<u>Heat Energy</u>: Calculations on Specific Heat Capacity and Latent Heat

I. Calculation on Specific Heat Capacity

1. Mixture Method

The quantity of heat (Q) gained or lost is calculated by:

$$Q = mc\Delta\theta = mc(\theta_2 - \theta_1)$$

Where m is mass, c is **specific heat capacity**, and $\Delta\theta$ is the change in temperature. The specific heat capacity is thus:

$$c = \frac{Q}{m(\theta_2 - \theta_1)}$$

2. Electric Method

In the electric method, the heat supplied (Q) is the electrical energy consumed.

$$Q = IVt$$

or

$$Q = I^2Rt$$

or

$$Q = \frac{V^2}{R}t$$

Where IVt (or I^2Rt or $\frac{V^2}{R}t$) is the electrical energy supplied (in Joules, J). The specific heat capacity is then calculated as:

$$c = \frac{IVt}{m(\theta_2 - \theta_1)}$$

Question 1

A 2000W electric heater is used to heat a metal object of mass 5kg, initially at 10°C. A temperature rise of 20°C is obtained after 10min. Calculate the specific heat capacity of the metal.

Solution Parameters: * Power, $P = 2000\text{W}$ * Mass, $m = 5\text{kg}$ * Initial temperature, $\theta_1 = 10^\circ\text{C}$ * Final temperature, $\theta_2 = 30^\circ\text{C}$ (since a rise of 20°C is obtained, $\theta_2 = \theta_1 + 20^\circ\text{C} = 10^\circ\text{C} + 20^\circ\text{C} = 30^\circ\text{C}$) * Time, $t = 10\text{min} = 10 \times 60\text{s} = 600\text{s}$

Using the electric method formula, where $P = IV$:

$$c = \frac{IVt}{m(\theta_2 - \theta_1)} = \frac{Pt}{m(\theta_2 - \theta_1)}$$

$$c = \frac{2000\text{W} \times (10 \times 60)\text{s}}{5\text{kg} \times (30°\text{C} - 10°\text{C})}$$

$$c = \frac{2000 \times 600}{5 \times 20}$$

$$c = \frac{1{,}200{,}000}{100} = 12{,}000 \text{ J/kg}^{\circ}\text{C}$$

12,000 J/kg°C *(or* 12kJ/kg°C*). The step-by-step calculation from the notes:* $c = \frac{2000 \times 10 \times 60}{5(30-10)} = \frac{1{,}200{,}000}{5 \times 20} = \frac{1{,}200{,}000}{100} = 12{,}000$ J/kg°C The handwritten solution $C = 1200$ is incorrect based on the preceding steps.*

Question 2

An electric current of 3A flowing through an electric heating element of resistance 20 Ω embedded in 1000g of an oil raises the temperature of the oil by 10°C in 10s. Calculate the specific heat capacity of the oil.

Solution Parameters: * Current, $I = 3\text{A}$ * Resistance, $R = 20\ \Omega$ * Mass, $m = 1000\text{g} = 1\text{kg}$ * Change in temperature, $\Delta\theta = 10°\text{C}$ * Time, $t = 10\text{s}$

Using the formula for heat generated by current: $Q = I^2Rt$.

$$c = \frac{I^2Rt}{m\Delta\theta}$$

$$c = \frac{(3\text{A})^2 \times 20\ \Omega \times 10\text{s}}{1000\text{g} \times 10°\text{C}}$$

Note: The original calculation used 1000g *in the denominator but resulted in* J/g°C*. Let's follow the notes' unit conversion approach for the final answer:*

$$c = \frac{3^2 \times 20 \times 10}{1000 \times 10} \frac{J}{\text{g}°\text{C}}$$

$$c = \frac{9 \times 200}{10000} = \frac{1800}{10000} = 0.18 \text{ J/g}^{\circ}\text{C}$$

(If converted to standard non decimal you have, $c = 0.18 \times 1000 = 180$ J/kg°C)

Question 3

A piece of substance of specific heat capacity 450 J/kg · K falls a vertical distance of 20m from rest. Calculate the rise in temperature (θ) of the substance upon hitting the ground when all its gravitational potential energy is converted into heat. (Take $g = 10\text{ m/s}^2$).

Solution Principle: Gravitational Potential Energy (PE) is converted into Heat Energy (Q).

$$\text{PE} = Q$$

$$mgh = mc\Delta\theta$$

We can cancel the mass (m) from both sides:

$$gh = c\Delta\theta$$

Parameters: * Specific Heat Capacity, $c = 450$ J/kg · K * Height/Distance, $h = 20$ m * Acceleration due to gravity, $g = 10$ m/s^2 * Rise in temperature, $\Delta\theta = \theta$

$$10 \text{ m/s}^2 \times 20 \text{ m} = 450 \text{ J/kg} \cdot \text{K} \times \theta$$

$$200 = 450\theta$$

$$\theta = \frac{200}{450} = \frac{4}{9}$$

$$\theta = \frac{4^\circ}{9}\text{C}$$

(Since the temperature change is the same in °C and K, $4/9$ K or $4/9$°C is acceptable).

Question 4

A block of Aluminium is heated electrically by a 25W heater. The temperature rises by 10°C in 5 minutes. Calculate the **heat capacity** of the aluminium.

Solution Parameters: * Power, $P = 25$W * Change in temperature, $\Delta\theta = 10$°C * Time, $t = 5$ min $= 5 \times 60$ s $= 300$ s

The formula for **Heat Capacity** (C) is $C = \frac{Q}{\Delta\theta}$. The heat supplied ($Q$) is $Q = Pt$.

$$C = \frac{Pt}{\Delta\theta}$$

Note: The formula used in the handwritten notes, $C = \frac{IVt}{\Delta\theta}$, correctly simplifies to $C = \frac{Pt}{\Delta\theta}$ since $P = IV$. The handwritten calculation also uses 7500 in the numerator, which seems to imply $P \times t = 25$ W $\times$ 300 s $=$ 7500 J. However, the displayed calculation is: $C = \frac{Pt}{\Delta\theta} = \frac{7500}{10}$ $C = 750$ J/°C This is the correct value for the **Heat Capacity**.*

Question 5

A 500W heater is used to heat 0.6kg of water from 25°C to 100°C in t_1 seconds. If another 1000W heater is used to heat 0.2kg of water from 10°C to 100°C in t_2 seconds, find the ratio $\frac{t_1}{t_2}$. (Specific heat capacity of water, $c_w = 4200$ J/kg°C).

Solution Parameters: * $P_1 = 500$W * $m_1 = 0.6$kg * $\Delta\theta_1 = 100$°C $-$ 25°C $=$ 75°C * $P_2 = 1000$W * $m_2 = 0.2$kg * $\Delta\theta_2 = 100$°C $-$ 10°C $=$ 90°C * $c = 4200$ J/kg°C

1. Calculate Heat required (Q) for each case:

$$Q = mc\Delta\theta$$

$$Q_1 = m_1 c \Delta\theta_1$$

$$Q_1 = 0.6\ \text{kg} \times 4200\ \text{J/kg°C} \times 75°\text{C} = 189{,}000\ \text{J}$$

$$Q_2 = m_2 c \Delta\theta_2$$

$$Q_2 = 0.2\ \text{kg} \times 4200\ \text{J/kg°C} \times 90°\text{C} = 75{,}600\ \text{J}$$

2. Calculate Time (t) for each case: Since $Q = Pt$, then $t = \frac{Q}{P}$.

$$t_1 = \frac{Q_1}{P_1}$$

$$t_1 = \frac{189{,}000\ \text{J}}{500\ \text{W}} = 378\ \text{s}$$

$$t_2 = \frac{Q_2}{P_2}$$

$$t_2 = \frac{75{,}600\ \text{J}}{1000\ \text{W}} = 75.6\ \text{s}$$

3. Find the ratio $\frac{t_1}{t_2}$:

$$\frac{t_1}{t_2} = \frac{378\ \text{s}}{75.6\ \text{s}} = 5$$

Note: The original question did not explicitly ask for a ratio but ended with "Find tit", which is interpreted as the ratio $\frac{t_1}{t_2}$. The notes only provide the values of t_1 and t_2, but the final step is implied.

Question 6

A given quantity of heat raises the temperature of 150g of water from 9°C to 15°C and increases the temperature of 100g of oil from 9°C to 25°C. Calculate the ratio of the specific heat capacity of oil to that of water, $\frac{c_{oil}}{c_{water}}$. (Take $c_{water} = 1$ cal/g°C).

Solution Principle: The quantity of heat (Q) supplied is the same for both the water and the oil: $Q_{water} = Q_{oil}$.

$$m_w c_w \Delta\theta_w = m_{oil} c_{oil} \Delta\theta_{oil}$$

Parameters for Water (w): * Mass, $m_w = 150$ g * Specific Heat Capacity, $c_w = 1$ cal/g°C * Change in temperature, $\Delta\theta_w = 15°\text{C} - 9°\text{C} = 6°\text{C}$ * Heat gained by water, $Q_w = 150\ \text{g} \times 1\ \text{cal/g°C} \times 6°\text{C} = 900$ cal

Parameters for Oil (oil): * Mass, $m_{oil} = 100$ g * Specific Heat Capacity, c_{oil} (unknown) * Change in temperature, $\Delta\theta_{oil} = 25°\text{C} - 9°\text{C} = 16°\text{C}$ * Heat gained by oil, $Q_{oil} = 100\ \text{g} \times c_{oil} \times 16°\text{C} = 1600\ c_{oil}$ cal

Equating Heat Quantities:

$$Q_{water} = Q_{oil}$$

$$900\ \text{cal} = 1600\ c_{oil}\ \text{cal}$$

$$c_{oil} = \frac{900}{1600} = \frac{9}{16} = 0.5625 \text{ cal/g}^\circ\text{C}$$

Ratio of Specific Heat Capacity:

$$\frac{c_{oil}}{c_{water}} = \frac{0.5625 \text{ cal/g}^\circ\text{C}}{1 \text{ cal/g}^\circ\text{C}} = 0.5625$$

Latent Heat

II. Latent Heat

Latent Heat is the amount of heat absorbed or given out by a body during a **change of state** at a **constant temperature**.

The quantity of heat (Q) involved in a change of state is given by:

$$Q = mL$$

Where: * Q = Quantity of heat * m = Mass of the body (substance) * L = **Specific Latent Heat**

The **Specific Latent Heat** (L) is defined as:

$$L = \frac{Q}{m} \quad \text{(Unit: J/kg or J/g)}$$

III. Specific Latent Heat of Fusion

The **Specific Latent Heat of Fusion** of a substance is the quantity of heat required to convert a **unit mass** of the solid substance to the liquid state **without a change in temperature** (at its melting point).

$$L_f = \frac{Q}{m} \quad \text{(Unit: J/kg or J/g)}$$

Calculation of Specific Latent Heat of Fusion (Method of Mixtures)

This method typically involves mixing ice at a low temperature with water (or oil) in a calorimeter at a higher temperature.

$$\text{Heat lost by calorimeter and water} = \text{Heat gained by ice at } 0^\circ\text{C} + \text{Heat gained by melted ice}$$

$$\text{Heat lost} = (m_c c_c + m_w c_w)(\theta_1 - \theta_f)$$

$$\text{Heat gained} = (m_i L_f) + (m_i c_w)(\theta_f - 0)$$

Formula from notes (simplified with $\theta_2 = \theta_f$ and $\theta_1 = \text{initial temp}$):

$$(m_w c_w + C)(\theta_1 - \theta_f) = m_i L_f + m_i c_w(\theta_f - 0)$$

Where: * L_f = Specific latent heat of fusion. * C = Thermal capacity of the calorimeter. * θ_1 = Initial temperature of water/calorimeter. * θ_f = Final temperature of the mixture. * m_w = Mass of water. * c_w = Specific heat capacity of water. * m_i = Mass of ice. * *Note: In the problem-solving section, C appears to be used for $m_c c_c$ in the full equation.*

Calculation 1 (Example using Latent Heat of Fusion)

A calorimeter contains 60g of water and 100g of ice at 0°C. A piece of hot metal of mass 1kg is gently added to the mixture in the calorimeter, and this causes all the ice to just melt. Calculate the initial temperature of the metal. (Assume the specific heat capacity of the calorimeter is negligible and all temperatures are in °C).

Given Constants: * Specific heat capacity of water, $c_w = 4.2 \times 10^3$ J/kg°C * Specific heat capacity of the metal, $c_{metal} = 4.2 \times 10^2$ J/kg°C * Specific latent heat of fusion of ice, $L_f = 3.36 \times 10^5$ J/kg

Solution Parameters: * Mass of water, $m_w = 60$ g * Mass of ice, $m_i = 100$ g * Mass of metal, $m_{metal} = 1$ kg * Initial temperature of mixture (ice + water), 0°C * Final temperature of mixture (all ice melts), $\theta_f = 0$°C * Initial temperature of metal, t (unknown) * **Total mass of ice/melted ice**, $m_{total} = 60 \text{ g} + 100 \text{ g} = 160 \text{ g} = 0.16$ kg. (The notes seem to have incorrectly used $m_i = 100\text{g} = 0.1\text{kg}$ as the mass of ice that melts). We will follow the notes' logic for the calculation but correct the interpretation. *The notes' interpretation uses the **mass of ice added (**$100\text{g} = 0.1\text{kg}$**)** for the calculation, assuming the* 60g *of water was the initial water in the calorimeter and the* 100g *was the ice.*

Heat Gain/Loss Principle:

$$\text{Heat Lost by Metal} = \text{Heat Gained by Ice (Melting)}$$

Since the final temperature is 0°C *(all ice* just* melts), there is **no heat gained by the water** or the melted ice in raising their temperature, and **no heat lost by the water** or the calorimeter.*

1. Heat required to melt the ice (at constant temperature 0°C**):**

$$Q_{gained} = m_i L_f$$

$$Q_{gained} = 0.1 \text{ kg} \times 3.36 \times 10^5 \text{ J/kg} = 3.36 \times 10^4 \text{ J}$$

2. Heat lost by the metal (cooling from t to 0°C**):**

$$Q_{lost} = m_{metal} c_{metal} (\theta_1 - \theta_f)$$

$$Q_{lost} = 1 \text{ kg} \times 4.2 \times 10^2 \text{ J/kg°C} \times (t - 0\text{°C}) = 4.2 \times 10^2 t \text{ J}$$

3. Equating Heat Lost and Heat Gained:

$$Q_{lost} = Q_{gained}$$

$$4.2 \times 10^2 t = 3.36 \times 10^4$$

$$t = \frac{3.36 \times 10^4}{4.2 \times 10^2} = \frac{33600}{420} = 80$$

Initial temperature of the metal $ = 80^$.

Question 2 (Latent Heat of Fusion)

0.5kg of water at 10°C is completely converted to ice at 0°C by extracting 188,000 J of heat from it. If the specific heat capacity of water is 4200 J/kg°C, calculate the specific latent heat of fusion (L_f).

Solution Principle: Total heat extracted is the sum of heat lost by the water cooling to 0°C and the latent heat lost when it freezes at 0°C.

$$\text{Total Heat Extracted} = Q_{cooling} + Q_{freezing}$$

$$\text{Total Heat Extracted} = m_w c_w(\theta_1 - \theta_f) + m_w L_f$$

Parameters: * Mass of water, $m_w = 0.5$ kg * Initial temperature, $\theta_1 = 10$°C * Final temperature, $\theta_f = 0$°C * Total Heat Extracted, $Q_{total} = 188{,}000$ J * Specific heat capacity of water, $c_w = 4200$ J/kg°C * Specific Latent Heat of Fusion, L_f (unknown)

1. Heat lost by water cooling from 10°C **to** 0°C**:**

$$Q_{cooling} = m_w c_w(\theta_1 - \theta_f)$$

$$Q_{cooling} = 0.5\text{ kg} \times 4200\text{ J/kg°C} \times (10\text{°C} - 0\text{°C}) = 21{,}000\text{ J}$$

2. Heat lost at constant temperature (freezing):

$$Q_{freezing} = m_w L_f = 0.5L_f$$

3. Total Heat Extracted:

$$188{,}000\text{ J} = 21{,}000\text{ J} + 0.5L_f$$

$$0.5L_f = 188{,}000 - 21{,}000$$

$$0.5L_f = 167{,}000$$

$$L_f = \frac{167{,}000}{0.5} = 334{,}000\text{ J/kg}$$

$$L_f = 3.34 \times 10^5\text{ J/kg}$$

IV. Specific Latent Heat of Vaporisation (Steam)

This is defined as the quantity of heat required or needed to change a **unit mass** of liquid to the gaseous state at a **constant temperature** (boiling point) and pressure.

- It is denoted by L_{steam}.
- It is measured in J/kg or J/g and is a **scalar quantity**

[Above Image of water boiling] . * A common relationship is $L_{\text{ice}} \approx \frac{1}{7} L_{\text{steam}}$.

V. Experiment to Determine Specific Latent Heat of Fusion of Ice

Aim

To determine the **Specific Latent Heat of Fusion** of solid ice.

Apparatus

Bunsen burner, *Calorimeter*, *Dry (crushed) ice*, *Thermometer*, *Stirrer*, *Water*, *Stirrer*, and *Weighing balance*.

Method

1. The **calorimeter** is first weighed (M_1) then filled with water and weighed again (M_2).
2. The calorimeter and water are then heated to a particular temperature (θ_1), which is measured by the thermometer.
3. The **solid ice** is wrapped, weighed ($M_3 - M_2$), and then dropped into the calorimeter and stirred until the temperature is about 6°C, which is below the room temperature. This is done to avoid **radiation error**.
4. The **final temperature** (θ_f) is recorded, and the calorimeter is weighed again (M_3) to find the mass of the ice added ($M_3 - M_2$).
5. Then, the **specific latent heat of fusion** of the ice can be found.

Data

- M_1: Mass of the calorimeter.
- M_2: The mass of **calorimeter** + **water**.
- M_3: The mass of **ice** + **water** + **calorimeter**.
- θ_1: The initial temperature of the water.
- θ_f: The final temperature of the water after adding ice.
- c_w: The specific heat capacity of water.
- c_c: The specific heat capacity of calorimeter.

Derived Masses/Quantities: * Mass of water: $m_w = M_2 - M_1$ * Mass of ice: $m_i = M_3 - M_2$ * Heat lost by calorimeter and water: $Q_{lost} = (m_w c_w + M_1 c_c)(\theta_1 - \theta_f)$ * Heat gained by ice melting at 0°C: $Q_{gained,\text{melting}} = (M_3 - M_2)L_f$ * Heat gained by melted ice when its temperature rises from 0°C to θ_f: $Q_{gained,\text{warming}} = (M_3 - M_2)c_w(\theta_f - 0)$

Final Equation (Since Heat Gained = Heat Lost):

$$(M_3 - M_2)L_f + (M_3 - M_2)c_w\theta_f = (M_2 - M_1)c_w(\theta_1 - \theta_f) + M_1 c_c(\theta_1 - \theta_f)$$

Precautions

1. Before taking the reading, the mercury thread must be **steady**.
2. The piece of ice must be **dried** before use.
3. The ice to be used must be in **small quantity** to prevent moisture from being deposited on the calorimeter.
4. The water must be **stirred continuously** to balance the temperature of the water.

Calculation 1 (Latent Heat of Fusion - Oil)

A Copper calorimeter of mass 60g contains 100g of oil at 20°C. A piece of ice of mass 25g at 0°C is added to the oil. Calculate the amount of ice left when the temperature of the calorimeter and its content becomes steady at 0°C.

Given Constants: * Specific heat capacity of Copper, $c_c = 400$ J/kg · K * Specific heat capacity of oil, $c_{oil} = 2400$ J/kg · K * Specific latent heat of fusion of ice, $L_f = 336{,}000$ J/kg

Solution Parameters: * Mass of calorimeter, $M_c = 60\text{ g} = 0.06\text{ kg}$ * Mass of oil, $M_{oil} = 100\text{ g} = 0.1\text{ kg}$ * Mass of ice added, $M_{ice,\text{initial}} = 25\text{ g} = 0.025\text{ kg}$ * Initial temperature of oil/calorimeter, $\theta_1 = 20°\text{C}$ * Initial temperature of ice, $\theta_2 = 0°\text{C}$ * Final temperature of mixture, $\theta_f = 0°\text{C}$ * $c_c = 400$ J/kg · K * $c_{oil} = 2400$ J/kg · K * $L_f = 336{,}000$ J/kg

Principle (Law of Mixtures):

$$\text{Heat Gained by Ice} = \text{Heat Lost by Calorimeter} + \text{Heat Lost by Oil}$$

Since the final temperature is 0°C, the heat gained by the ice is *only* the latent heat required for melting (Q_f).

1. Heat lost by the calorimeter (Q_1):

$$Q_1 = M_c c_c (\theta_1 - \theta_f)$$

$$Q_1 = 0.06\text{ kg} \times 400\text{ J/kg}\cdot\text{K} \times (20°\text{C} - 0°\text{C})$$

$$Q_1 = 24 \times 20 = 480\text{ J}$$

2. Heat lost by the oil (Q_2):

$$Q_2 = M_{oil} c_{oil} (\theta_1 - \theta_f)$$

$$Q_2 = 0.1\text{ kg} \times 2400\text{ J/kg}\cdot\text{K} \times (20°\text{C} - 0°\text{C})$$

$$Q_2 = 240 \times 20 = 4{,}800\text{ J}$$

3. Total heat available for melting the ice (Q_{melt}):

$$Q_{\text{melt}} = Q_1 + Q_2$$

$$Q_{\text{melt}} = 480\text{ J} + 4{,}800\text{ J} = 5{,}280\text{ J}$$

4. Mass of ice melted (M_{melted}):

$$Q_{\text{melt}} = M_{\text{melted}} L_f$$

$$M_{\text{melted}} = \frac{Q_{\text{melt}}}{L_f}$$

$$M_{\text{melted}} = \frac{5{,}280\text{ J}}{336{,}000\text{ J/kg}}$$

$$M_{\text{melted}} = 0.015714\text{ kg} \approx 15.71\text{ g}$$

5. Mass of ice left:

$$\text{Mass Left} = M_{ice,\text{initial}} - M_{\text{melted}}$$

$$\text{Mass Left} = 25\ \text{g} - 15.71\ \text{g} = 9.29\ \text{g}$$

The handwritten notes use the mass in kg *in the final steps but present the answer in grams:* $M_{\text{melted}} = 5280/336000\ \text{kg} \approx 0.01575\ \text{kg} = 15.75\ \text{g}$

$$\text{Ice left} = 25\ \text{g} - 15.75\ \text{g} = 9.25\ \text{g}$$

$$\text{Mass Left} \approx 9.25\ \text{g}$$

Calculation 2 (Latent Heat of Vaporisation)

All the heat generated in a 5 Ω resistor by 2A flowing for 30s is used to evaporate 5g of a liquid at its boiling point. Calculate the specific latent heat (L) of the liquid.

Solution Principle: Electrical Heat Generated = Heat Absorbed by Liquid.

$$I^2Rt = mL$$

Parameters: * Resistance, $R = 5\ \Omega$ * Current, $I = 2\text{A}$ * Time, $t = 30\ \text{s}$ * Mass of liquid, $m = 5\ \text{g}$ * Specific Latent Heat, L (unknown)

1. Electrical Heat Generated (Q):

$$Q = I^2Rt$$

$$Q = (2\ \text{A})^2 \times 5\ \Omega \times 30\ \text{s} = 4 \times 5 \times 30 = 600\ \text{J}$$

2. Heat Absorbed by Liquid (Q):

$$Q = mL$$

$$600\ \text{J} = 5\ \text{g} \times L$$

$$L = \frac{600\ \text{J}}{5\ \text{g}} = 120\ \text{J/g}$$

Evaporation, Boiling, and Sublimation

VI. Boiling

Boiling is defined as the change from **liquid** to **vapour** when the **saturation vapour pressure** is equal to the **atmospheric pressure** (or the surrounding pressure).

When a liquid is boiled at a particular temperature, it starts giving up energy to the molecules as gases. Once the kinetic energy is absorbed per molecule and is sufficient, the molecules escape.

The temperature at which the liquid boils to become vapour is known as the **saturated temperature** or **boiling point**.

Factors Affecting Boiling

1. **Impurities**: Impurities affect the boiling point of a liquid because their presence **increases** the boiling point of the liquid compared to the boiling point of a pure solvent.
2. **Pressure**: Pressure affects the boiling point of a liquid because an **increase in pressure** will lead to an **increase in the boiling point**.

Application of Pressure on Boiling

1. It is used in the principle of a **pressure cooker**.
2. An aircraft flying at high altitudes where the air is of **lower pressure** than normal needs to be pressurized so that the people can be at their normal pressure.
3. Astronauts must also wear their suit for breathing and to be at the right pressure.

VII. Evaporation

Evaporation is when a **volatile liquid** (i.e., one that evaporates easily, such as *alcohol* or *ether*) exposed to the atmosphere, molecules from the surface of the liquid gradually **escape** from the liquid to change to the vapour state.

Evaporation takes place at **all temperatures** and only from the **surface** of the liquid.

Factors Influencing the Rate of Evaporation

1. **Temperature**: The rate of evaporation **increases** with higher temperature.
2. **Pressure**: The rate of evaporation **decreases** with an increase in pressure.
3. **Area of liquid surface exposed**: The greater the surface area of the liquid exposed, the more rapid will be the evaporation.
4. **The nature of the liquid**: Different liquids evaporate at different rates; the lower the boiling point of a liquid, the greater will be the rate of evaporation.
5. **Wind and Dryness of Air**: It is a common observation that clothes hung out on a dry, windy day dry out very quickly. The dryness of the air around the clothes causes **rapid evaporation** of the water from the wet material. Wind blows away the water vapour around the materials and causes more evaporation to take place.

Differences Between Boiling and Evaporation

Evaporation	Boiling
1. It occurs at **all temperatures**.	1. It occurs at the **boiling point** of the liquid.
2. It **causes cooling**.	2. It **does not cause cooling** (the heat supplied is used for the change of state).
3. It occurs **only at the surface**.	3. It occurs in **every part** of the liquid (as bubbles).
4. It is **not affected by the mass** of the liquid exposed.	4. It is **affected by the mass** of the liquid.
5. It does not depend on the container of the liquid.	5. It depends on the container because they absorb the energy first.

Similarities Between Boiling and Evaporation

1. They both involve the **escape of molecules** into the atmosphere.
2. They both depend on the **nature of the liquid**.
3. They both depend on the **pressure**.
4. They both depend on the **surface area**.
5. They both depend on **impurities**.

VIII. Sublimation

Sublimation is the process whereby a substance changes from the **solid** to the **vapour** state **without going through the liquid state**. *Example: Dry ice (*CO_2*) when changed to vapour, and Iodine crystals.*

IX. Water Vapour in the Atmosphere

Water vapour is present in the atmosphere in various forms, due to the presence of temperature and the surrounding environment. The water vapour in the atmosphere exists in these forms:

- **Mist**
- **Rain**
- **Cloud**
- **Snow/Hail**
- **Humidity**
- **Fog**
- **Frost**
- **Dew**

Mist

When moist air near the earth's surface and a few distance above it is cooled, the water vapour in it **condenses** and forms tiny droplets which are suspended in the air. Mist can also be formed when wind blows **warm, moist air** over a **cold surface**. Mist is closer to the ground and restricts visibility such that one cannot see very far when there is a mist.

Cloud

A **Cloud** is a mass of small water droplets that float in the air. When a mist or a fog is formed at high altitude, it is called a **Cloud**. When water drops from a cloud combine together, larger water drops are formed and **rainfall** occurs.

Hail

Hail is caused due to the **freezing of rain drops** in the atmosphere. Hail are of different sizes and are hard while **snow** is flaky.

Frost

This occurs when the temperature of the atmosphere is low. The dew formed on leaves and grasses freezes.

Dew

Dew is normally found in the early hours of the morning when the temperature of the atmosphere is low. It falls on grasses or leaves, condensed in the form of **fine water droplets**.

Dew Point

Dew point is the temperature at which the water present in the air is just enough to **saturate** the air.

Humidity

This refers to the **amount of water vapour present in the air**. If the air in the environment is **dry**, the sweat from our body evaporates faster than when the air is **damp** (made up of water vapour).

Relative Humidity (RH**)** is defined as the ratio of the mass of water vapour present in a certain volume of air to the mass of water vapour required to ** saturate** the same volume of air at the same temperature.

Formula:

$$\text{Relative Humidity} = \frac{\text{Mass of } H_2O \text{ vapour in a given volume of air}}{\text{Mass of } H_2O \text{ vapour required to saturate the same volume of air at the same temperature}}$$

OR

$$\text{RH} = \frac{\text{SVP of water at dew point}}{\text{SVP of water at original air temperature}}$$

Where **SVP** = **Saturated Vapour Pressure**.

The instrument used in measuring relative humidity is the **Hygrometer**.

Gas Laws

X. Pressure

Pressure (P) is defined as **force per unit area**, and its unit is the Newton per meter squared (N/m^2) or Pascal (Pa).

$$P = \frac{F}{A}$$

Since $F = mg$ (for weight):

$$P = \frac{mg}{A}$$

In terms of fluid height (h), density (ρ), and gravity (g):

$$P = \frac{\rho V g}{A} = \frac{\rho A h g}{A}$$

$$P = \rho g h \quad (\text{N/m}^2)$$

Example: Atmospheric Pressure Calculate the pressure exerted by a column of mercury of height $H = 76\ \text{cmHg} = 0.76\ \text{mHg}$. * Density of mercury, $\rho = 13{,}600\ \text{kg/m}^3$ * $g = 10\ \text{m/s}^2$ (or $9.8\ \text{m/s}^2$)

Using $g = 9.8\ \text{m/s}^2$:

$$P = \rho g h$$

$$P = 13{,}600\ \text{kg/m}^3 \times 9.8\ \text{m/s}^2 \times 0.76\ \text{m}$$

$$P \approx 101{,}292.8\ \text{N/m}^2 \approx 1.013 \times 10^5\ \text{N/m}^2$$

This value, $1.013 \times 10^5\ \text{N/m}^2$*, means the **atmospheric pressure***.

XI. Pressure Law (Amonton's Law)

This states that the **pressure** of a fixed mass of gas in an exact enclosed container is **directly proportional** to the **absolute temperature** (provided the volume of the container is kept constant).

$$P \propto T \quad (\text{V constant})$$

$$P = kT \quad (\text{where } k \text{ is a constant})$$

$$\frac{P}{T} = k$$

Therefore:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} = \cdots = \frac{P_n}{T_n}$$

Example 1

The pressure of a gas at constant volume is 100 cmHg at 27°C. Calculate the pressure at 87°C.

Solution Parameters: * $T_1 = 27°\text{C} + 273 = 300\ \text{K}$ * $T_2 = 87°\text{C} + 273 = 360\ \text{K}$ * $P_1 = 100\ \text{cmHg}$

Using the Pressure Law:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{100\ \text{cmHg}}{300\ \text{K}} = \frac{P_2}{360\ \text{K}}$$

$$P_2 = \frac{100 \times 360}{300}$$

$$P_2 = 120\ \text{cmHg}$$

Example 2

The pressures of a gas at constant volume registered 150 cmHg at 0°C and 300 cmHg at a higher temperature. Calculate the **absolute temperature** (T) at the higher pressure.

Solution Parameters: * $P_1 = 150\ \text{cmHg}$ * $P_2 = 300\ \text{cmHg}$ * $T_1 = 0°\text{C} + 273 = 273\ \text{K}$ * $T_2 = T$ (unknown)

Using the Pressure Law:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{150\ \text{cmHg}}{273\ \text{K}} = \frac{300\ \text{cmHg}}{T}$$

$$T = \frac{300 \times 273}{150}$$

$$T = 2 \times 273 = 546\ \text{K}$$

XII. Boyle's Law

This states that the **volume** of a fixed mass of gas varies **inversely** as its **pressure**, provided the **temperature remains constant**.

$$V \propto \frac{1}{P}$$

$$V = \frac{k}{P}$$

$$PV = k \quad (\text{constant})$$

Therefore:

$$P_1 V_1 = P_2 V_2$$

Example 1

Calculate the volume fraction change of a fixed mass of gas whose pressure is **tripled** at constant temperature.

Solution Let the initial pressure and volume be P_1 and V_1. The new pressure $P_2 = 3P_1$. The new volume is V_2 (unknown).

Using Boyle's Law:

$$P_1 V_1 = P_2 V_2$$

$$P_1 V_1 = (3P_1) V_2$$

Dividing by P_1:

$$V_1 = 3V_2$$

$$V_2 = \frac{V_1}{3}$$

The new volume (V_2) is one-third of the initial volume (V_1).

Example 2

The pressure of a fixed mass of gas is given as 850 cmHg when its volume is 20 cm^3. Calculate the volume of the gas when its pressure is 600 cmHg.

Solution Parameters: * $P_1 = 850$ cmHg * $V_1 = 20\ \text{cm}^3$ * $P_2 = 600$ cmHg * V_2 (unknown)

Using Boyle's Law:

$$P_1V_1 = P_2V_2$$

$$850 \times 20 = 600 \times V_2$$

$$V_2 = \frac{850 \times 20}{600}$$

$$V_2 = \frac{17000}{600} \approx 28.33\ \text{cm}^3$$

Example 3

A fixed mass of gas occupies a volume of 2.5 litres at a pressure of 5 N/m^2. If the temperature is constant, find the volume at a pressure of 8 N/m^2.

Solution Parameters: * $P_1 = 5\ \text{N/m}^2$ * $V_1 = 2.5$ litres * $P_2 = 8\ \text{N/m}^2$ * V_2 (unknown)

Using Boyle's Law:

$$P_1V_1 = P_2V_2$$

$$5 \times 2.5 = 8 \times V_2$$

$$V_2 = \frac{5 \times 2.5}{8} = \frac{12.5}{8}$$

$$V_2 = 1.5625\ \text{litres}$$

XIII. Charles' Law

This states that the **volume** of a given mass of gas at a constant pressure is **directly proportional** to its **absolute** (or **Kelvin**) **temperature**.

$$V \propto T \quad \text{(P constant)}$$

$$V = kT$$

$$\frac{V}{T} = k \quad \text{(constant)}$$

Therefore:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Example 1

A gas has a volume of 500 cm^3 at $27°\text{C}$ and a pressure of 60 cm of mercury. Calculate the volume when the temperature is increased to $127°\text{C}$, the pressure remaining constant.

Solution Parameters (Since pressure is constant): * $V_1 = 500 \text{ cm}^3$ * $T_1 = 27°\text{C} + 273 = 300 \text{ K}$ * $T_2 = 127°\text{C} + 273 = 400 \text{ K}$ * V_2 (unknown)

Using Charles' Law:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{500 \text{ cm}^3}{300 \text{ K}} = \frac{V_2}{400 \text{ K}}$$

$$V_2 = \frac{500 \times 400}{300} = \frac{200{,}000}{300} \approx 666.67 \text{ cm}^3$$

Example 2

A column of air 10.0 cm long is trapped in a tube at $27°\text{C}$. What is the length of the column at $100°\text{C}$? (Assume volume is proportional to length).

Solution Parameters: * $L_1 = 10 \text{ cm}$ * $T_1 = 27°\text{C} + 273 = 300 \text{ K}$ * $T_2 = 100°\text{C} + 273 = 373 \text{ K}$ * L_2 (unknown)

Assuming Volume is proportional to Length, $\frac{V}{T} = k \implies \frac{L}{T} = k$:

$$\frac{L_1}{T_1} = \frac{L_2}{T_2}$$

$$\frac{10 \text{ cm}}{300 \text{ K}} = \frac{L_2}{373 \text{ K}}$$

$$L_2 = \frac{10 \times 373}{300} = \frac{3730}{300} \approx 12.43 \text{ cm}$$

XIV. General Gas Law (Combined Gas Law)

The general relationship between **pressure** (P), **volume** (V), and **temperature** (T) for a given mass of gas is called the **equation of state** or **Ideal Gas Law**.

By a combination of Boyle's and Charles' laws, we obtain that:

$$\frac{PV}{T} = \text{a constant}$$

Therefore:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Example (Combined Gas Law)

A mass of gas at 7°C and 70 cm of mercury has a volume of 1200 cm^3. Determine its volume at 27°C and a pressure of 75 cm of mercury.

Solution Parameters: * $P_1 = 70$ cmHg * $V_1 = 1200\ \text{cm}^3$ * $T_1 = 7°\text{C} + 273 = 280$ K * $P_2 = 75$ cmHg * $T_2 = 27°\text{C} + 273 = 300$ K * V_2 (unknown)

Using the Ideal Gas Law:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Rearranging for V_2:

$$V_2 = \frac{P_1V_1T_2}{P_2T_1}$$

$$V_2 = \frac{70 \times 1200 \times 300}{75 \times 280}$$

$$V_2 = 1200\ \text{cm}^3$$

Waves

XV. Production and Propagation of Waves

A **wave** is a **disturbance** which travels through a medium and transfers **energy** from one point to another **without any permanent displacement** of the medium itself.

Wave motion is the process of transferring a disturbance (in the form of kinetic energy) from one point to another in a medium **without any transfer of the particles** of the medium.

Types of Waves

1. **Mechanical waves**
2. **Electromagnetic waves**

Mechanical Waves

These are waves that require a **material medium** for their propagation. *Example: Water waves in a ripple tank, **sound wave***.

Electromagnetic Waves

These are waves that **do not require** a material medium for their propagation, but they travel successfully in **free space (vacuum)**. *Example: Light, radio waves, X-rays, etc.* * They travel with the **speed of light** in a vacuum (3.0×10^8 m/s) on a straight line. * They exhibit all properties associated or connected with light. * They are **undeflected** in electric and magnetic fields.

Difference Between Electromagnetic and Mechanical Waves

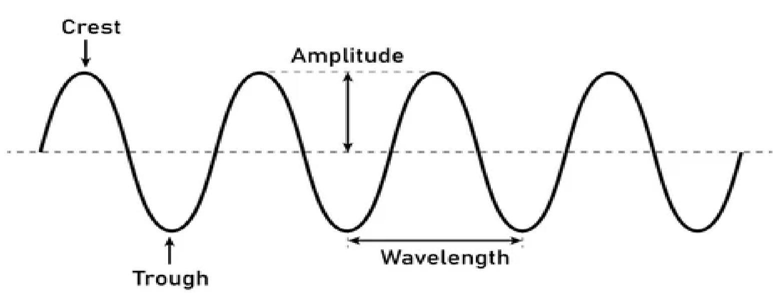
Electromagnetic Waves	Mechanical Waves
1. Travel with the speed of light (3.0×10^8 m/s).	1. Travel with a velocity/speed **less than** the speed of light.
2. A material medium is **not required** (travel successfully through vacuum/free space).	2. A material medium **is required**.

XVI. Types of Mechanical Waves

1. **Transverse wave**
2. **Longitudinal wave**
3. **Standing/Stationary wave**
4. **Progressive or Travelling wave**

1. Transverse Wave

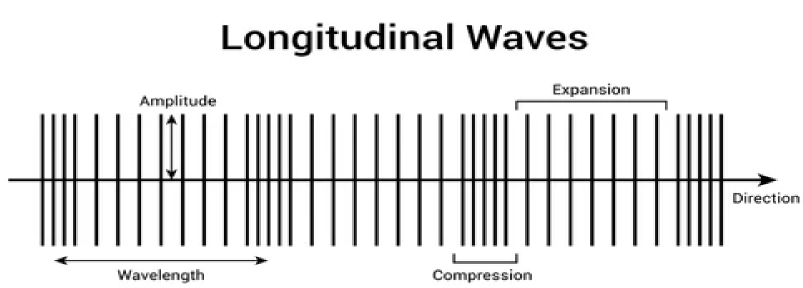
This is a type of wave which travels **perpendicularly** to the direction of the **propagation or vibration** of the wave. *Example: Water waves in a ripple tank, waves on a plucked string, and also electromagnetic waves such as **light wave**, **radio waves**, **X-rays**, etc.*



(Above image of Transverse wave)

2. Longitudinal Wave

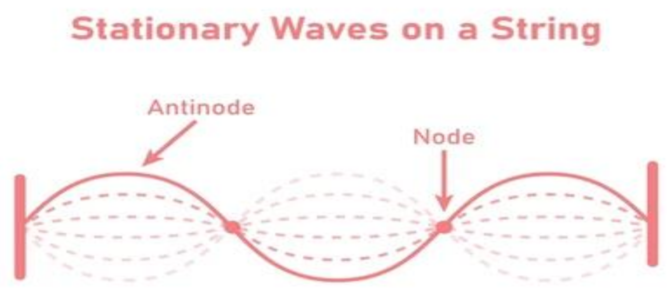
These are waves in which the vibration occurs in the **same direction** as the direction traveled by the wave. *Example:* ***Sound waves***. The direction of air particles are the same as the sound waves. Most musical instruments are played either by the vibration of stretched strings or by the vibration of a pipe.



(Above image of Longitudinal Wave)

3. Standing/Stationary Waves

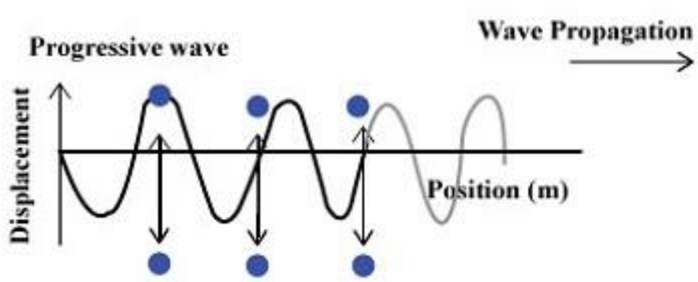
A **stationary wave** is a wave obtained when two **progressive waves** of **equal amplitude** and **frequency** are travelling in **opposite directions** and combined together. *Example: Waves obtained by plucking a string fixed at both ends.* The standing waves are due to the **interference** of two waves traveling in opposite directions. For them to interfere, they must have the **same frequency** and **amplitude** (e.g., *sinusoidal wave*).



(Above image of Standing/Stationary Waves)

4. Progressive or Travelling Waves

These occur when a travelling wave moves **continuously** from one point to another. It is a continuous process.

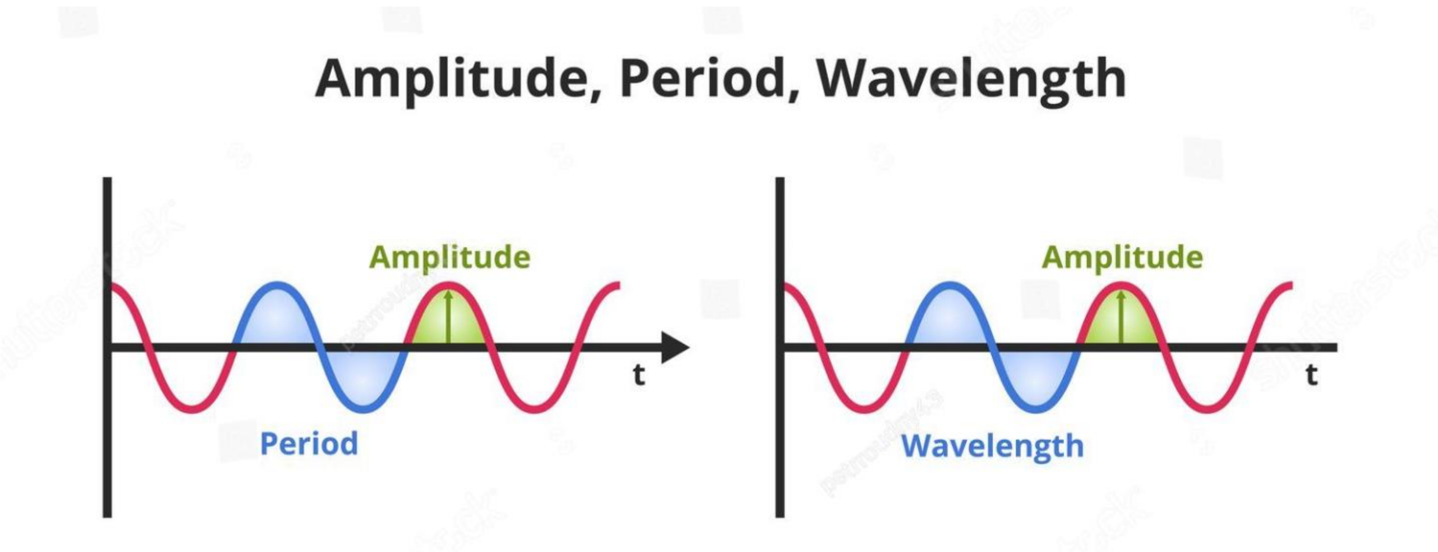


(Above image of Progressive or Travelling Wave)

XVII. Terms Used in Wave Motion and Mathematical Relationships

1. **Amplitude (A)**: This is the **maximum displacement** of a particle from the **point of rest**. It is denoted as A and measured in **metres** (m).
2. **Wave Front**: This is any line or section taken through a wave in which all particles are in the **same phase**. It indicates the series of up and down movements along the water wave (or a light wave).
3. **Phase (ϕ)**: Phase is defined as the ratio of the **displacement** of the vibrating particles at any instant to the **amplitude** of the vibrating particle.
4. **Vibration**: This is the **to and fro movement** of a particle from one extreme position to the other and back.

5. **Wavelength (λ)**: This is the distance between two successive **crests** or **troughs** of the wave. It is denoted by λ (*lambda*) and measured in **metres** (m).



(Above image Explaining Wavelength)

6. **Period (T)**: This is the **time taken** for one complete oscillation. It is denoted by T and measured in **seconds** (s).
7. **Frequency (f)**: This is the **number of cycles** which the wave completes in one second. It is measured in **cycles per second**, which are called **Hertz** (Hz), kHz, MHz, etc.
    - 1 kHz $= 10^3$ Hz
    - 1 MHz $= 10^6$ Hz

Relationship between Period and Frequency:

$$T = \frac{1}{f}$$

Also:

$$T = \frac{2\pi}{\omega}$$

$$f = \frac{\omega}{2\pi}$$

Where ω is the **angular velocity** (in rad/s).

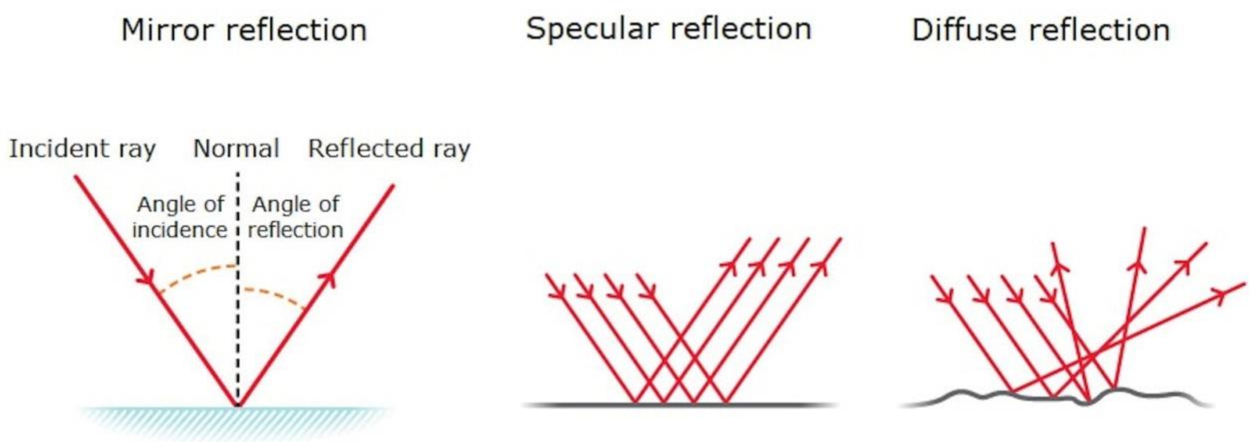
Wave Velocity (V): Wave velocity is defined as $V = f\lambda$.

$$V = \frac{\lambda}{T}$$

XVIII. Properties of Waves

1. Reflection

Reflection is the change in the **direction** of waves when they hit an obstacle. The type of wave formed depends on the type of obstacle they hit or meet. *Example: Shadow and parallel waves are set up from a plane metal strip standing up in the water of a ripple tank. Similarly, when the plane metal is replaced by a curved metal strip, the reflection results in rays from a spherical wave.*



(Above image explaining Reflection)

2. Refraction

Refraction occurs between two media when the wave direction of propagation **changes** as it enters a different medium. *Example: When a straight wave passes from **deep** to **shallow water**, the **wavelength becomes shorter**. During this process, the **frequency remains the same** but the **velocity** and **wavelength** change.* Waves travel more slowly in shallow water (same frequency, shorter wavelength).

The **refractive index** (η) can be expressed as:

$$\eta = \frac{V_1}{V_2}$$

Where: * V_1 = Velocity in deep water (or first medium) * V_2 = Velocity in shallow water (or second medium) *Also, for a plane light wave refracted from one medium to a more optically dense medium:*

$$\eta = \frac{\text{Velocity of light in first medium}}{\text{Velocity of light in second medium}}$$

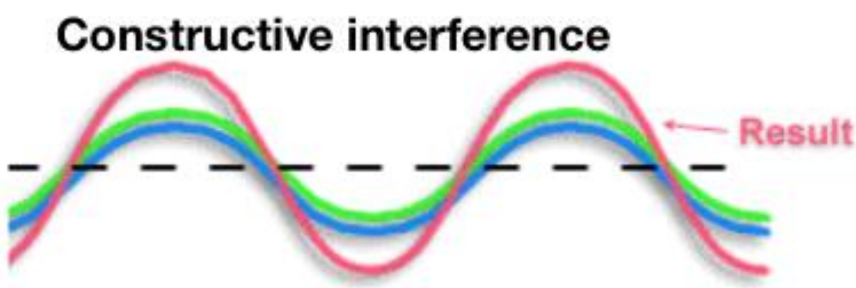
3. Diffraction

Diffraction is a phenomenon whereby waves **bend around obstacles**. It is also the **spreading** of waves after passing through tiny **openings** or **apertures** (a hole or a slit). * The **smaller** the width of the aperture (compared to the wavelength), the **greater** will be the spreading of the waves. * The **bigger** the width of the aperture (compared to the wavelength), the **smaller** will be the spreading of the waves.

4. Interference

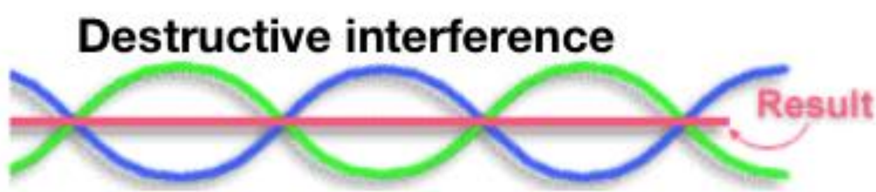
Interference occurs when two waves from a source cross each other's path. That is the **interaction of two coherent waves** which move simultaneously through the same medium. It can be classified into two types: * **Constructive Interference** * **Destructive Interference**

Constructive Interference This occurs if the **crest** of one wave arrives simultaneously as the **crest** of the other.



(Above image Explainig Constructive Interference)

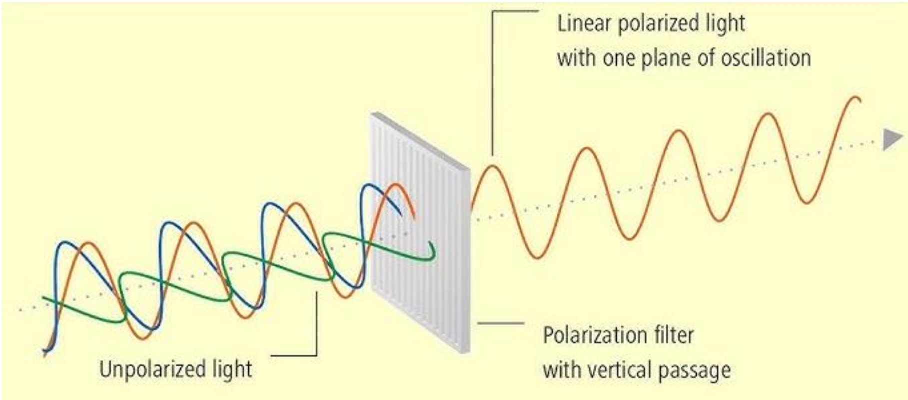
Destructive Interference This occurs if the **crest** of one wave arrives simultaneously as the **trough** of the other.

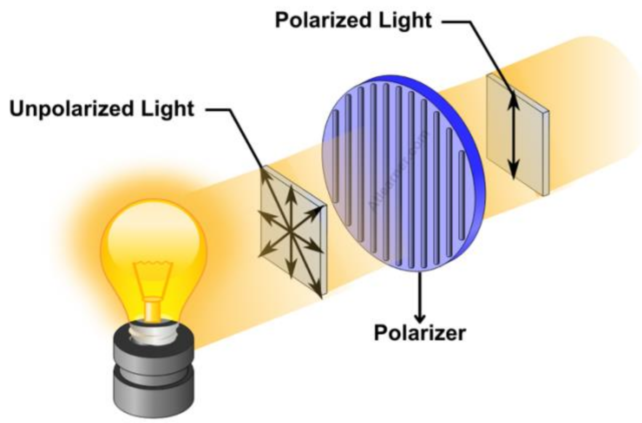


(Above image of Destructive Interference)

5. Polarization

Polarization simply means that the confinement of waves to one direction occurs **only in transverse waves**. **Plane polarization of light** is the fluctuations or vibrations that are constricted to vibrate **only in one plane** perpendicular to the direction of the light.



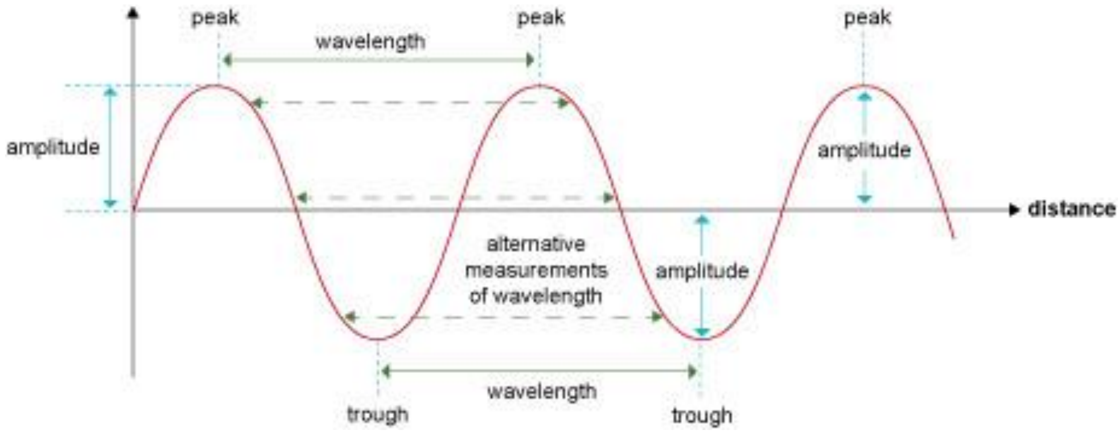


(*Above <u>images</u> Explaining Polarization)*

Applications of Plane-Polarized Light

1. Production of three-dimensional pictures/films.
2. Determination of concentration of sugar solutions.
3. For a study, areas of great stress in glass or celluloid are cut to a special design.
4. Polarized cameras.
5. Sun glasses to reduce the intensity of light.

XIX. Representation of Waves



(Above image Explaining Representation of Waves)

A **progressive wave** can be represented by the equation:

$$y = A\sin(\omega t \pm \phi)$$

The equation for a progressive wave travelling in the **positive x-direction** is typically written as:

$$y = A\sin(\omega t - kx)$$

Where: * y = Vertical displacement * x = Horizontal displacement * A = Amplitude * ω = Angular Velocity (rad/s) * ϕ = Phase angle (rad) * $V = f\lambda$ * $\omega = 2\pi f = \frac{2\pi}{T}$ * $k = \frac{2\pi}{\lambda}$ (Wave Number) * $\phi = \frac{2\pi x}{\lambda}$ (Phase in terms of distance)

Substituting ω and k into the main equation:

$$y = A\sin\left(2\pi f t - \frac{2\pi x}{\lambda}\right)$$

$$y = A\sin\left[2\pi\left(ft - \frac{x}{\lambda}\right)\right]$$

Since $f = \frac{1}{T}$ and $f\lambda = V$:

$$y = A\sin\left[2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)\right]$$

Example 1 (Wave Equation)

The plane progressive wave is represented by the equation $y = 4\sin(100\pi t - 50\pi x)$. Find the: i. Amplitude (A) ii. Frequency (f) iii. Wavelength (λ) iv. Velocity (V)

Solution Compare the given equation $y = 4\sin(100\pi t - 50\pi x)$ with the standard form $y = A\sin(\omega t - kx)$.

i. **Amplitude (A):**

$$A = 4\text{ m}$$

ii. **Frequency (f):**

$$\omega = 2\pi f$$

$$100\pi = 2\pi f$$

$$f = \frac{100\pi}{2\pi} = 50\text{ Hz}$$

iii. **Wavelength (λ):**

$$k = \frac{2\pi}{\lambda}$$

$$50\pi = \frac{2\pi}{\lambda}$$

$$\lambda = \frac{2\pi}{50\pi} = \frac{2}{50} = 0.04\text{ m} \quad (\text{or } 4\text{ cm})$$

iv. **Velocity (V):**

$$V = f\lambda$$

$$V = 50\text{ Hz} \times 0.04\text{ m} = 2\text{ m/s}$$

Example 2 (Wave Equation)

A progressive wave is given as $y = 0.5\sin 2\pi(40t - 20x)$. Find the: i. Speed (V) ii. Wavelength (λ) iii. Period (T)

Solution Given: $y = 0.5\sin 2\pi(40t - 20x)$ Expand the equation: $y = 0.5\sin(80\pi t - 40\pi x)$ Compare with $y = A\sin(2\pi f t - \frac{2\pi x}{\lambda})$ or $y = A\sin(\omega t - kx)$.

Finding Frequency (f):

$$2\pi f = 80\pi$$

$$f = \frac{80\pi}{2\pi} = 40\text{ Hz}$$

Finding Wavelength (λ):

$$\frac{2\pi}{\lambda} = 40\pi$$

$$\lambda = \frac{2\pi}{40\pi} = \frac{1}{20} = 0.05 \text{ m}$$

i. **Speed (V):**

$$V = f\lambda$$

$$V = 40 \text{ Hz} \times 0.05 \text{ m} = 2 \text{ m/s}$$

ii. **Wavelength (λ):**

$$\lambda = 0.05 \text{ m}$$

iii. **Period (T):**

$$T = \frac{1}{f}$$

$$T = \frac{1}{40} = 0.025 \text{ s}$$

Example 3 (Wave Velocity)

If $V = 3 \times 10^8$ m/s and $\lambda = 6 \times 10^{-7}$ m, what is the frequency (f)?

Solution

$$V = f\lambda$$

$$f = \frac{V}{\lambda}$$

$$f = \frac{3 \times 10^8 \text{ m/s}}{6 \times 10^{-7} \text{ m}} = 0.5 \times 10^{8-(-7)} = 0.5 \times 10^{15} \text{ Hz}$$

$$f = 5 \times 10^{14} \text{ Hz}$$

Example 4 (Wave Period)

When the wavelength of a wave travelling with a velocity of 360 m/s is 60 cm, calculate the period (T) of the wave.

Solution Parameters: * Velocity, $V = 360$ m/s * Wavelength, $\lambda = 60$ cm $= 0.60$ m

1. Find Frequency (f):

$$f = \frac{V}{\lambda}$$

$$f = \frac{360 \text{ m/s}}{0.60 \text{ m}} = 600 \text{ Hz}$$

2. Calculate Period (T):

$$T = \frac{1}{f}$$

$$T = \frac{1}{600} \approx 0.00167 \text{ s}$$

Assignment (Geometric Progression)

Note/Correction: The final page contains an assignment on Geometric Progression (GP), which is a Mathematics topic, not Physics. It is added here for completeness.

1. The 5^{th} and 8^{th} terms of a G.P. are 48 and 12 respectively. Find the sum of the 6^{th} term.
2. The 4^{th} term of a G.P. is 500. If the common ratio is 5, find its first term.
3. Find the 8^{th} term and the number of terms in the G.P. $3,6,\ldots,768$.
4. Find the value of n in the G.P. $5, n-5, 125$.
5. The 3^{rd} and 5^{th} terms of a G.P. are 25 and 100 respectively. Find the 7^{th} term of the G.P.
6. If $x-1$, $x+1$ and $3x+3$ form a G.P., find the value of x.