Department	**Mechanical Engineering**		**Program**	**B. Tech**	
Subject Name	**Heat Transfer**		**Subject Code**	**MEC 704**	
Semester	**5th**	**Credits**	**4**	**Teacher Incharge/Mentor**	Prof. (Dr. Adnan Qayoum)
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UNIT 1

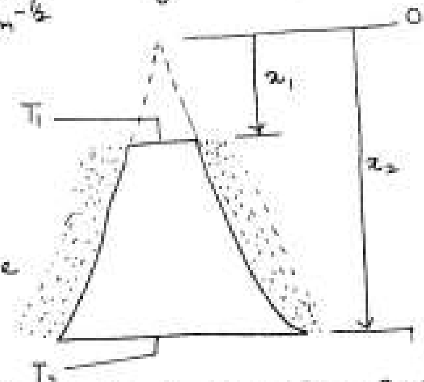
Links to the Resources:
Link to the resources:
1. www.learncheme.com/screencasts/heat-transfer
2.https://thermalfluidscentral.org
Lecture notes:
1.http://ocw.mit.etu/index.htm
2.http://nptel.ac.in

Text Book : Heat and Mass Transfer by **J.P Holman**

Tutorial Problems

HEAT TRANSFER

Q1. A truncated solid cone is of circular cross-section, and its diameter is related to the axial coordinate by an expression of the form $D = ax^{3/2}$, where $a = 1.0\,m^{-1/2}$.



The sides are well insulated, while the top surface of the cone at x_1 is maintained at T_1 and the bottom surface at x_2 is maintained at T_2.

i) Obtain an expression for the temperature distribution $T(x)$

ii) What is the rate of heat transfer across the cone if it is constructed of pure aluminium with $x_1 = 0.075\,m$, $T_1 = 100°C$, $x_2 = 0.225\,m$, and $T_2 = 20°C$.

Q2. A certain material 2.5 cm thick, with a cross-sectional area of $0.1\,m^2$, has one side maintained at 35°C and the other at 95°C. The temperature at the centre plane of the material is 62°C, and the heat flow through the material is 1 kW. Obtain an expression for the thermal conductivity of the material as a function of temperature.

Q3. A plane wall is constructed of a material having a thermal conductivity that varies as the square of temperature according to the relation $k = k_0(1+\beta T^2)$. Derive an expressions for the heat transfer in such a wall.

Q4. A wall is constructed of 2.0 cm of copper, 3.0 mm of asbestos sheet [k = 0.166 W/m.°C], and 6.0 cm of fiber glass. Calculate the heat flow per unit area for an overall temperature difference of 500°C.

Q5. A wall is constructed of a section of stainless steel [k = 16 W/m.°C] 4.0 mm thick with identical layers of plastic on both sides of the steel. The overall heat transfer coefficient, considering convection on both sides of the plastic, is 120 $W/m^2.°C$. If the overall temperature difference across the arrangement is 60°C, calculate the temperature difference across the stainless steel.

Q6. An ice-chest is constructed of styrofoam [$k = 0.033\ W/m \cdot °C$] with inside dimensions of 25 by 40 by 100 cm. The wall thickness is 5.0 cm. The outside of the chest is exposed to air at 25°C with $h = 10\ W/m^2 \cdot °C$. If the chest is completely filled with ice, calculate the time for the ice to completely melt. State your assumptions. The heat of fusion for water is 330 kJ/kg

Q7. A spherical tank, 1m in diameter, is maintained at a temperature of 120°C and exposed to a convection environment with $h = 25\ W/m^2 \cdot °C$ and $T_\infty = 15°C$, what thickness of urethane foam should be added to ensure that the outer temperature of insulation does not exceed 40°C? What percentage reduction in heat loss results from installing this insulation?

Q8. A steel pipe with a 5-cm OD is covered with a 6.4mm asbestos insulation followed by a 2.5cm layer of fiber-glass insulation. The pipe wall temperature is 315°C, and the outside temperature is 38°C. Calculate the interface temperature between the asbestos and fiber glass.

Q9. A 1.0 mm-diameter wire is maintained at a temperature of 400°C and exposed to a convection environment at 40°C with $h = 120\ W/m^2 \cdot °C$. Calculate the thermal conductivity which will just cause an insulation thickness of 0.2mm to produce a "critical radius". How much of this insulation must be added to reduce the heat transfer by 75 percent from that which would be experienced by the bare wire?

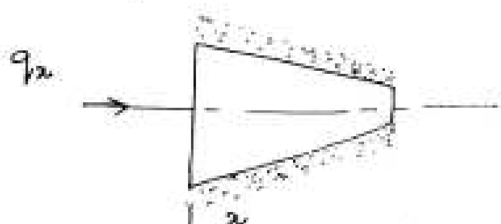
Q10. A cylindrical tank 80cm in diameter and 2.0m high contains water at 80°C. The tank is 90 percent full, and insulation is to be added so that the water temperature will not drop more than 2°C per hour. Using the information given in the data book, specify an insulating material and calculate the thickness required for the specified cooling rate.

Q11. A house wall may be approximated as two 1.2-cm layers of fiber insulating board, a 8.0-cm layer of loosely packed asbestos, and a 10-cm layer of common brick. Assuming convection heat transfer coefficients of $15\ W/m^2 \cdot °C$ on both sides of the wall, calculate the overall heat transfer coefficient for this arrangement.

Q12 A certain material has a thickness of 30cm and a thermal conductivity of 0.04 W/m.°C. At a particular instant in time the temperature distribution with x, the distance from the left face, is $T = 150x^2 - 30x$, where x is in meters. Calculate the heat flow rate at $x = 0$ and $x = 30$cm. Is the solid heating up or cooling down?

Q13. A hot steam pipe having an inside surface temperature of 250°C has an inside diameter of 8cm and a wall thickness of 5.5mm. It is covered with a 9 cm layer of insulation having $k = 0.5$ W/m.°C, followed by a 4 cm layer of insulation having $k = 0.25$ W/m.°C. The outside temperature of the insulation is 20°C. Calculate the heat lost per meter of length. Assume $k = 47$ W/m.°C for the pipe.

Q14 Assume steady state, one dimensional heat conduction through the symmetric shape shown.



Assuming that there is no internal heat generation, derive an expression for the thermal conductivity $k(x)$ for these conditions: $A(x) = (1-x)$, $T(x) = 300(1 - 2x - x^3)$, and $q = 6000$ W, where A is in square meters, T in Kelvins, and x is in meters.

Q15. The temperature of the human body drops from the core (or arterial blood) level $T_a = 36.5$°C to the skin level T_s across a subskin layer of thickness $\delta \sim 1$cm and conductivity $k \cong 0.42$ W/m.K

(i) Calculate the skin temperature when the body is swept by the flow of 20°C air with a heat transfer coefficient of 30 W/m².K.

(ii) Calculate the skin temperature when the external fluid is 10°C water and the skin-water heat transfer coefficient is 500 W/m².K

(iii) How much greater is the rate of body heat loss to water (ii) than to air (i)?

Q1. Derive an expression for the temperature distribution in a plane wall having uniformly distributed heat sources and one face maintained at a temperature T_1 while the other face is maintained at a temperature T_2. The thickness of the wall may be taken as 2L.

Q2. A plane wall of thickness 2L has an internal heat generation which varies according to $\dot{q} = \dot{q}_0 \cos ax$, where $\dot{q}_0$ is the heat generated per unit volume at the center of the wall ($x=0$) and a is a constant. If both sides of the wall are maintained at a constant temperature of T_w, derive an expression for the total heat loss from the wall per unit surface area.

Q3. Heat is generated uniformly in a stainless steel plate having $k = 20$ W/m°C. The thickness of the plate is 1.0 cm and the heat generation rate is 500 MW/m³. If the two sides of the plate are maintained at 100 and 200°C respectively, calculate the temperature at the center of the plate.

Q4. Derive an expression for the temperature distribution in a hollow cylinder with heat sources which vary according to the linear relation

$$\dot{q} = a + br$$

with $\dot{q}_i$ the generation rate per unit volume at $r = r_i$. The inside and outside temperatures are $T = T_i$ at $r = r_i$ and $T = T_o$ at $r = r_o$

Q5. A plate having a thickness of 4.0 mm has an internal heat generation of 200 MW/m³ and a thermal conductivity of 25 W/m°C. One side of the plate is insulated and the other side is maintained at 100°C. Calculate the maximum temperature in the plate.

Q6. A plane wall 6.0 cm thick generates heat internally at the rate of 0.3 MW/m³. One side of the wall is insulated, and the other side is exposed to an environment at 93°C. The convection heat-transfer coefficient between the wall and the environment is 570 W/m²°C. The thermal conductivity of the wall is 21 W/m°C. Calculate the maximum temperature in the wall

Q1. An aluminium rod 2.5 cm in diameter and 15 cm long protrudes from a wall which is maintained at 260°C. The rod is exposed to an environment at 16°C. The convection heat-transfer coefficient is 15 W/m^2.°C. Calculate the heat lost by the rod.

Q2. An aluminum fin 1.6 mm thick is placed on a circular tube with 2.5-cm OD. The fin is 6.4 mm long. The tube wall is maintained at 150°C, the environment temperature is 15°C, and the convection heat-transfer coefficient is 23 W/m^2.C. Calculate the heat lost by the fin.

Q3. A circumferential fin of rectangular cross-section surrounds a 2.5 cm-diameter tube. The length of the fin is 6.4 mm, and the thickness is 3.2 mm. The fin is constructed of mild steel. If air blows over the fin so that a heat transfer coefficient of 28 W/m^2.°C is experienced and the temperatures of the base and air are 260 and 93°C, respectively, calculate the heat transfer from the fin.

Q4. A 2.5-cm diameter tube has circumferential fins of rectangular profile spaced at 9.5-mm increments along its length. The fins are constructed of aluminium and are 0.8 mm thick and 12.5 mm long. The tube wall temperature is maintained at 200°C, and the environment temperature is 93°C. The heat transfer coefficient is 110 W/m^2.°C. Calculate the heat loss from the tube per meter of length.

Q5. A straight rectangular fin 2.0 cm thick and 14 cm long is constructed of steel and placed on the outside of a wall maintained at 200°C. The environment temperature is 15°C, and the heat transfer coefficient for convection is 20 W/m^2-°C. Calculate the heat lost from the fin per unit depth.

Q6. A straight fin having a triangular profile has a length of 5 cm and a thickness of 4 mm and is constructed of a material having k = 23 W/m.°C. The fin is exposed to surroundings with a convection coefficient of 20 W/m^2.°C and a temperature of 40°C. The base of the fin is maintained at 200°C. Calculate the heat lost per unit depth of the fin.

Q7. A long, circular aluminium rod is attached at one end to a heated wall and transfers heat by convection to a cold fluid.

(i) if the diameter of the rod is tripled, by how much would the rate of heat removal change?

(ii) if a copper rod of the same diameter is used in place of aluminium, by how much would the rate of heat removal change?

Q8. Determine the percentage increase in heat transfer associated with attaching aluminium fins of rectangular profile to a plane wall. The fins are 50mm long, 0.5mm thick, and are equally spaced at a distance of 4mm (250 fins/m). The convection coefficient associated with the bare wall is 40 W/m².K, while that resulting from attachment of the fins is 30 W/m².K

Q9. Consider the use of straight, stainless steel fins of rectangular and triangular profiles on a plane wall whose temperature is 100°C. The adjoining fluid is at 20°C, and the associated convection coefficient is 75 W/m².K. Each fin is 6mm thick and 20mm long. Compare the efficiency, the effectiveness, and the heat loss per unit width associated with the two kinds of fins.

Q10. Annular aluminium fins of rectangular profile are attached to a circular tube having an outside diameter of 50mm and an outer surface temperature of 200°C. The fins are 4mm thick and 15mm long. The system is in ambient air at a temperature of 20°C, and the surface convection coefficient is 40 W/m².K.

i) What are the fin efficiency and effectiveness?

ii) If there are 125 such fins per meter of tube length, what is the rate of heat transfer per unit length of tube?

Q11. Annular fins that are 2mm thick and 15mm long are installed on an aluminium tube of 30-mm diameter. The thermal contact resistance between a fin and the tube is known to be 2×10^{-4} m².K/W. If the tube wall is at 100°C and the adjoining fluid is at 25°C, with a convection coefficient of 75 W/m².K, what is the rate of heat transfer from a single fin? What would be the rate of heat transfer if contact resistance could be eliminated?

Q1. Steel balls 12mm in diameter are annealed by heating to 1150K and then slowly cooling to 400K in an air environment for which $T_\infty = 325$ K and $h = 20$ W/m².K. Assuming the properties of the steel to be $k = 40$ W/m.K, $\rho = 7800$ kg/m³ and $c = 600$ J/kg.K, estimate the time required for the cooling process.

Q2. A sphere 30mm in diameter initially at 800K is quenched in a large bath having a constant temperature of 320K with a convection heat transfer coefficient of 75 W/m².K. The thermo-physical properties of the sphere material are: $\rho = 400$ kg/m³, $c = 1600$ J/kg.K and, $k = 1.7$ W/m.K.

(i) Calculate the time required for the surface of the sphere to reach 415 K.
(ii) Determine the heat flux (W/m²) at the outer surface of the sphere at the time determined in part (i)
(iii) Determine the energy (J) that has been lost by the sphere during the process of cooling to the surface temperature of 415 K.
(iv) At the temperature determined by part (i), the sphere is quickly removed from the bath and covered with perfect insulation, such that there is no heat loss from the surface of the sphere. What will be the temperature of the sphere after a long period of time has elapsed?

Q3. Two large blocks of different materials, such as copper and concrete, have been sitting in a room (23°C) for a very long time. Which of the two blocks, if either, will feel colder to the touch? Assume the blocks to be semi-infinite solids and your hand to be at a temperature of 37°C.

Q4. Asphalt pavement may achieve temperatures as high as 50°C on a hot summer day. Assume that such a temperature exists throughout the pavement, when suddenly a rainstorm reduces the surface temperature to 20°C. Calculate the total amount of energy (J/m²) that will be transferred from the asphalt over a 30 min period in which the surface is maintained at 20°C.

Q5. Estimate the time required to cook a hot dog in boiling water. Assume that the hot dog is initially at 6°C, that the convection heat transfer coefficient is 100 W/m².K, and that the final temperature is 80°C at the centerline. Treat the hot dog as a long

cylinder of 20 mm diameter having the properties: ②
$\rho = 880\ kg/m^3$, $c = 3350\ J/kg.K$ and $k = 0.52\ W/m.K$.

Q6. A long rod 40 mm in diameter, fabricated from sapphire (aluminium oxide) and initially at a uniform temperature of 800 K, is suddenly cooled by a fluid at 300 K having a heat transfer coefficient of 1600 $W/m^2.K$. After 35 seconds, the rod is wrapped in insulation and experiences no heat losses. What will be the temperature of the rod after a long period of time?

Q7. A thick concrete wall having a uniform temperature of 54°C is suddenly subjected to an airstream at 10°C. The heat transfer coefficient is 62.6 $W/m^2.°C$. Calculate the temperature in the concrete slab at a depth of 7cm after 30 min.

Q8. On a hot summer day a concrete driveway may reach a temperature of 50°C. Suppose that a stream of water is directed on the driveway so that the surface temperature is suddenly lowered to 10°C. How long will it take to cool the concrete to 25°C at a depth of 5cm from the surface?

Q9. A large slab of aluminium has a thickness of 10 cm and is initially uniform in temperature at 400°C. Suddenly it is exposed to a convection environment at 90°C with $h = 1400\ W/m^2°C$. How long does it take the centerline temperature to drop to 180°C?

Q10. A small cubical furnace 50 by 50 by 50 cm on the inside is constructed of fireclay brick [$k = 1.04\ W/m.°C$] with a wall thickness of 10cm. The inside of the furnace is maintained at 500°C and the outside is maintained at 50°C. Calculate the heat lost through the walls.

Any other information:

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