Assignment 1 Solutions

QUESTION-1

1.1 Answer: Convection

Explanation:

When water is heated in a pot, the primary mode of heat transfer responsible for heating the water is convection.

Initially, heat is transferred from the stove to the pot through conduction. However, within the water itself,
as the water near the bottom heats up, it becomes less dense and rises, while cooler, denser water sinks. This
creates circulating currents known as convection currents, which distribute heat throughout the liquid.

1.2 Answer: Conduction

Explanation:

When a metal rod is heated at one end, heat travels to the cooler end through conduction. The metal's lattice
structure allows the rapid transfer of kinetic energy between vibrating molecules, making conduction the dominant
mode of heat transfer.

QUESTION-2

Answer:

- Steady-state (if the water temperature is maintained constant).
- One-dimensional (radial direction).

Explanation:

If the tank maintains a constant temperature, heat loss occurs without changing the system's temperature over time
(steady-state). If it cools down over time, it becomes transient. Since the tank is cylindrical and the temperature
varies primarily in the radial direction, it is considered a one-dimensional heat transfer problem.

QUESTION-3

Derivation of the steady one-dimensional heat conduction equation for a long cylinder with internal heat generation:

Step 1: Energy Balance

At steady state: Heat In - Heat Out + Heat Generation = 0

Step 2: Apply Fourier's Law:

Heat entering at radius r:

$q_{in} = -k (2pirL) dT/dr$

Heat exiting at radius r+dr:

$q_{out} = -k (2pi(r+dr)L) dT/dr$

Heat Generation:

Generation = g (2pirLdr)

Step 3: Substitute into Energy Balance Equation and Simplify:

Taking the limit as dr   0:

$(1/r) d/dr (r dT/dr) + g/k = 0$

Variables:

r = Radial distance (m)

T = Temperature (K)

k = Thermal conductivity (W/m K)

g = Volumetric heat generation (W/m^3)

QUESTION-4

Given equation:

$^2T/ x^2 = (1/alpha)\ \ T/ t$

(a) Transient: The presence of the time derivative term T/ t indicates that the temperature changes over time.

(b) One-dimensional: Temperature varies only with x, meaning there is no variation in y or z directions.

(c) No heat generation: The equation lacks a heat generation term.

(d) Constant thermal conductivity: Since alpha = k/(c_p) is constant, k does not vary with temperature.

QUESTION-5

Given:

Thickness $L = 0.03$ m

Heat generation rate $g = 5 \times 10^6$ W/m^3

Total heat generated = Heat lost from both surfaces:

$g (A L) = 2 q A$

Solving for q:

$q = (g L) / 2$

Calculation:

$q = (5 \times 10^6 \text{ W/m}^3 \times 0.03 \text{ m}) / 2 = 75{,}000 \text{ W/m}^2 = 75 \text{ kW/m}^2$

Assumptions:

- Steady-state operation.
- Uniform heat generation.
- Negligible edge effects.