B. Sc Engg. (ME)/5th Sem, B Sc. TE (2 Yr) (TVE)/ 1st Sem — Friday, 22 December, 2023

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ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)
DEPARTMENT OF MECHANICAL AND PRODUCTION ENGINEERING

Semester Final Examination — Winter Semester: A.Y. 2022-2023
Course No.: ME 4513 — Time: 3.0 Hours
Course Title: *Principle of Heat and Mass Transfer* — Full Marks: 150

There are **06 (Six)** Questions. Answer all of them. Marks in the margin indicate full marks. Do not write on this question paper. Symbols carry their usual meanings. Assume reasonable values for any missing data. Programmable calculators are not allowed.

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1. **(a)** Discuss the Wien's displacement law for electromagnetic spectrum. **[15]**
   (b) Discuss the fundamental relations for calculating the view factors. **[CO1]** **[PO1]**

2. **(a)** Consider a thin element of thickness Δx in a large plane wall. Assume the density of the wall is ρ, the specific heat is C, and the area of the wall normal to the direction of heat transfer is A. Derive the one-dimensional transient heat conduction equation in a plane wall for variable thermal conductivity and reduce the equation for the following cases: **[20]** **[CO2]** **[PO2]**
   i. For Constant Thermal Conductivity
   ii. For Steady State condition with Heat Generation
   iii. For transient with No Heat Generation

   (b) Consider a long cylindrical layer (or spherical) of inner radius r_1, outer radius r_2, length L. The two surfaces of the layer are maintained at constant temperatures T_1 and T_2. There is no heat generation in the layer and the thermal conductivity is constant. For one-dimensional heat conduction through the cylindrical layer, we have T(r). Also, consider steady one-dimensional heat flow through the layer that is exposed to convection on both sides to fluids at temperatures $T_{\alpha 1}$ and $T_{\alpha 2}$ with heat transfer coefficients h_1 and h_2, respectively. Analyze the heat transfer case for the two geometries and obtain the ratio of heat transfer for alternate geometry as: **[25]** **[CO2]** **[PO2]**

$$\frac{Q_{Cylinder}}{Q_{Sphere}} = \frac{\dfrac{1}{(4\pi r_1^{\,2})h_1} + \dfrac{r_2 - r_1}{4\pi r_1 r_2 k} + \dfrac{1}{(4\pi r_2^{\,2})h_2}}{\dfrac{1}{(2\pi r_1 L)h_1} + \dfrac{\ln\left(\frac{r_2}{r_1}\right)}{2\pi L k} + \dfrac{1}{(2\pi r_2 L)h_2}}$$

3. Consider steady heat transfer in an L-shaped solid body whose cross section is given in **Figure 1**. Heat transfer in the direction normal to the plane of the paper is negligible, and thus heat transfer in the body is two-dimensional. The thermal conductivity of the body is, k -=15 W/m·°C, and heat is generated in the body at a rate of $g = 2 \times 10^6$ W/m^3. The left surface of the body is insulated, and the bottom surface is maintained at a uniform temperature of 90°C. The entire top surface is subjected to convection to ambient air at T_α=25°C with a convection coefficient of h = 80 W/m^2·°C, and the right surface is subjected to heat flux at a uniform rate of q_R= 5000 W/m^2. The nodal network of the problem consists of 15 equally spaced nodes with Δx=Δy= 1.2 cm, as shown in the figure. Five of the nodes are at the bottom surface, and thus their temperatures are known. Obtain the finite difference equations at the remaining nine nodes and determine the nodal temperatures by solving them. **[45]** **[CO3]** **[PO3]**

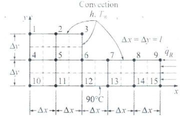

Figure 1

Again consider the above mentioned case for transient heat transfer. Using the explicit method, obtain the finite difference equations for remaining nine nodes and determine the temperature at the top corner (node 3) of the body after 1, 3, 5, 10, and 60 min.

4. A cylindrical tank (as shown in **Figure 2**) of 1.0 m diameter and 5 m total length has hemispherical ends. It contains liquid oxygen which has boiling point and heat of vaporization -180°C and 210°kJ/kg respectively. It is required to insulate the tank so as to reduce the boil-off rate of oxygen in steady state to 14kg/h. Determine the total thermal conductivity of the insulating material if its maximum thickness is limited to 70 mm. Assume room temperature outside the insulation as 25°C. **[15] [CO4] [PO4]**

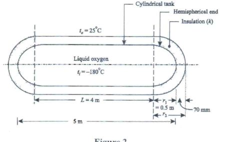

Figure 2

5. An egg with mean diameter of 40 mm and initially at 20ºC is placed in a boiling water pan for 4 minutes and found to be boiled to the customer's taste (as shown in **Figure 3**). For how long should a similar egg for same customer be boiled when taken from a refrigerator at 5 ºC? Take the following properties for egg: k=10 W/mºC, ρ=1200 kg/m^3, C=2 kJ/kg.ºC, h=100 W/m^{2}ºC, Use Lump Theory transient heat transfer for the investigation. **[15] [CO4] [PO4]**

Figure 3

6 Find an expression for distribution of temperature and heat flow due to conduction in a circular conical rod (as shown in **Figure 4**) with diameter at any section given by D=cx where x is the distance measured from the apex of the cone and c is a certain numerical constant. Assume that lateral surface is well insulated, there is no internal heat generation and heat flow takes place under steady state conditions. [15] [CO4] [PO4]

What will be the heat flow rate if the smaller and longer ends are located at x_1=50 mm and x_2=250 mm and have temperatures 400°C and 200°C respectively? Take: c=0.22 and k=3.6 W/m°C.

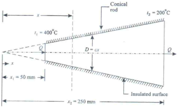

Figure 4