Summary of the Lesson on Heat

This chapter covers the fundamental concepts of heat, including its nature, units of measurement, temperature scales, modes of heat transfer, effects of heat, and applications.

1. Heat and Temperature

- **Heat** is a form of energy that results from the motion of molecules in an object.
- **Temperature** is the measure of heat energy present in an object.
- Heat always flows from a **hotter object** to a **colder object** until **thermal equilibrium** is reached.

Formulas:

1. **Heat Energy Relation with Temperature**
   $Q = mc\Delta T$ where:
   - Q = Heat energy (Joules)
   - m = Mass of the object (kg)
   - c = Specific heat capacity ($J/kg°C$)
   - ΔT = Change in temperature (°C)
2. **Units of Heat Energy:**
   - 1 calorie = **4.18 Joules**
   - 1 kilocalorie = **1000 calories**

Example:
Find the heat required to raise the temperature of 2 kg of water from 25°C to 75°C.
Given c for water = $4.18J/g°C$ = $4180J/kg°C$

$$Q = (2)(4180)(75 - 25) = 418000J$$

2. Temperature Scales and Conversion

- **Celsius Scale**: 0°C (freezing point of water) to 100°C (boiling point of water)

- **Fahrenheit Scale**: 32°F (freezing) to 212°F (boiling)
- **Kelvin Scale**: 273 K (freezing) to 373 K (boiling)

Conversion Formulas:

1. **Celsius to Fahrenheit:** $F = \frac{9}{5}C + 32$
2. **Fahrenheit to Celsius:** $C = \frac{5}{9}(F - 32)$
3. **Celsius to Kelvin:** K = C + 273

Example: Convert 90°F to °C.

$$C = \frac{5}{9}(90 - 32) = 32.2°C$$

3. Effects of Heat

1. **Change in Temperature**
   - Heat causes temperature to rise.
2. **Change in Size (Expansion and Contraction)**
   - **Thermal Expansion**: Increase in length, area, or volume due to heating.
   - **Thermal Contraction**: Decrease in size due to cooling.

Types of Expansion:

- **Linear Expansion:** $\Delta L = L_0 \alpha \Delta T$
- **Superficial Expansion:** $\Delta A = A_0 \beta \Delta T$
- **Cubical Expansion:** $\Delta V = V_0 \gamma \Delta T$ where:
  - α , β , γ are expansion coefficients.

Example: A 1 m iron rod expands by 0.001 m when heated from 20°C to 120°C. Find α .

$$\alpha = \frac{\Delta L}{L_0 \Delta T} = \frac{0.001}{1 \times 100} = 10^{-5}/°C$$

3. **Change in State**
   - **Melting (Fusion)**: Solid → Liquid (Absorbs heat)
   - **Boiling (Vaporization)**: Liquid → Gas (Absorbs heat)
   - **Condensation**: Gas → Liquid (Releases heat)
   - **Freezing (Solidification)**: Liquid → Solid (Releases heat)

- **Sublimation**: Solid → Gas (Absorbs heat)

4. Modes of Heat Transfer

1. Conduction

- Transfer of heat through direct contact in solids.
- **Formula for Heat Conduction**: $Q = \frac{kA(T_1 - T_2)t}{d}$ where:
  - k = Thermal conductivity
  - A = Cross-sectional area
  - T_1, T_2 = Temperatures
  - d = Thickness
  - t = Time

Example: A metal rod conducts **1000 J** of heat in **5 seconds**. If its length is **2 m**, area is **0.01 m²**, and temperature difference is **50°C**, find k .

$$k = \frac{Qd}{A(T_1 - T_2)t} = \frac{1000 \times 2}{0.01 \times 50 \times 5} = 80 \text{ W/m°C}$$

2. Convection

- Heat transfer in liquids and gases through movement of particles.
- Examples:
  - **Sea breeze and Land breeze**
  - **Hot air rising in a room**

3. Radiation

- Heat transfer without a medium.
- Example:
  - **Sun's heat reaching Earth.**

Factors Affecting Radiation:

- **Black surfaces**: Best absorbers and emitters.
- **White/silvery surfaces**: Best reflectors.

5. Applications of Heat Concepts

1. **Expansion Applications:**
    - **Bridges have expansion joints** to avoid cracking.
    - **Gaps in railway tracks** prevent buckling.
    - **Electric wires sag in summer and tighten in winter** due to thermal expansion.
2. **Convection Applications:**
    - **Ventilation in houses** to remove hot air.
    - **Refrigerators** keep the freezer on top to allow cold air to sink.
    - **Chimneys in factories** remove hot gases.
3. **Radiation Applications:**
    - **Thermos Flask** reduces heat transfer through conduction, convection, and radiation.
    - **Black car seats absorb heat, while white reflects it**.

Example Problems

1. **A 500 g metal block requires 2100 J of heat to raise its temperature by 20°C. Find its specific heat capacity.**
   $c = \frac{Q}{m\Delta T} = \frac{2100}{0.5 \times 20} = 210 \text{ J/kg°C}$
2. **What is the temperature at which Fahrenheit reading is five times the Celsius reading?**
   Using $C = \frac{5}{9}(F - 32)$ and given F = 5C , solve: $C = \frac{5}{9}(5C - 32)$ 9C = 25C - 160
   16C = 160 C = 10°C, F = 50°F

Key Takeaways

1. Heat always flows from a hotter to a colder body.
2. Temperature scales: Celsius, Kelvin, Fahrenheit.
3. Heat transfer methods: **Conduction, Convection, Radiation**.
4. Expansion occurs in **solids, liquids, and gases**.
5. Heat energy affects **temperature, size, and state of matter**.