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# B.M.S. College of Engineering, Bengaluru-560019

**Autonomous Institute Affiliated to VTU**

## September / October 2023 Supplementary Examinations

**Programme: B.E.** **Semester: VI**
**Branch: Mechanical Engineering** **Duration: 3 hrs.**
**Course Code: 20ME6DCFHT/16ME5DCFHT** **Max Marks: 100**
**Course: Fundamentals of Heat Transfer**

**Instructions**: 1. Answer any FIVE full questions, choosing one full question from each unit.
2. The Heat Mass Transfer Data hand book and steam tables are permitted.
3. Missing data, if any, may be suitably assumed.



**UNIT - I**

1 a) (i) Consider heat conduction through a wall of thickness L and area A. Under what conditions will the temperature distributions in the wall be a straight line? **10**

(ii) Derive an expression for temperature distribution and maximum temperature for a plane wall with uniform heat generation. Draw the temperature profile for the cases where both the surfaces are maintained at same temperature.

b) A 3 m high and 5m wide wall consists of long 16 cm × 22 cm cross section horizontal bricks (k = 0.72 W/m·K) separated by 3 cm thick plaster layers (k = 0.22 W/m·K). There are also 2 cm thick plaster layers on each side of the brick and a 3 cm thick rigid foam (k = 0.026 W/m·K) on the inner side of the wall, as shown in Figure 1. The indoor and the outdoor temperatures are 20° C and − 10° C, respectively, and the convection heat transfer coefficients on the inner and the outer sides are $h_1 = 10$ W/ m $^2$ K and $h_2 = 25$ W/ m $^2$ K, respectively. Assuming one-dimensional heat transfer and disregarding radiation, determine the rate of heat transfer through the wall. **10**

**OR**

2 a) i) The fins attached to a surface are determined to have an effectiveness of 0.9. Do you think the rate of heat transfer from the surface has increased or decreased as a result of the addition of these fins? **10**

ii) Considering the general equation for heat flow through a rectangular fin, derive an expression for heat dissipation from a fin losing heat at tip with usual notations.

b) Derive an expression for Instantaneous heat flow rate and total heat transfer by heat conduction in solids having infinite thermal conductivity. **10**

ii) The temperature of a gas stream is to be measured by a thermocouple whose junction can be approximated as a 1 mm diameter sphere, as shown in Figure 2. The properties of the junction are k = 35 W/m·K, $\rho = 8500$ kg/ $m^3$ , and $C_p$ = 320 J/kg·K, and the convection heat transfer coefficient between the junction and the gas is h = 210W/ $m^2$K. Determine how long it will take for the thermocouple to read 99 percent of the initial temperature difference.

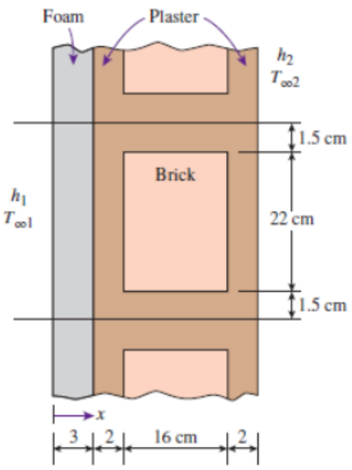


Figure 1

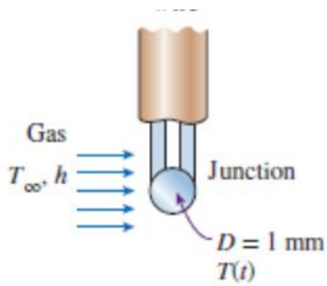


Figure 2

## UNIT - II

3 a) (i)What is the physical significance of the Prandtl number? Does the value of the Prandtl number depend on the type of flow or the flow geometry? Does the Prandtl number of air change with pressure? Does it change with temperature? **10**

(ii)Derive the Blasius solution for boundary layer thickness '$\delta$' as a function of $Re_x$ and x for the laminar flow over a flat plate. Consider the governing momentum equation is, $u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \vartheta\frac{\partial^2 u}{\partial y^2}$ .

b) (i)Consider laminar forced convection in a circular tube. The heat flux will be higher near the inlet of the tube or near the exit? Write your comment. **10**

(ii)Engine oil at 30°C is flowing with a velocity of 2 m/s along the length of a flat plate, maintained at 90°C. Calculate, at a distance of 40 cm from the leading edge: hydrodynamic and thermal boundary layer thicknesses by the exact method, local and average values of heat transfer coefficient, and heat transferred from the first 40 cm of the plate for unit width.

**OR**

4 a) i) What fluid property is responsible for the development of the velocity boundary layer? For what kind of fluids there will be no velocity boundary layer in a pipe. **10**

ii) Discuss the development of the velocity boundary layer and the thermal boundary layer in a tube and also express the velocity and dimensionless temperature profiles mathematically.

iii) Plot the temperature variation over the tube length for constant wall temperature and constant heat flux conditions.

b) Water is to be heated from 15° C to 65° C as it flows through a 3 cm-internal-diameter 5 m long tube (Figure 3). The tube is equipped with an electric resistance heater that provides uniform heating throughout the surface of the tube. The outer surface of the heater is well insulated, so in steady operation, all the heat generated in the heater is transferred to the water in the tube. If the system is to provide hot water at a rate of 10 L/min, determine the power rating of the resistance heater. Also estimate the inner surface temperature of the tube at the exit. **10**

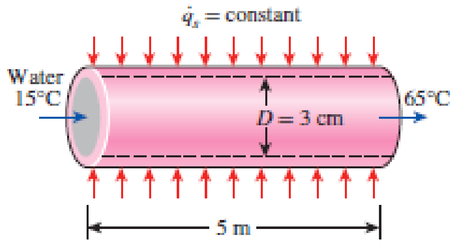


Figure 3

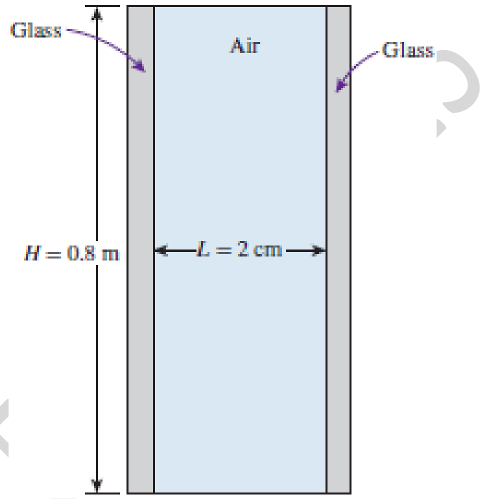


Figure 4



## UNIT - III

5 a) i) Consider a hot boiled egg in a spacecraft that is filled with air at atmospheric pressure and temperature at all times. Will the egg cool faster or slower when the spacecraft is in space instead over the ground? **10**

(ii) Explain how does the Grashoff's number different from the Reynold's number.

ii ) Draw the temperature and velocity profiles formed inside the boundary layer for vertical plate, (1) When a plate temperature is lower than the ambient and (2) When a plate temperature is higher than the ambient.

b) The vertical 0.8 m high, 2 m wide double-pane window shown in Figure 4 consists of two sheets of glass separated by a 2 cm air gap at atmospheric pressure. If the glass surface temperatures across the air gap are measured to be 12° C and 2° C, determine the rate of heat transfer through the window. The properties of air at the average temperature of $T_{avg}$ (7°C) and 1 atm pressure are k= 0.02416 W/m·K., Pr = 0.7344, and ν = 1.400 ×10 $^{-5}$m$^2$/s. **10**

## UNIT - IV

6 a) Derive an expression for shape factor in case of Radiation heat Exchange between two black surfaces. **10**

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| | b) | Consider the $5\text{m} \times 5\text{m} \times 5\text{m}$ cubical furnace shown in Figure 5, whose surfaces closely approximate black surfaces. The base, top, and side surfaces of the furnace are maintained at uniform temperatures of 800 K, 1500 K, and 500 K, respectively. Determine (a) the net rate of radiation heat transfer between the base and the side surfaces, (b) the net rate of radiation heat transfer between the base and the top surface, and (c) the net radiation heat transfer from the base surface. | **10** |

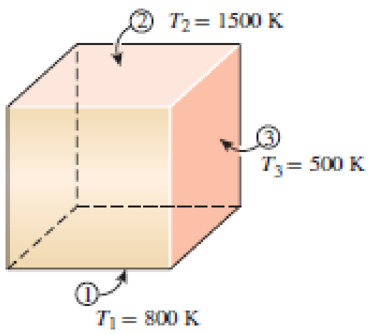


Figure 5

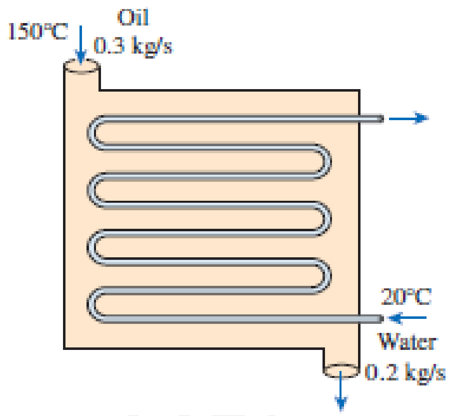


Figure 6



**UNIT - V**

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| 7 | a) | Derive an expression for effectiveness by NTU method for parallel flow heat exchanger. | **10** |
| | b) | Hot oil is to be cooled by water in a one-shell-pass and eight-tube-passes heat exchanger (Figure.6). The tubes are thin-walled and are made of copper with an internal diameter of 1.4 cm. The length of each tube pass in the heat exchanger is 5 m, and the over-all heat transfer coefficient is 310 W/m$^2$ ·K. Water flows through the tubes at a rate of 0.2 kg/s and the oil through the shell at a rate of 0.3 kg/s. The water and the oil enter at temperatures of 20°C and 150°C, respectively. Determine the rate of heat transfer in the heat exchanger and the outlet temperatures of the water and the oil. The specific heats of water and oil to be 4.18 and 2.13 kJ/kg·° C, respectively. | **10** |

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