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# Question Paper Code : 27369

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2015.

Fifth Semester

Mechanical Engineering

ME 6502 — HEAT AND MASS TRANSFER

(Regulations 2013)

Time : Three hours                                                    Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Will the thermal contact resistance be greater for smooth or rough plain surfaces? Why?

2. Distinguish between fin efficiency and its effectiveness.

3. What is Dittus-Boelter equation? When does it apply?

4. Define Grashof number and explain its significance in free convection heat transfer.

5. What is meant by sub-cooled and saturated boiling?

6. What advantage does the NTU method have over the LMTD method?

7. Define irradiation and radiosity.

8. What is the greenhouse effect? Why is it a matter of great concern among atmospheric scientists?

9. What is the driving force for
   (a) heat transfer and
   (b) mass transfer?

10. Define Lewis number and state its physical significance.

PART B — ($5 \times 16 = 80$ marks)

11. (a) (i) Consider a 1.2 m high and 2 m wide double-pane window consisting of two 3 mm thick layers of glass (k = 0.78 W/mK) separated by a 12 mm wide stagnant air space (k = 0.026 W/mK). Determine the steady rate of heat transfer through this double-pane window and the temperature of its inner surface when the room is maintained at 24°C while the temperature of the outdoors is –5°C. Take the convection heat transfer coefficients on the inner and outer surfaces of the window to be 10 $W/m^2 K$ and 25 $W/m^2K$ respectively. (8)

(ii) Derive the general 3-dimensional heat conduction equation in Cartesian coordinates. (8)

Or

(b) A cylinder 1 m long and 5 cm in diameter is placed in an atmosphere at 45°C. It is provided with 10 longitudinal straight fins of material having k =120 W/mK. The height of 0.76 mm thick fins is 1.27 cm from the cylinder surface. The heat transfer coefficient between cylinder and atmospheric air is 17 $W/m^2$ K. Calculate the rate of heat transfer and the temperature at the end of fins if surface temperature of cylinder is 150°C. (16)

12. (a) (i) A long 10 cm diameter steam pipe whose external surface temperature is 110°C passes through some open area that is not protected against the winds. Determine the rate of heat loss from the pipe per unit length when the air is at 1 atm and 10°C and the wind is blowing across the pipe at a velocity of 8 m/s. (8)

(ii) An air stream at 0°C is flowing along a heated plate at 90°C at a speed of 75 m/s. The plate is 45 cm long and 60 cm wide. Calculate the average values of friction coefficient for the full length of the plate. Also calculate the rate of energy dissipation from the plate. (8)

Or

(b) (i) Explain the concept of hydrodynamic and thermal boundary layers. (6)

(ii) A 6 m long section of an 8 cm diameter horizontal hot water pipe passes through a large room whose temperature is 20°C. If the outer surface temperature and emissivity of the pipe are 70°C and 0.8 respectively, determine the rate of heat loss from the pipe by

(1) natural convection

(2) radiation. (10)

13. (a) Water is boiled at atmospheric pressure by horizontal polished copper heating element of diameter D = 5 mm and emissivity 0.05 immersed in water. If the surface temperature of the heating wire is 350°C, determine the rate of heat transfer from the wire to the water per unit length of the wire. (16)

Or

(b) Hot oil ($C_p$ = 2200 J/kg K) is to be cooled by water ($C_p$ = 4180 J/kg K) in a 2-shell-pass and 12-tube-pass heat exchanger. The tubes are thin-walled and are made of copper with a diameter of 1.8 cm. The length of each tube pass in the heat exchanger is 3 m, and the overall heat transfer coefficient is 340 W/m²K. Water flows though the tubes at a total rate of 0.1 kg/s, and the oil through the shell at a rate of 0.2 kg/s. The water and the oil enter at temperatures 18°C and 160°C, respectively. Determine the rate of heat transfer in the heat exchanger and the outlet temperatures of the water and the oil. (16)

14. (a) (i) Two very large parallel plates are maintained at uniform temperatures of $T_1$ = 1000 K and $T_2$ = 800 K and have emissivities of $\varepsilon_1 = \varepsilon_2 = 0.2$, respectively. It is desired to reduce the net rate of radiation heat transfer between the two plates to one-fifth by placing thin aluminum sheets with an emissivity of 0.15 on both sides between the plates. Determine the number of sheets that need to be inserted. (10)

(ii) Define the following terms :

(1) Monochromatic emissivity

(2) Gray body

(3) Shape factor. (6)

Or

(b) (i) The spectral emissivity function of an opaque surface at 1000 K is approximated as

$\varepsilon_{\lambda 1} = 0.4, 0 \leq \lambda < 2 \mu m$ ;

$\varepsilon_{\lambda 2} = 0.7,\ 2 \mu m \leq \lambda < 6 \mu m$ ;

$\varepsilon_{\lambda 3} = 0.3,\ 6 \mu m \leq \lambda < \infty$

Determine the average emissivity of the surface and the rate of radiation emission from the surface, in W/m². (8)

(ii) Emissivities of two large parallel plates maintained at 800°C and 300°C are 0.3 and 0.5 respectively. Find the net radiant heat exchange per square metre for these plates? (8)

15. (a) (i) A 3-cm-diameter Stefan tube is used to measure the binary diffusion coefficient of water vapor in air at 20°C at an elevation of 1600 m where the atmospheric pressure is 83.5 kPa. The tube is partially filled with water, and the distance from the water surface to the open end of the tube is 40 cm. Dry air is blown over the open end of the tube so that water vapor rising to the top is removed immediately and the concentration of vapor at the top of the tube is zero. In 15 days of continuous operation at constant pressure and temperature, the amount of water that has evaporated is measured to be 1.23 g. Determine the diffusion coefficient of water vapor in air at 20°C and 83.5 kPa. (10)

(ii) State some analogies between heat and mass transfer. (6)

Or

(b) (i) A thin plastic membrane separates hydrogen from air. The molar concentrations of hydrogen in the membrane at the inner and outer surfaces are determined to be 0.045 and 0.002 kmol/$m^3$, respectively. The binary diffusion coefficient of hydrogen in plastic at the operation temperature is $5.3 \times 10^{-10}$ $m^2$ /s. Determine the mass flow rate of hydrogen by diffusion through the membrane under steady conditions if the thickness of the membrane is

(1) 2 mm and

(2) 0.5 mm. (8)

(ii) Dry air at 15°C and 92 kPa flows over a 2 m long wet surface with a free stream velocity of 4 m/s. Determine the average mass transfer coefficient. (8)