameter with 2 mm thick insulation (K = 0.11 W/mK). If the convective heat transfer co-efficient between the insulating surface and air is 25 W/m^{2}L, find the critical thickness of insulation. And also find the percentage of change in the heat transfer rate if the critical radius is used.**

6. **An aluminium alloy fin of 7 mm thick and 50 mm long protrudes from a wall, which is maintained at 120°C. The ambient air temperature is 22°C. The heat transfer coefficient and conductivity of the fin material are 140 W/m^{2}K and 55 W/mK respectively. Determine**
1. Temperature at the end of the fin.
2. Temperature at the middle of the fin.
3. Total heat dissipated by the fin.

7. **A copper plate 2 mm thick is heated up to 400°C and quenched into water at 30°C. Find the time required for the plate to reach the temperature of 50°C. Heat transfer co-efficient is 100 W/m^{2}K. Density of copper is 8800 kg/m^3. Specific heat of copper = 0.36 kJ/kg K.**
Plate dimensions = 30 × 30 cm.

8. A steel ball (specific heat = 0.46 kJ/kgK. and thermal conductivity = 35 W/mK) having 5 cm diameter and initially at a uniform temperature of 450°C is suddenly placed in a control environment in which the temperature is maintained at 100°C. Calculate the time required for the balls to attained a temperature of 150°C. Take h = 10W/m^{2}K.

9. Alloy steel ball of 2 mm diameter heated to 800°C is quenched in a bath at 100°C. The material properties of the ball are K = 205 kJ/m hr K, ρ = 7860 kg/m^3, C_ρ = 0.45 kJ/kg K, h = 150 KJ/ hr m^2 K. Determine (i) Temperature of ball after 10 second and (ii) Time for ball to cool to 400°C.

10. A large steel plate 5 cm thick is initially at a uniform temperature of 400°C. It is suddenly exposed on both sides to a surrounding at 60°C with convective heat transfer co-efficient of 285 W/m^{2}K. Calculate the centre line temperature and the temperature inside the plate 1.25 cm from themed plane after 3 minutes.
Take K for steel = 42.5 W/mK, α for steel = 0.043 m^2/hr.

Unit 2 Convection

Part-A

1. **Define convection.**

2. Define Reynolds number (Re) & Prandtl number (Pr).

3. **Define Nusselt number (Nu).**

4. Define Grash of number (Gr) & Stanton number (St).

5. What is meant by Newtonian and non – Newtonian fluids?

6. What is meant by laminar flow and turbulent flow?

7. **What is meant by free or natural convection & forced convection?**

8. **Define boundary layer thickness.**

9. **What is the form of equation used to calculate heat transfer for flow through cylindrical pipes?**

10. **What is meant by Newtonian and non – Newtonian fluids?**

Part-B

1. **Air at 20°C, at a pressure of 1 bar is flowing over a flat plate at a velocity of 3 m/s. if the plate maintained at 60°C, calculate the heat transfer per unit width of the plate. Assuming the length of the plate along the flow of air is 2m.**

2. Air at 20°C at atmospheric pressure flows over a flat plate at a velocity of 3 m/s. if the plate is 1 m wide and 80°C, calculate the following at x = 300 mm.

1. Hydrodynamic boundary layer thickness,
2. Thermal boundary layer thickness,
3. Local friction coefficient,
4. Average friction coefficient,
5. Local heat transfer coefficient
6. Average heat transfer coefficient,
7. Heat transfer.

3. **Air at 30°C flows over a flat plate at a velocity of 2 m/s. The plate is 2 m long and 1.5 m wide. Calculate the following:**
   1. **Boundary layer thickness at the trailing edge of the plate,**
   2. **Total drag force,**
   3. **Total mass flow rate through the boundary layer between x = 40 cm and x = 85 cm.**

4. **Air at 290°C flows over a flat plate at a velocity of 6 m/s. The plate is 1m long and 0.5 m wide. The pressure of the air is 6 $kN/^2$. If the plate is maintained at a temperature of 70°C, estimate the rate of heat removed form the plate.**

5. Air at 40°C flows over a flat plate, 0.8 m long at a velocity of 50 m/s. The plate surface is maintained at 300°C. Determine the heat transferred from the entire plate length to air taking into consideration both laminar and turbulent portion of the boundary layer.

Also calculate the percentage error if the boundary layer is assumed to be turbulent nature from the very leading edge of the plate.

6. **250 Kg/hr of air are cooled from 100°C to 30°C by flowing through a 3.5 cm inner diameter pipe coil bent in to a helix of 0.6 m diameter. Calculate the value of air side heat transfer coefficient if the properties of air at 65°C are**

K = 0.0298 W/mK

μ = 0.003 Kg/hr – m

Pr = 0.7

ρ = 1.044 Kg/m^3

7. **In a long annulus (3.125 cm ID and 5 cm OD) the air is heated by maintaining the temperature of the outer surface of inner tube at 50°C. The air enters at 16°C and leaves at 32°C. Its flow rate is 30 m/s. Estimate the heat transfer coefficient between air and the inner tube.**

8. **Engine oil flows through a 50 mm diameter tube at an average temperature of 147°C. The flow velocity is 80 cm/s. Calculate the average heat transfer coefficient if the tube wall is maintained at a temperature of 200°C and it is 2 m long.**

9. **A large vertical plate 4 m height is maintained at 606°C and exposed to atmospheric air at 106°C. Calculate the heat transfer is the plate is 10 m wide.**

10. A thin 100 cm long and 10 cm wide horizontal plate is maintained at a uniform temperature of 150°C in a large tank full of water at 75°C. Estimate the rate of heat to be supplied to the plate to maintain constant plate temperature as heat is dissipated from either side of plate.

Unit-3 Phase Change Heat Transfer and Heat Exchangers

Part-A

1. What is meant by Boiling and condensation?

2. Give the applications of boiling and condensation.

3. **What is meant by pool boiling?**

4. What is meant by Film wise and Drop wise condensation?

5. Give the merits of drop wise condensation?

6. What is heat exchanger?

7. What are the types of heat exchangers?

8. What is meant by Direct heat exchanger (or) open heat exchanger?

9. What is meant by Indirect contact heat exchanger?

10. What is meant by Regenerators?

11. What is meant by Recuperater (or) surface heat exchangers?

12. What is meant by parallel flow and counter flow heat exchanger?

13. What is meant by shell and tube heat exchanger?

14. What is meant by compact heat exchangers?

15. What is meant by LMTD?

16. What is meant by Fouling factor?

Part-B

1. **Water is boiled at the rate of 24 kg/h in a polished copper pan, 300 mm in diameter, at atmospheric pressure. Assuming nucleate boiling conditions calculate the temperature of the bottom surface of the pan.**

2. A nickel wire carrying electric current of 1.5 mm diameter and 50 cm long, is submerged in a water bath which is open to atmospheric pressure. Calculate the voltage at the burn out point, if at this point the wire carries a current of 200A.

3. **Water is boiling on a horizontal tube whose wall temperature is maintained ct 15°C above the saturation temperature of water. Calculate the nucleate boiling heat transfer coefficient. Assume the water to be at a pressure of 20 atm. And also find the change in value of heat transfer coefficient when**

1. **The temperature difference is increased to 30°C at a pressure of 10 atm.**
2. **The pressure is raised to 20 atm at Δ T = 15°C**

4. **A vertical flat plate in the form of fin is 500m in height and is exposed to steam at atmospheric pressure. If surface of the plate is maintained at 60°C. calculate the following.**

1. The film thickness at the trailing edge
2. Overall heat transfer coefficient
3. Heat transfer rate
4. The condensate mass flow rate.

Assume laminar flow conditions and unit width of the plate.

5. Steam at 0.080 bar is arranged to condense over a 50 cm square vertical plate. The surface temperature is maintained at 20°C. Calculate the following.

a. **Film thickness at a distance of 25 cm from the top of the plate.**
b. **Local heat transfer coefficient at a distance of 25 cm from the top of the plate.**
c. **Average heat transfer coefficient.**
d. **Total heat transfer**
e. **Total steam condensation rate.**
f. **What would be the heat transfer coefficient if the plate is inclined at 30°C with horizontal plane.**

6. A condenser is to designed to condense 600 kg/h of dry saturated steam at a pressure of 0.12 bar. A square array of 400 tubes, each of 8 mm diameter is to be used. The tube surface is maintained at 30°C. Calculate the heat transfer coefficient and the length of each tube.

Unit-4 Radiation

Part-A

1. Define emissive power [E] and monochromatic emissive power. [$E_{b\lambda}$]

2. What is meant by absorptivity, reflectivity and transmissivity?

3. What is black body and gray body?

4. State Planck's distribution law.

5. State Wien's displacement law.

6. State Stefan – Boltzmann law.

7. Define Emissivity.

8. State Kirchoff's law of radiation.

9. Define intensity of radiation (I_b).

10. State Lambert's cosine law.

11. What is the purpose of radiation shield?

12. Define irradiation (G) and radiosity (J)

13. What is meant by shape factor?

Part-B

1. A black body at 3000 K emits radiation. Calculate the following:

- **i) Monochromatic emissive power at 7 μm wave length.**
- **ii) Wave length at which emission is maximum.**
- **iii) Maximum emissive power.**
- **iv) Total emissive power,**
- **v) Calculate the total emissive of the furnace if it is assumed as a real surface having emissivity equal to 0.85.**

2. **Assuming sun to be black body emitting radiation at 6000 K at a mean distance of 12×10^{10} m from the earth. The diameter of the sun is 1.5×10^9 m and that of the earth is 13.2×10^6 m. Calculation the following.**

1. Total energy emitted by the sun.
2. The emission received per m^2 just outside the earth's atmosphere.
3. The total energy received by the earth if no radiation is blocked by the earth's atmosphere.
4. The energy received by a 2 × 2 m solar collector whose normal is inclined at 45° to the sun. The energy loss through the atmosphere is 50% and the diffuse radiation is 20% of direct radiation.

3. Two black square plates of size 2 by 2 m are placed parallel to each other at a distance of 0.5 m. One plate is maintained at a temperature of 1000°C and the other at 500°C. Find the heat exchange between the plates.

4. Two parallel plates of size 3 m × 2 m are placed parallel to each other at a distance of 1 m. One plate is maintained at a temperature of 550°C and the other at 250°C and the emissivities are 0.35 and 0.55 respectively. The plates are located in a large room whose walls are at 35°C. If the plates located exchange heat with each other and with the room, calculate.

1. Heat lost by the plates.

2. Heat received by the room.

5. **A gas mixture contains 20% CO_2 and 10% H_2o by volume. The total pressure is 2 atm. The temperature of the gas is 927°C. The mean beam length is 0.3 m. Calculate the emissivity of the mixture.**

6. **Two black square plates of size 2 by 2 m are placed parallel to each other at a distance of 0.5 m. One plate is maintained at a temperature of 1000°C and the other at 500°C. Find the heat exchange between the plates.**

Unit-5 Mass Transfer

Part-A

1. What is mass transfer?

2. Give the examples of mass transfer.

3. What are the modes of mass transfer?

4. What is molecular diffusion?

5. What is Eddy diffusion?

6. What is convective mass transfer?

7. State Fick's law of diffusion.

8. What is free convective mass transfer?

9. Define forced convective mass transfer.

10. Define Schmidt Number.

11. Define Scherwood Number.

Part-B

1. **Hydrogen gases at 3 bar and 1 bar are separated by a plastic membrane having thickness 0.25 mm. the binary diffusion coefficient of hydrogen in the plastic is 9.1 × 10^{-3} m^2/s. The solubility of hydrogen in the membrane is 2.1 × 10^{-3}** $\frac{kg-mole}{m^3\ bar}$

An uniform temperature condition of 20° is assumed.

Calculate the following

1. Molar concentration of hydrogen on both sides
2. Molar flux of hydrogen
3. Mass flux of hydrogen

2. Oxygen at 25°C and pressure of 2 bar is flowing through a rubber pipe of inside diameter 25 mm and wall thickness 2.5 mm. The diffusivity of O2 through rubber is 0.21×10^{-9} m^2/s and the solubility of O2 in rubber is $3.12 \times 10^{-3} \frac{kg-mole}{m^3-bar}$. Find the loss of O_2 by diffusion per metre length of pipe.

3. **An open pan 210 mm in diameter and 75 mm deep contains water at 25°C and is exposed to dry atmospheric air. Calculate the diffusion coefficient of water in air. Take the rate of diffusion of water vapour is 8.52×10^{-4} kg/h.**

4. **An open pan of 150 mm diameter and 75 mm deep contains water at 25°C and is exposed to atmospheric air at 25°C and 50% R.H. Calculate the evaporation rate of water in grams per hour.**

5. Air at 10°C with a velocity of 3 m/s flows over a flat plate. The plate is 0.3 m long. Calculate the mass transfer coefficient.