Assignment - 1

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QUESTION-1

1.1 The primary mode of heat transfer responsible for heating water in the pot is **convection**. The heat from the stove first conducts through the metal base of the pot, which then transfers energy to the water molecules at the bottom. These molecules gain energy, become less dense, and rise while cooler molecules move downward, setting up convection currents that distribute heat throughout the water.

1.2 When holding a metal rod over a flame, the other end of the rod becomes hot due to **conduction**. Heat transfers through the rod as kinetic energy is passed from one molecule to another without any movement of the material itself. Since metal is a good conductor, this process happens efficiently.

QUESTION-2

Heat loss from a **200-L cylindrical hot water tank** occurs through conduction, convection, and possibly radiation.

- This problem is likely **transient** rather than steady because the temperature of the water inside changes over time as heat is lost.
- The heat transfer process is **three-dimensional** since heat can be lost through the cylindrical walls (radial direction), top and bottom surfaces (axial direction), and through the fluid inside.

QUESTION-3: Heat Conduction Equation for a Long Cylinder with Heat Generation

Step 1: Consider a Cylindrical Shell Element

A **thin cylindrical shell** of:

- Radius = r
- Thickness = dr
- Length = L

Heat flow in (at r):

$$Q_r = -kA\frac{dT}{dr} = -k(2\pi rL)\frac{dT}{dr}$$

Heat flow out (at $r + dr$):

$$Q_{r+dr} = -k(2\pi(r+dr)L)\frac{dT}{dr}\bigg|_{r+dr}$$

Heat generated inside shell volume:

$$Q_{\text{gen}} = g(2\pi r dr L)$$

Step 2: Apply Energy Conservation

$$Q_r - Q_{r+dr} + Q_{\text{gen}} = 0$$

Expanding,

$$-k(2\pi rL)\frac{dT}{dr} + k(2\pi(r+dr)L)\frac{dT}{dr}\bigg|_{r+dr} + g(2\pi r dr L) = 0$$

Dividing by $2\pi L dr$,

$$\frac{1}{r}\frac{d}{dr}\left(kr\frac{dT}{dr}\right) + g = 0$$

For constant k,

$$\frac{1}{r}\frac{d}{dr}\left(r\frac{dT}{dr}\right) + \frac{g}{k} = 0$$

This is the **steady-state heat conduction equation for a long cylinder with internal heat generation**.

QUESTION-4

Given the equation:

$$\frac{\partial^2 T}{\partial x^2} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

(a) The presence of the **time derivative** $\frac{\partial T}{\partial t}$ indicates that heat transfer is **transient**.
(b) The equation contains a **single spatial coordinate (x)**, meaning heat transfer is **one-dimensional**.
(c) There is **no heat generation** in the medium, as there is no term representing internal heat generation.
(d) The absence of a thermal conductivity function implies that the medium has **constant thermal conductivity**.

QUESTION-5

For a **3-cm-thick stainless steel plate** with uniform heat generation:

Given:

- Thickness $L = 3$ cm = 0.03 m
- Heat generation rate $q_g = 5 \times 10^6$ W/m^3

For steady-state heat flux, using the formula:

$$q = \frac{q_g L}{2}$$

$$q = \frac{(5 \times 10^6)(0.03)}{2} = 75,000 \text{ W/m}^2$$

Thus, the heat flux on the surface is **75,000 W/m^2**.
