SUBJECT:

PHYSICS

CLASS:

SENIOR SECONDARY SCHOOL 2

TERM:

SECOND

SCHEME OF WORK

WEEK	TOPIC
1	Heat energy – temperature and its measurement
2	Heat capacity and specific heat capacity
3	Calculations on specific heat capacity
4	Evaporation, boiling and melting points and their determination. Effects of impurities and pressure on boiling and melting
5	Latent heat – Fusion and vaporization
6	Vapor pressure – Saturated and unsaturated vapor pressure and its relation to boiling. Humidity ,Relative Humidity, Dew point and its relationship to weather

- ***Mid-term project***

7	Gas Laws – Boyle's, Charles', Pressure and General gas law
8	Production and propagation of waves
9	Properties of waves – reflection, refraction, diffraction, interference and polarization
10	Light waves – source, reflection, reflection plane and curved mirrors
11	Refraction of light – refractive index, its determination, total internal reflection and critical angle
12	Revision
13	Examination

WEEK ONE

HEAT ENERGY

- Heat
- Temperature
- Measurement of temperature
- Thermometers

Heat

Heat is a measure of total internal energy of a body. It is a form of energy due to a temperature difference. It is measured in Joule, J

Temperature

Temperature is the degree of hotness or coldness of a body. The unit of temperature is in degree Celsius (^{0}C) or Kelvin (K)

Measurement of temperature

Temperature is measured by using thermometers. Thermometers have two reference temperatures or fixed points called the upper fixed point and lower fixed point.

The upper fixed point is the temperature of steam from pure water boiling at standard atmospheric pressure of 760mm of mercury. It is 100^0C

The lower fixed point is the temperature of pure melting ice at the standard atmospheric pressure of 760mm of mercury. It is 0^0C

Temperature scales

The difference in temperature between the upper and lower fixed points is called fundamental interval of a thermometer. The calibration of this interval depends on any of the three scales below:

1. Celsius scale
2. Fahrenheit scale
3. Kelvin or Absolute scale

The S. I. Unit of temperature is the Kelvin. However, it is also measured in degree Celsius and Fahrenheit.

Thermometers

Thermometers are instruments used to measure temperature. Thermometers are named using the thermometric properties employed in the measurement of temperature. Each one makes use of the change in the physical properties of materials they are made of, to indicate temperature change.

	NAME OF THEERMOMETER	THERMOMETRIC SUBSTANCE	THERMOMETRIC SUBSTANCE	ADVANTAGE
1	Liquid-in-glass thermometer	Alcohol or mercury	Change in the volume of the liquid with temperature	Portable and easy to use
2	Gas thermometer	Gas	Change of gas pressure at constant volume with temperature	Accurate measurement of temperature and gives wider ranges of temperature
3	Thermocouple thermometer	Two dissimilar metals	Changes in the e.m.f. between two different metals kept at different temperature	Quick response to temperature changes and wider ranges of temperature
4	Resistance thermometer	Resistance wire	Change in electrical resistance of wire with temperature	It responds to a small change in temperature, very accurate and measure wider range of temperature

5	Bimetallic thermometer	Two different metals	The differential expansion of the two metals of the bimetallic strip	

1. **The liquid-in-glass thermometer**: The liquid-in-glass thermometer depends on the uniform expansivity of the liquid used with temperature change. Any liquid that will be used as a thermometric liquid must be good conductor of heat, be easily seen in glass, have a high boiling point, have a low freezing point, have a low specific heat capacity, must not wet glass and must expand uniformly.
2. **The clinical thermometer**: This has a constriction and it has a short range (35^0C – 43^0C). The narrow constriction prevents the mercury from flowing back into the bulb immediately after the thermometer has been removed from the patient's body.
3. **Platinum resistance thermometer**: This thermometer depends on the variation in the electrical resistance of a conductor with temperature as expressed below:

$$\frac{R_t - R_0}{R_{100} - R_0} = \frac{t}{100}$$

$R_t = resistance\ at\ temperature\ t^0C$

$R_0 = resistance\ at\ temperature\ 0^0C$

$R_{100} = resistance\ at\ temperature\ 100^0C$

4. **The Thermocouple**: A thermocouple consists of two different metals joined together by a circuit containing a galvanometer. The working of a thermocouple depends on the variation of the electromotive force (e.m.f) between junctions. The equation of the relationship is
$E = a + bt + ct^2$, where a, b and c are constants
5. **Constant – volume gas thermometer:** This depends on the variation in the pressure of a gas at constant volume with changes in the temperature of the gas.
The equation is:

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

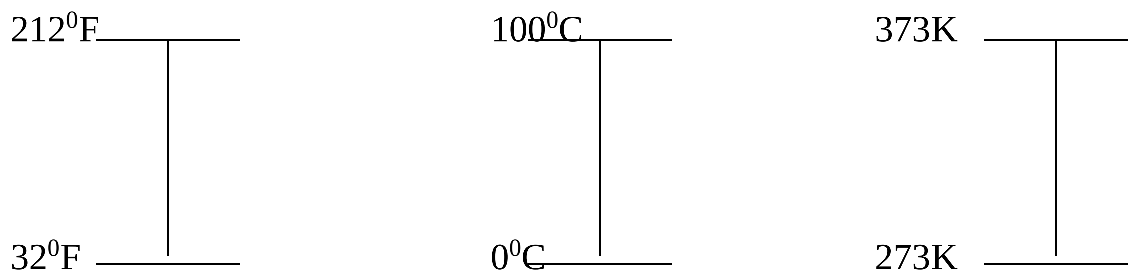
ABSOLUTE SCALE OF TEMPERATURE

Temperature has no property of direction but has magnitude or size, which depends on the scale being used.

The absolute scale of temperature is thermodynamic scale because it gives us the idea of the lowest possible temperature or absolute zero with the value of -273^0K.

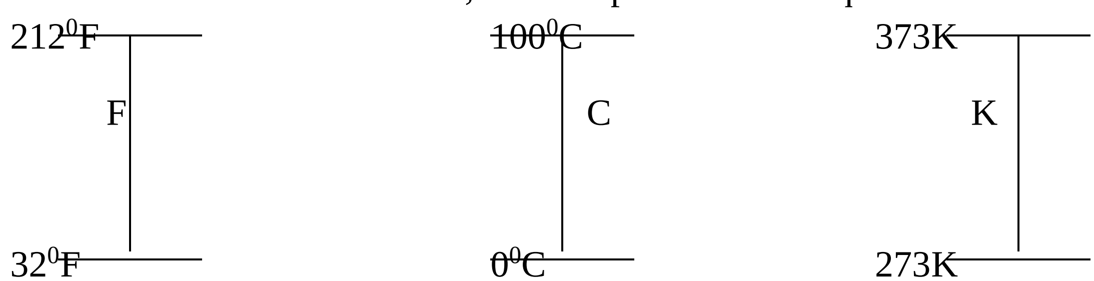
The absolute zero is the lowest possible temperature below which nothing can be cooled since temperature is the measure of the average or mean kinetic energy of the molecules of a substance. It follows that as we subtract heat from a substance, its temperature drops and hence its kinetic energy until it eventually becomes zero under which the molecules remain stationary.

The Celsius seal is the most commonly used scale. This scale is based on two fixed points – the lower fixed point (O^{0}C) and the upper fixed point (100^{0}C). The gap between these points is called the fundamental interval.



Fahrenheit scale Celsius scale Kelvin scale

To convert from one scale to another, use interpolation technique.



Fahrenheit scale Celsius scale Kelvin scale

Where:

F is the unknown in Fahrenheit scale;

C is the unknown in the Celsius scale
K is the unknown in the Kelvin scale
The formula below can be used

$$\frac{212-32}{F-32}=\frac{100-0}{C-0}=\frac{373-273}{K-273}$$

$$\frac{180}{F-32}=\frac{100}{C-0}=\frac{100}{K-273}$$

CLASSWORK 1

1. Define (i) ice point (ii) steam point
2. Give five properties of thermometric liquid
3. The length of mercury thread when it is at 0^0C, 100^0C and at an unknown temperature θ is 5mm, and 125mm respectively. Find the value of θ

ASSIGNMENT 1
SECTION A

1. An un-graduated thermometer reads 2.0cm and 112.0cm at ice and steam points respectively. Determine the true temperature in Kelvin, when the thermometer reads 5.0cm (a) 303.0K (b) 300.0K (c) 278.0K (d) 30.0K (e) 30.3K
2. Clinical thermometer differs from other mercury in glass thermometers because it has I. a constriction II. A wide range III. A short range IV. A narrow bore (a) I and II only (b) I and III only (c) III and IV only (d) I, II and III only (e) I, III and IV only
3. A platinum resistance thermometer has a resistance of 4Ω at 0^0C and 12Ω at 100^0C. Assuming that the resistance changes uniformly with temperature, calculate the resistance of the temperature when the temperature is 45^0C (a) 6.0Ω (b) 6.5Ω (c) 7.6Ω (d) 8.4Ω (e) 16.0Ω
4. The purpose of constriction in a clinical thermometer is to (a)prevent the mercury from expanding beyond the bulb (b) prevent the mercury from falling back into the bulb until required (c) enable the mercury to expand slowly (d) serve as the lower limit of the scale to be read (e) none of the above

5. Mercury has an advantage over other liquids as thermometric liquid because it (a) has low expansivity (b) has higher conductivity (c) vaporizes easily (d) relatively low freezing point (e) none of the above

SECTION B

1. What is temperature?
2. Distinguish between temperature and heat
3. Give three advantages of mercury over alcohol as a thermometric liquid
4. The pressure at ice point for a constant volume gas is 4.81×10^4Pa. while that of the steam point is 6.48×10^4Pa. what temperature will this thermometer indicate at 50^0C

WEEKS TWO & THREE

HEAT CAPACITY AND SPECIFIC HEAT CAPACITY

- Heat capacity
- Specific heat capacity

MEASUREMENT OF HEAT ENERGY

In order to assess the quantity of heat energy possessed by a body, three quantities are needed. They are:

- the change in temperature (θ)
- the specific heat capacity of the body (C)
- mass of the body (m)

The quantity of heat Q of a body is a product of the three quantities above as expressed by the equation.

$Q = MC\Delta\theta$ …1

It is measured in Joules

Heat capacity

This is the quantity of heat required to raise the temperature of a substance by one degree. It is measured in Joules/K.

$$Heat\ capacity = Mass\ of\ specific\ \times specific\ heat\ capacity\ of\ the\ substance$$

$C = mc$ …2

Specific heat capacity

Specific heat capacity of a substance is the heat required to raise the temperature of a unit mass of the substance through one degree change in temperature

The quantity of heat Q received by a body is proportional to its mass (m), and temperature change $(\theta_2 - \theta_1)$ and on the nature of the material the body is made of.

Thus;

$Q = mc\Delta\theta$ …3

$Q = mc(\theta_2 - \theta_1)$ …4

C is a constant of proportionality called the specific heat capacity of the body, which depends on the nature of the body.

$c = \frac{Q}{m(\theta_2 - \theta_1)}$ …5

The unit of specific heat capacity is $J/_{KgK}$

It can be determined by using

- the method of mixtures
- the electrical method

DETERMINATION OF SPECIFIC HEAT CAPACITY BY MIXTURE METHOD

The solid lead block is weighed on a balance to be M_s. A lagged calorimeter is dried and weighed to be M_c. It is then reweighed to be M_{cw} when half filled with water. The initial temperature of the water is taken to be θ_1.

The lead block is suspended in boiling water with a temperature θ_2 after which it is transferred to the calorimeter and the mixture stirred to maintain a uniform temperature θ_3

The specific heat capacity of the lead can be calculated using the fact that heat loss by the lead = heat gained by calorimeter and water.

Given the specific heat capacity of calorimeter and water to be C_s, C_c and C_w respectively

Heat loss by the lead = heat gained by calorimeter and water

$$M_s C_s(\theta_2 - \theta_3) = M_c C_c(\theta_3 - \theta_1) + (M_{cw} - M_c) C_w(\theta_3 - \theta_1) \quad \ldots 6$$

$$C_c = \frac{M_2 C_c(\theta_3 - \theta_1) + (M_3 - M_2) C_w(\theta_3 - \theta_1)}{M_s\big((\theta_2 - \theta_3)\big)} \quad \ldots 7$$

DETERMINATION OF SPECIFIC HEAT CAPACITY BY ELECTRICAL METHOD

For a solid:

To calculate the specific heat capacity C_b of a solid brass block, we make two holes in a weighed brass block into which a thermometer and a heating element connected to a source of power supply are inserted. Oil is poured in the holes to ensure thermal conductivity. Assuming no heat is lost to the surrounding, the total amount of electrical heat energy supplied by the coil is equal to heat gained by the brass

Heat energy supplied by the coil = Heat gained by the brass

$$IVt = MC_b\Delta\theta \qquad \ldots 8$$

$where\ I = current; V = voltage; t = time$

From ohms law,

$$V = IR \qquad \ldots 9$$

So equation 8,

$$I^2vt = MC_b\Delta\theta \qquad \ldots 10$$

$$\frac{V^2t}{R} = MC_b\Delta\theta \qquad \ldots 11$$

For a liquid

$$Heat\ energy\ supplied\ by\ the\ coil = Heat\ gained\ by\ the\ liquid + heat\ gained\ by\ calorimeter$$

$$IVt = M_lC_l\Delta\theta + M_cC_c\Delta\theta \qquad \ldots 12$$

CALCULATIONS ON SPECIFIC HEAT CAPACITY

- Calculations on specific heat capacity

Calculations on specific heat capacity

EXAMPLE

250g of lead at 170^0C is dropped into 100g of water at 0^0C. If the final steady temperature is 12^0C, calculate the specific heat capacity of lead. ($C_w = 4.2 \times 10^3$ $Jkg^{-1}k^{-1}$)

$$Heat\ lost\ lead\ =\ heat\ gained\ by\ water$$
$$0.25\ x\ c\ x\ (170 - 12)\ =\ 0.1\ x\ 4200\ (12 - 0)$$
$$C = \frac{420 \times 12}{0.25 \times 158}$$
$$C\ =\ 127.6\ J/kgk$$

CLASSWORK 2 & 3

1. Define is heat capacity?
2. A metal of mass 0.5kg is heated to 100^0C, transferred to a well lagged calorimeter of heat capacity 80 J/k containing water of heat capacity 420 J/k at 15^0C. If the final steady temperature of the mixture is 25^0C, find the specific heat capacity of the metal
3. Explain the meaning of the statement, *the specific heat capacity of a substance is 777*$JKg^{-1}K^{-1}$

ASSIGNMENT 2 & 3
SECTION A

1. A waterfall is 630m high. What is the change in temperature of a quantity of water that falls from the top to the bottom of the waterfall? [Neglect heat lost to the surroundings, take acceleration due to gravity as $10ms^{-2}$ and Specific capacity of water as 4200 $JKg^{-1}K^{-1}$] (a) 0.15^0C (b) 1.50^0C (c) 15.0^0C (d) 21.0^0C (e) 150.0^0C
2. An electric heater rated 12V is used to heat 450g of water when a current of 5A was passed through it. What is the final temperature after 30minutes? [Specific capacity of water = 4200 $JKg^{-1}K^{-1}$] (a) 57k (b) 20k (c) 57k (d) 80k (e) 40k

3. If 60g of water at 90^0C is poured into a calorimeter containing 20g of water at 30^0C, calculate the final steady temperature of the mixture (a) 90^0C (b) 75^0C (c) 68^0C (d) 25^0C (e) 101^0C
4. How much heat is required to change 10kg of an object from 20^OC to 70^OC? [Specific heat capacity of the object is $200JKg^{-1}K^{-1}$](a) $1x10^5J$ (b) $1x10^4J$ (c) 40J (d) 10^5J (e) $40x10^5J$
5. Which of the following is not used to determine the heat content of a body? (a) mass of the body (b) volume of the body (c) specific heat capacity of the body (d) temperature of the body (e) all of the above

SECTION B

1. A piece of copper of mass 120g is heated in an enclosure to a temperature of 125^0C. It is then taken and held in the air for 30 seconds and dropped carefully into a copper calorimeter of mass 105g containing 200g of water at 20^0C. The temperature of the water rises to 25^0C. Calculate the rate at which heat is being lost from the copper when it is held in the air. [Specific heat capacity of copper = 400 $JKg^{-1}K^{-1}$, Specific capacity of water = 4200 $JKg^{-1}K^{-1}$]
2. An immersion heater supplies heat at the rate of $500Js^{-1}$ (i) what is quantity of heat produced in 24 minutes (ii) if there is no heat loss, calculate the rise in temperature if a brass of 3kg initially at 30^0C absorbed all the heat produced by the heater

WEEK FOUR

- Evaporation
- Boiling points
- Melting points
- Effects of impurities and pressure on boiling and melting

Evaporation

Evaporation is defined as the process by which liquid molecules breaks away from the surface of the liquid to remain as vapor. It can also be simply defined as the process by which liquid changes to gas or vapor.

Boiling point

As heat is being added to a liquid, its temperature increases steadily until at a certain temperature when rapid evaporation is seen to occur in every parts of the liquid with the bubbles of vapor escaping to the surface. This process is known boiling.

As a matter of distinction, evaporation occurs only at the surface of the liquid while boiling occurs throughout the entire mass of the liquid. Also evaporation takes place at all temperature but boiling occurs at a particular temperature called boiling point.

Effects of pressure on boiling

An increase in pressure at the surface of a liquid of a liquid raises the boiling point of the liquid and conversely, a decrease in pressure lowers the boiling point of the liquid.

Effects of impurities on boiling

The presence of impurities or of dissolved substances in a liquid raises the boiling point of the liquid but lowers the freezing point

Melting points

Melting point is a temperature at which a solid substance has its bond broken such that it now flows as liquid. It is also defined as the constant temperature at which a substance changes state from solid to liquid. On the reverse, the constant temperature at which a substance changes state from liquid to solid is called ***freezing point***

APPLICATION IN PRESSURE COOKER

The fact that increased pressure raises the boiling point is put into a useful application in the pressure cooker. The increased pressure of the trapped gas above the liquid raises the boiling of the liquid inside the cooker. This provides a high cooking temperature needed to conserve fuel and save time.

APPLICATION IN REFRIGERATORS

Refrigerators make use of the cooling effect of evaporation. The volatile liquid such as liquid ammonia or Freon evaporates inside copper coil surrounding the freezing compartment, supported by electric pump which reduced the pressure. As the volatile liquid evaporates in those coils, it absorb heat from the surround air, consequently and cooling the inside of the refrigerator and its content.

The vapor produced is pumped off into the condenser, where it is compressed by the pump and condenses back to liquid. The latent heat given out during this condensation is quickly dissipated by an arrangement of cooling fins at the back of refrigerator.

Heat is eliminated by convection and radiation to the surroundings and by conduction into fins. The liquid is again passed into the evaporator coil and thus the level of cooling is regulated by a thermostat connected to the switch.

CLASSWORK 4

1. Define evaporation
2. What is boiling?
3. Differentiate between boiling and evaporation

ASSIGNMENT 4
SECTION A

1. A phenomenon which is used to describe the process by which a substance changes from solid to gas is called (a) evaporation (b) freezing (c) sublimation (d) melting (e) vaporization
2. What effect will reducing the surface pressure of a liquid have on its boiling point? (a) increase its boiling point (b) reduces its boiling point (c) it does not have effect (d) increases its boiling point by 5^0C (e) none of the above
3. Which of the following statement is true about evaporation (a) evaporation occurs at all temperature except at boiling points (b) evaporation only occurs at boiling point (c) evaporation occurs at all temperature (d) all of the above (e) none of the above

4. Impurities change the boiling points of liquid. So, salt added to water will (a) increase its boiling point (b) reduces its boiling point (c) it does not have effect (d) reduces its boiling point by 5^0C(e) none of the above
5. Which of the following statement is true for an ice if the pressure is lowered? (a) the melting point is increased (b) the boiling point is unchanged (c) the melting point is lowered (d) the melting point is unchanged (e) none of the above

SECTION B

1. Write the effect of impurities and pressure changes on melting, freezing and boiling
2. Describe an experiment to determine the boiling point of a liquid

WEEK FIVE

LATENT HEAT

- Latent heat of Fusion
- Latent heat of vaporization

Sometimes when heat energy is given to a substance, it does not increase its temperature, rather, it changes the state of the substance; such heat is referred to as latent heat. There are two types of latent heat:

- Latent heat of fusion
- Latent heat of vaporization

Latent heat of Fusion

Latent heat of fusion: This is the quantity of energy needed to change solid to liquid without any change in temperature.

Latent heat of vaporization

Latent heat of vaporization: This is the amount of energy needed to change liquid to gases (vapor) or steam at constant temperature.

SPECIFIC LATENT HEAT

This is the quantity of heat required to change a unit mass of a substance from one state to another without a change in its temperature.

(a) **SPECIFIC LATENT HEAT OF FUSION (L_f)**

This is the quantity of heat required to change a unit mass of a solid to liquid without a change in its temperature. The specific latent heat of fusion of ice is 33600 J/kg.

$Q = Ml_f$ …1

(b) **SPECIFIC LATENT HEAT OF VAPORISATION (L_v)**

This is the quantity of heat required to convert a unit mass of liquid to vapor (gaseous state) without any change in temperature. For water the value is 2.26 x 10^6 J/kg

$Q = Ml_v$ …2

EXAMPLE

1. How much heat energy is needed to change 3g of ice at 0^0C to steam at 100^0C? (L_f = 336 KJ/kg, C_w = 4200 J/kgk, L_v = 2.26 x 10^6 J/kg

First stage:

Heat required for the ice to melt at 0^0C

$Q_1 = Ml_f$

$Q_1 = 0.003 x 336000$

Second Stage:

Heat required to raise the temperature of the melted ice from 0^0C to 100^0C

$Q_2 = Mc\Delta\theta$

$Q_2 = 0.003 x 4200 x 100$

Third Stage:

Heat required to convert the liquid to steam

$Q_3 = Ml_v$

$Q_3 = 0.003 x 2260000$

The total energy,

$Q = Q_1 + Q_2 + Q_3$

$Q = 0.003 (336000 + 420000 + 2260000)$

$Q = 9048J$

CLASSWORK 5

1. Differentiate between specific heat capacity and specific latent heat
2. Calculate the total energy required to evaporate completely 1kg of ice that is initially at – 10^0C. Given that:

[Specific capacity of Ice = 2.2 x 10^3 J/kgk, Specific heat that capacity of water = 4.2 x 10^3 J/kgk, Specific latent heat of fusion of Ice = 3.36 x 10^5 J/kg, Specific latent heat of vaporization = 2.26 x 10^6 J/kg]

ASSIGNMENT 5

SECTION A

1. Determine the heat required to change 10g of ice at 0^OC to water at 10^OC if specific latent heat of ice is 335J/g and specific heat capacity of water is 4.2J/gk (a) 3.77 x 10^3J (b) 4.00 x 10^3J (c) 4.50 x 10^3J (d) 1.33x 10^3J (e) 4.9x 10^3J
2. Which of the following is the correct SI unit of specific latent heat? (a) Jkgk (b) $Jkg^{-1}k$-^{1} (c) $Jkgk^{-1}$ (d) Jkg^{-1} (e) Jkg
3. Latent heat of fusion changes substances from its (a) solid state to liquid state (b) from liquid to solid (c) from liquid to gas
4. The heat required to change 1kg of ice at 0^0C to water at the same temperature is called (a) specific latent heat of vaporization (b) specific heat capacity (c) specific latent heat of fusion (d) heat capacity (e) specific heat capacity

SECTION B

1. An electric heater immersed in water of mass m, raised the temperature of the water from 40^0C to 100^0C in 5.0 minutes. After another 11.25minutes, one-quarter of the water has been converted to steam. Calculate the specific latent heat of vaporization of water. [Specific heat capacity of water = 4200 $Jkg^{-1}K^{-1}$]
2. Calculate the energy required to vaporize 50g of water initially at 80^0C. [Specific heat capacity of water = $4.2Jg^{-1}K^{-1}$; specific latent heat of vaporization of water = 2260 Jg^{-1}]

WEEK SIX

VAPOUR PRESSURE

- Saturated and unsaturated vapor pressure and its relation to boiling
- Humidity
- Relative Humidity
- Dew point and its relationship weather

Vapor Pressure

When a liquid evaporates in a closed container, the vapor formed above the liquid exerts a pressure. According to kinetic molecular theory, the molecules of the vapor are in constant motion and will hence exert a pressure just like the molecules of a gas. This pressure is called the ***vapor pressure of the liquid***.

Saturated and unsaturated vapor pressure and its relation to boiling

A saturated vapor is a vapor that is in contact with its own liquid within a confined space. When the enclosed space above a liquid is saturated with vapor molecules and can hold no more molecules, the pressure exerted by this saturated vapor is said to be ***the saturated vapor pressure (s. v. p)*** of the liquid. The vapor is said to be saturated when the number of molecules escaping from the liquid per unit is equal to the number returning to the liquid per unit time. The saturated vapor is thus said to be in a state of dynamic equilibrium with its own liquid. Saturated vapor pressure increases with temperature.
On the other hand, the unsaturated vapor is the vapor which is not in contact with its own liquid in a confine space. It is not in dynamic equilibrium with its own liquid. The rate at which the liquid evaporates is greater than the rate at which the liquid condenses. Thus, the pressure exerted by a vapor which is not in contact with its own liquid in a confined space is called unsaturated vapor pressure.

Humidity

Humidity is the measure of wetness of the atmosphere. The exact amount of water vapor in the atmosphere at a given temperature is called ***absolute humidity.*** At higher temperature, the atmosphere contains more water vapor compared to water vapor present at low temperature.

Relative Humidity

Relative humidity is defined as the ratio of the mass of water vapor per unit volume present in the atmosphere to the mass per unit volume of the water vapor needed to saturate the atmosphere.

$$Relative\ humidity = \frac{s.v.p. at\ dew\ point}{s.v.p. at\ room\ temperature} \times 100\%$$

An instrument known as the hygrometer is used to measure relative humidity of air.

Dew point and its relationship to weather

Dew point is the temperature at which the water vapors present in the air just sufficient to saturate it. It is also defined as the temperature at which the pressure of the water is vapor is equal to the saturation vapor pressure.

Mist – mist occur in wet air with high relative humidity above 75% when water vapor in the air is cooled below its dew point. Mist limits visibility to about 1000m or less.

Fog – fog is formed when water vapor in the air is cooled down to its dew point. Fog is of more effect than the mist as it can reduce visibility to less than 200m.

CLASSWORK 6

1. Define vapor pressure
2. Differentiate between saturated and unsaturated vapor pressure

ASSIGNMENT 6

SECTION A

1. The temperature at which the saturated vapor pressure of a liquid is equal to the atmospheric pressure gives rise to a phenomenon called (a) boiling point (b) melting point (c) evaporation (d) freezing point (e) no answer
2. The instrument used to measure relative humidity of an environment is (a) hydrometer (b) hygrometer (c) humid-meter (d) hygroscope (e) none of the above
3. Which of these statements is/are correct? (i) the atmosphere above is cooler than the ones below (ii) for unsaturated vapor, the rate at which the liquid evaporates is greater than the rate at which the liquid condenses (iii) mist is of lesser weather effect than fog (a) all of the above (b) (i) and (ii) only (c) (i) and (iii) only (d) (ii) and (iii) only (e) none of the above
4. Which of these is true of saturated vapor pressure? (i) saturated vapor pressure of a liquid increases with temperature (ii) saturated vapor pressure of a liquid does not have contact with the liquid (iii) saturated vapor pressure is in a state of dynamic equilibrium with its own liquid (a) all of the above (b) (i) and (ii) only (c) (i) and (iii) only (d) (ii) and (iii) only (e) none of the above

5. The temperature at which the water vapors present in the air just sufficient to saturate it is referred to as (a) relative humidity (b) vaporization (c) dew point (d) condensation point (e) no answer

SECTION B

1. Explain the following terms: (i) Dew point (ii) Fog (iii) Mist
2. Write short note on these: (i) humidity (ii) pressure
3. Differentiate between mist and fog

Mid-term project

Using a white card board, draw the diagrammatic set up of determining the specific heat capacity of a solid substance

WEEK SEVEN

GAS LAWS

- Boyle's Law
- Charles' Law
- Pressure Law
- General gas Law

In an attempt to study the behavior of gases in relation to volume, temperature and pressure, the following conditions are investigated

- variation of volume with pressure at constant temperature, Boyle's law $(PV = constant)$
- variation of volume with temperature at constant pressure, Charles law $({}^{V}/_{T} = constant)$
- variation of pressure with temperature at constant volume, pressure law $({}^{P}/_{T} = K)$

Boyle's Law

Boyle's law states that the pressure of a fixed mass of gas varies inversely as the volume at constant temperature.

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

$$P = \frac{k}{V} \qquad ---2$$

$$PV = k \qquad ---3$$

$$P_1V_1 = P_2V_2 \qquad ---4$$

Charles' Law

Charles law states that for a fixed mass of gas at constant pressure, the volume is proportional to its absolute temperature

$$V \propto T \qquad ---5$$

$$\frac{V}{T} = constant \qquad ---6$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad ---7$$

Pressure Law

Pressure law states that the pressure of a fixed mass of gas at constant volume is proportional to its absolute temperature.

$P \propto T$ ---8

$\frac{P}{T} = constant$ ---9

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

Absolute Zero of Temperature

When the graphs of volume – temperature or pressure – temperature are extrapolated backwards they cut the temperature axis at -273^{0}C. This temperature is called absolute zero, the temperature at which the volume of the gas theoretically becomes zero as it is being cooled. At his temperature, molecules of gas stop moving completely. This temperature is a mere assumption, as gases are known to liquefy more often than not before such a temperature is reached.

General gas Law

The general gas law is the combination of the Boyle's, Charles and Pressure Law.
It follows that
From Boyle's law

$PV = k$

From Charles' law

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

From Gay-Lussac's or Pressure law

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

In combination, we have

$\frac{PV}{T} = k$ ---11

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ ---12

Equation 12 is known as general gas law or relation. This can be written in the form:

$PV = nRT$ ---13

Where: n=number of moles of gas
R=the universal molar gas constant = 8.31JK^{-1}

CLASSWORK 7

1. State these laws and write its mathematical expression
   - Charles' law
   - Boyle's law
2. A vessel is filled with a gas at a temperature 50^0C and a pressure of 76cmHg. Calculate the final pressure if the volume of the gas is doubled while it is heated to 90^0C

ASSIGNMENT 7

SECTION A

1. The equation $P^xV^yT^z$ = constant is Boyle's law if (a) x=0, y=0, z=1 (b) x=1, y=0, z=0 (c) x=1, y=1, z=0 (d) x=1, y=1, z=1 (e) x=1, y=1, z=-1
2. A column of air 10cm long is trapped in a tube at 27^0C. What is the length of the volume at 100^0C? (a) 12.4cm (b) 13.7cm (c) 18.5cm (d) 37.0cm (e) 100cm
3. The volume of certain quantity of gas at 27^0C is $1200cm^3$. Calculate its volume at 127^0C if the pressure remains constant. (a) $300cm^3$ (b) $400cm^3$ (c) $1000cm^3$ (d) $1600cm^3$ (e) $250cm^3$
4. A fixed mass of gas of volume $600cm^3$ at a temperature of 27^0C is cooled at constant pressure to a temperature of 0^0C. What is the change in volume? (a) $54cm^3$ (b) $273cm^3$ (c) $300cm^3$ (d) $546cm^3$ (e) $600cm^3$
5. A mass of gas occupies $20cm^3$ at 5^0C and 760mmHg pressure. What is its volume at 30^0C and 800mmHg pressure? (a) $41.4cm^3$ (b) $20.7cm^3$ (c) $50cm^3$ (d) $0.4cm^3$ (e) $25cm^3$

SECTION B

1. (a) State the ideal gas equation (b) Draw graphs to show Boyle's law and Charles law
2. (a) What is meant by absolute zero of temperature? (b) State the assumptions of the kinetic molecular theory of gases.

WEEK EIGHT

WAVES

- Production of waves
- Propagation of waves

WAVES

A wave is a disturbance which travels through a medium transferring energy from one point to another without causing any permanent displacement of the medium

A wave motion is process of transferring a disturbance from one point to another without any transfer of particles of the medium.

Types of waves

Waves are broadly classified into two types

a. Based on the medium of propagation: ***mechanical wave*** and ***electromagnetic wave***
b. Based on the comparison of the wave direction with the direction of vibration of the particle: ***transverse wave*** and ***longitudinal wave***

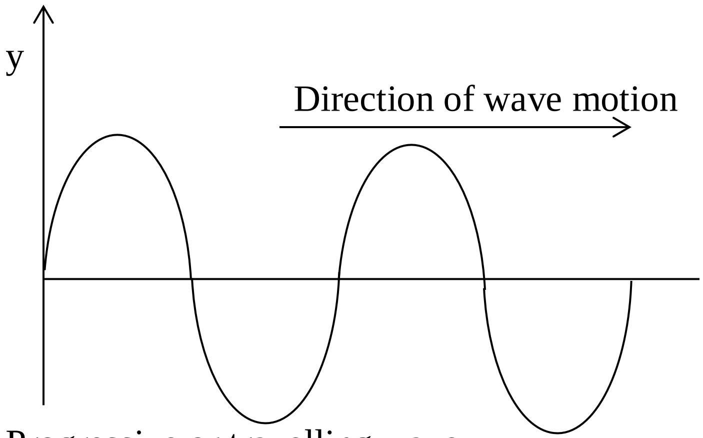
Production and Propagation of waves: Based on the medium of propagation

1. **Production and propagation of mechanical waves**

A mechanical wave is the wave that requires material medium for its mode of propagation (or for it to transfer energy away from the source). Examples are waves travelling through springs, water waves, and sound waves

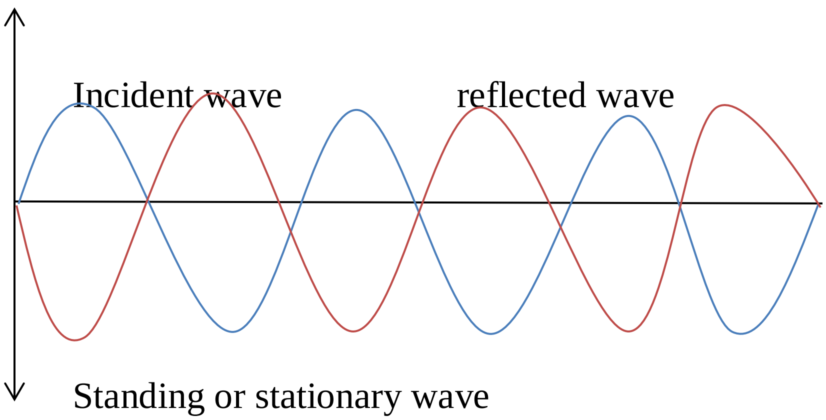
2. **Production and propagation of electromagnetic waves**

Electromagnetic waves are waves that do not need material medium for its mode of propagation (or for it to transfer energy away from the source). Examples are radio waves, visible light, ultra-violet rays, x-rays, gamma rays. Electromagnetic waves travels at the speed of light (3.0×10^8m).
A wave which travels along a medium transferring energy from one part of the medium to another is called a ***progressive wave.*** The progressive wave can be divided into ***transverse*** and ***longitudinal waves***



Progressive or travelling wave

A standing or stationary wave: this is formed when two waves travelling in the opposite direction meets or by superimposition of incident wave and its reflection. The amplitude of the standing wave varies along the wave.



Standing or stationary wave

Production and Propagation of waves: Based on the comparison of the wave direction with the direction of vibration of the particle

1. **Transverse waves**

A transverse wave is a wave in which travel perpendicularly to the direction of the vibrations producing the waves.

2. **Longitudinal wave**

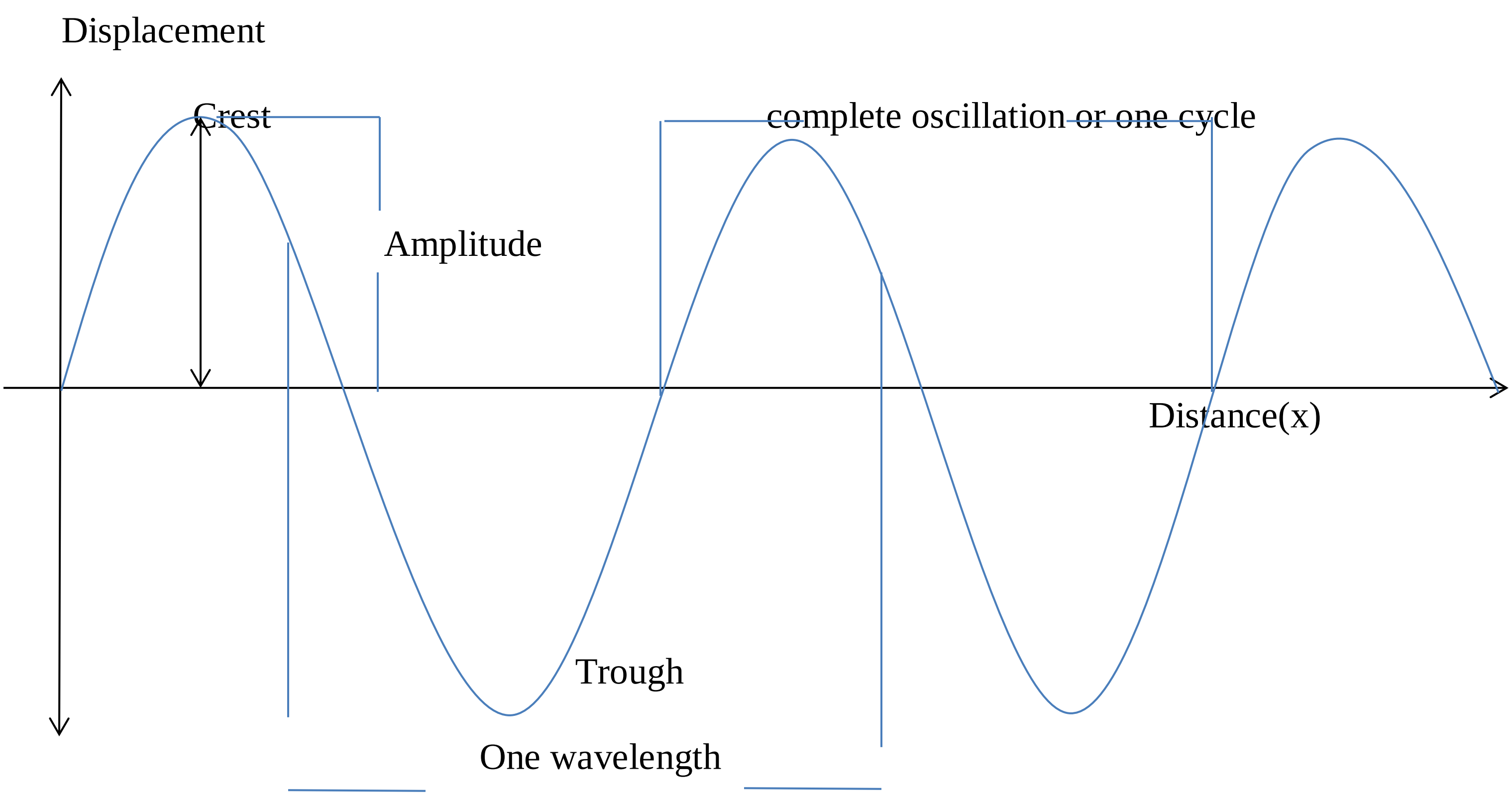
Longitudinal waves are waves which travel in a direction parallel to the vibrations of the medium.

TERMS USED IN DESCRIBING WAVES

1. *Phase* - particles which are at the same vertical direction from their positions of rest and are moving in the same direction are said to be in phase.
2. *Cycle* - is a complete to-and-fro movement or oscillation of a vibrating particle
3. *The amplitude (A)* - is the maximum displacement of a particle from its rest or mean position. It is measured in meter (m).
4. *The period (T)* - is the time required for a particle to perform one complete cycle or oscillation

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

   $T = \frac{1}{f}$ ---2
5. *Frequency (f)* - is the number of complete cycles made in one seconds. It is measured in Hertz (Hz)
6. *Wavelength (λ)* - is the distance covered by the waves after one complete oscillation. For transverse waves, it is the distance between successive crests or troughs while for longitudinal wave, it is the distance between successive compressions or rarefactions. It is measured in meter (m).
7. *Wave-velocity (v)* is the distance traveled by the waves in one second. The S.I unit is m/s



MATHEMATICAL RELATIONSHIP

$v = wave - velocity$
$f = frequency\ (Hz)$
$\lambda = wavelength\ (m)$
$T = period\ (S^{-1})$
$Velocity = frequency \times wavelength$

$$v = f\lambda \qquad ---3$$

$$v = \frac{distance\ travelled\ by\ wave}{corresponding\ time\ taken}$$

$$v = \frac{\lambda}{T} \qquad ---4$$

From equation 1, $f = \frac{1}{T}$

We have:

$$v = \frac{\lambda}{T} \qquad ---5$$

$$v = f\lambda \qquad ---6$$

$$\lambda = vT \qquad ---7$$

Worked example

A radio station broadcasts at frequency of 300 KHz. If the speed of the wave is 3 x 108 ms^{-1}, calculate the period and wavelength of the wave?

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

$$T = \frac{1}{300000}$$

$$T = 3.3 \times 10^{-6} S$$

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

$$v = \frac{3 \times 10^8}{3 \times 10^5}$$

$$\lambda = 1000m$$

Mathematical representation of wave motion – Progressive wave

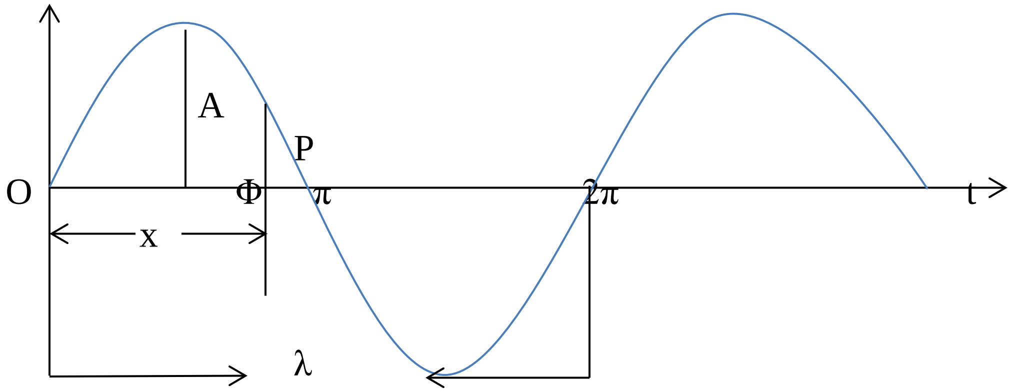
The general equation for stationary wave is given by:

$$y = A \sin\left(\frac{2\pi x}{\lambda}\right) \qquad ---8$$

Where

$A = amplitude\ of\ the\ wave$

$\lambda = \ wavelength\ of\ the\ wave$
$y = vertical\ displacement\ of\ the\ wave$
$x = horizontal\ coordinate\ of\ the\ vibrating\ particle$



Considering O and P that are out of phase by Φ, then we have

$$y = A\sin\left(\frac{2\pi x}{\lambda} - \Phi\right) \qquad \text{---8}$$

Where:

$$\frac{\Phi}{2\pi} = \frac{x}{\lambda} \qquad \text{---9}$$

$$\Phi = \frac{2\pi x}{\lambda} \qquad \text{---10}$$

But $x = vt$

$$\Phi = \frac{2\pi vt}{\lambda} \qquad \text{---11}$$

Substituting equation 11 into equation 8 gives:

$$y = A\sin\left(\frac{2\pi x}{\lambda} - \frac{2\pi vt}{\lambda}\right) \qquad \text{---12}$$

$$y = A\sin\frac{2\pi}{\lambda}(x - vt) \qquad \text{---13}$$

Also from equation 12, putting $v = f\lambda$ we can have

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

$$y = A\sin\left(\frac{2\pi x}{\lambda} - 2\pi ft\right) \qquad \text{---14}$$

Recall that $\omega = 2\pi f$

Thus, equation 12 can be re-written as:

$$y = A\sin\left(\frac{2\pi x}{\lambda} - \omega t\right) \qquad \text{---15}$$

Example:

A plane progressive wave is given by the equation $y = \ Asin\ (2000\pi t - 0.5x)$

Calculate: (i) The wavelength of the wave (ii) The speed (iii) The frequency (iv) The period

Solution:

By comparing the given equation $y = Asin\,(2000\pi t - 0.5x)$ with the standard equation $y = A\sin\left(\frac{2\pi x}{\lambda} - 2\pi f t\right)$

We have for:

(i) The wavelength of the wave

$2\pi f t = 200\ \pi t$

2ft=2000t

f=1000Hz

(ii) The speed

$\frac{2\pi x}{\lambda} = 0.5x$

$\frac{2\pi}{\lambda} = 0.5$

$\lambda = 2\pi \times 2$

λ=12.57m

(iii) The frequency

$v = f\,\lambda$

$v = 1000 \times 12.57$

v=12570m/s

(iv) The period

$t = {}^{1}/_{f}$

$t = {}^{1}/_{1000}$

$t = 10^{-3}s^{-1}$

CLASSWORK 8

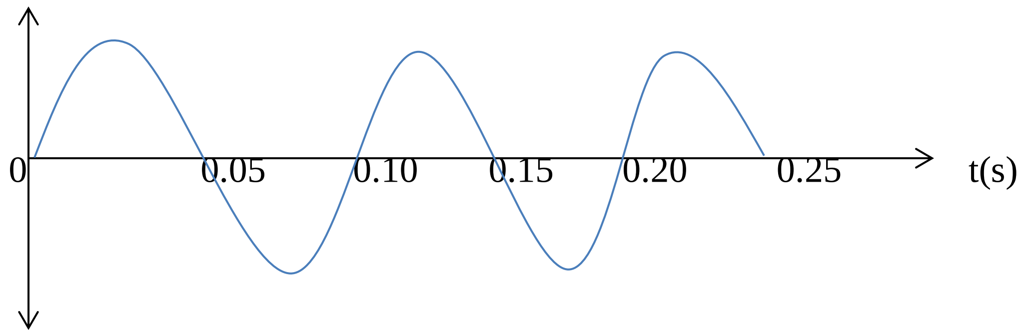
1. What is wave?
2. Elias radio station broadcasts at a frequency of 21MHz. If the speed of light in the air $3\times10^{8}ms^{-1}$, calculate the wavelength of the broadcast.
3. Define stationary wave

ASSIGNMENT 8

SECTION A

1. An electromagnetic radiation has a speed of $3\times10^{8}ms^{-1}$ and a frequency of 10^{6}Hz, calculate its wavelength (a) 3.3×10^{3}m (b) 3.0×10^{2}m (c) 3.0×10^{-2}m (d) 3.3×10^{8}m (e) 3.3×10^{-3}m

2. A body oscillates in simple harmonic motion according to the equation $x = 0.05\cos(3\pi + \frac{\pi}{3})$ where x is expressed in meters. What does 0.05 represents? (a) velocity (b) frequency (c) period (d) amplitude (e) none of the above
3. Which of the following is not a mechanical wave (a) wave propagated in stretched string (b) waves in a closed pipe (c) radio waves (d) water waves (e) sound waves
4. The maximum displacement of particles of wave from their equilibrium positions is called (a) wave velocity (b) period (c) amplitude (d) wavelength (e) frequency
5. D(cm)



The diagram above represents the displacement D versus t graph of a progressive wave. Deduce the frequency of the wave
(a) 20Hz (b) 10 Hz (c) 5 Hz (d) 4 Hz (e) 50 Hz

SECTION B

1. (a) What is wave motion?
   (b) The equation $y = A\sin\frac{2\pi}{\lambda}(vt - x)$ represents a wave train in which y is the vertical displacement of a particle at a distance x from the origin in the medium through which the wave travelling. Explain, with the aid of a diagram, what A and λ represents.
2. A radio waves transmitted from a certain radio station is represented by the wave equation: $y = 0.75\sin(0.67\pi x - 2 \times 10^8 \pi t)$
   Calculate the (i) wavelength of the wave (ii) frequency of the wave (ii) velocity of the wave. Where x, y are in meters while t is in seconds

WEEK NINE

PROPERTIES OF WAVES

- ❖ Reflection
- ❖ Refraction
- ❖ Diffraction
- ❖ Interference
- ❖ Polarization

PROPERTIES OF WAVES
All waves exhibit the following properties

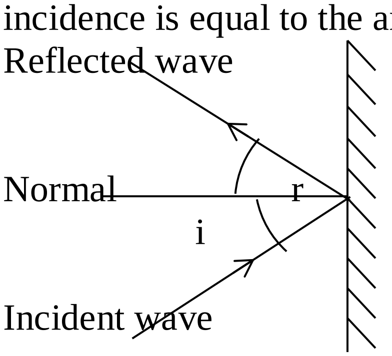
- Reflection
- Refraction
- Diffraction
- Interference

Apart from the properties listed above transverse waves has another properties called polarization.

Reflection

This is a property of wave which occurs when a travelling wave strikes a surface and it bounces back. The travelling wave is the incident wave while the one that bounces back is the reflected rain. In case of water waves generated in a ripple tank, if the waves were made to incident normally on a plane strip, the wave will be reflected back along their original course.

If the waves are incident at a particular angle, it will be observed that the angle of incidence is equal to the angle of reflection in line with the laws of reflection



Reflection of plane parallel wave from a plane surface

LAWS OF REFLECTION

- The incident ray, the reflected ray and the normal, at point of incidence, all lie on the same plane.
- The angle of incidences is equal to the angle of reflection

Refraction

This is the change in the speed and direction of waves as it passes from one medium to another.

When plane waves pass from deep to shallow water, their wavelength becomes shorter and thereby travels slowly. A change in the wavelength and speed produce a change in the direction of travel of waves when they cross the boundary. It is important to note that during refraction, the wavelength remains constant.
Refractive index is the ratio of the sine of the incident angle (i) to the sine of the angle of refraction (r). It is also the ratio of the velocity of the wave in the first medium (v_1) to the velocity in the second medium (v_2)

$$Refractive\ index\ = \eta = \frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{velocity\ in\ air}{velocity\ in\ medium}$$

Diffraction

This is the spreading out of a wave on passing through a narrow opening.
If waves are directed towards a large gap compared with the wavelength of the waves, slightly bent or beam of waves are formed on passing through the gap.
If the barriers are placed closer to leave a narrow gap waves forms spherical wave fronts on passing through a narrow shit.

Diffraction occurs when the wavelength of the wave is longer than the width of the opening or the size of the obstacles.

Interference

This is a phenomenon which occurs when two similar waves traveling in the same direction cross each other. If the waves are in phase or step so that they travel the same distance at equal time and the crest or trough of the two waves arrive simultaneously or one is a complete wavelength ahead of the other. The resulting wave will build up to twice the amplitude of the two waves; this is called ***constructive or additive interference.***
If the crest of one wave arrives with the troughs of the waves, and vice-versa, the waves cancel each other out to give zero resultant, this is called ***destructive interference***.

Polarization

This is an exclusive property of transverse waves only. It is the production of transverse vibration in only one plane. A transverse wave which vibrates in only one plane is said to be plane-polarized.

Polarized light can be produced by passing an ordinary light through a polarizer called Polaroid or crystal of calcite, tourmaline or quartz. The arrangement of molecules within this polarizer will only permit the passage of light in a particular plane and then absorb light due to other vibration. Thus, when an unpolarized light is passed through a polarizer, the emergent light consists in only one plane.

Application of Polaroid

The Polaroid is used in sunglasses to reduce the intensity of incident light and to eliminate reflected light glare.

CLASSWORK 9

1. (a) List the properties of waves that you know
   (b) Explain any two
2. Define and explain the types of interference

ASSIGNMENT 9

SECTTION A

1. When a wave travels from air to water medium (a) the speed reduces (b) the speed increases (c) reflection occurs (d) all of the above (e) none of the above
2. The phenomenon which occurs when two similar waves traveling in the same direction cross each other (a) reflection (b) diffraction (c) refraction (d) polarization (e) interference
3. Water waves are generated by dropping a stone into a calm pool of water. If a small piece of cork is floating in the path of the waves, the cork, as the wave progresses, will (a) sink into the water (b) move up and down about the same position (c) move toward the center of the pool (d) move along with the waves toward the bank of the pool (e) none of the above
4. Surface waves travelling in deep water at $15ms^{-1}$ are incident at a shallow water boundary. If the angles of incidence and refraction are $45^0$and 30^0 respectively, calculate the speed of the waves in the shallow water (a) 8.1 ms^{-1} (b) 10.0 ms^{-1} (c) 10.6 ms^{-1} (d) 22.5 ms^{-1} (e) $15ms^{-1}$
5. Which of the following is an exclusive property of transverse waves only (a) reflection (b) diffraction (c) refraction (d) polarization (e) interference

SECTION B

1. What is polarization? State three uses of a Polaroid

2. Differentiate between reflection and refraction

WEEK TEN

LIGHT WAVES

- Light waves
- Source of Light waves
- Reflection of Light waves
- Reflection of plane and curved mirrors

Light waves

Light wave is a visible source of energy. It is also a wave motion. It has a very short wavelength of 5×10^{-4}mm. Light travels at a speed of $3.0\times10^{8}ms^{-1}$

Source of Light waves

There are various sources of light: natural and artificial, luminous and non-luminous. Natural sources of light include the sun and the stars. Artificial sources of light are the candle, electric torch, the electric lamp, incandescent, arc light and fluorescent light.

Self-luminous or luminous sources of light are those that generate and emit light by themselves e. g. the sun, stars, fire flies and some deep sea fishes

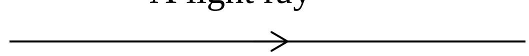
Non-luminous objects are seen when they reflect or throw back light from a luminous objects. Examples of non-luminous objects are moon, paper, mirror, wall etc.

When light falls on such surface, it is may be absorbed, transmitted or reflected, sometimes a combination of the above processes may occur

Light rays and beams

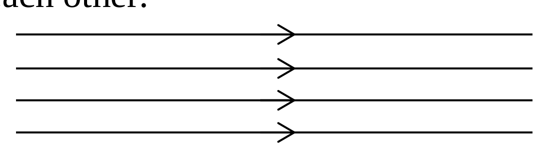
A ray is the direction of the path in which light is travelling. It is represented by a straight-line with an arrowhead

A light ray



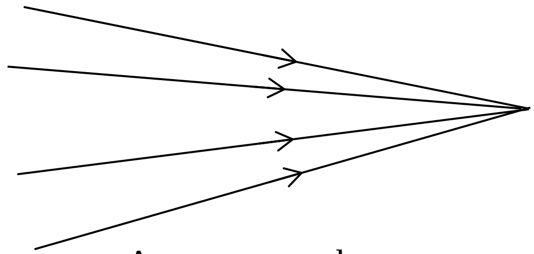
A beam is a collection of two or more rays of light. Beams can be parallel, convergent or divergent.

A parallel beam is two or more rays travelling in the same direction but can never intersect each other.



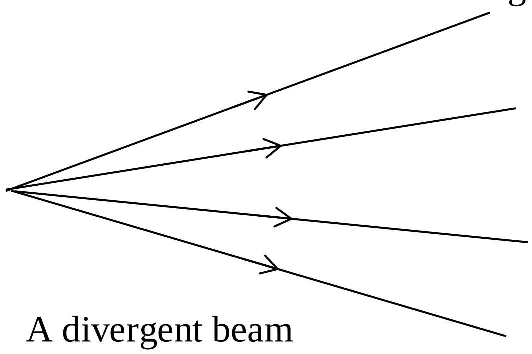
A parallel beam

A beam of light is said to be convergent when they meet at a point



A convergent beam

The divergent beam occurs when a collection of light rays has the same source is spread out apart.



A divergent beam

RECTILINEAR PROPAGATION OF LIGHT

The phenomenon of light travelling in straight line is known as rectilinear propagation of light. It can be demonstrated by placing a candle flame at the end of a straight pipe, light of the flame will be seen clearly at the other side of the pipe. If the pipe is then bent and the process repeated, nothing will be seen at the other end, this clearly shows that light travels in straight line. Two natural effects that result from the rectilinear propagation of light are the formation of eclipse and shadow, The principle of operation of the pin hole camera also depends on the fact that light travels in straight lines.

SHADOW

A shadow is an area in which light rays from a source cannot reach. It is produced by the obstruction of light by an opaque object. There are two types of shadow: partial (penumbra) shadow and total (umbra) shadow. If the light source is large, the shadow formed consist of two parts, a completely dark area known as umbra and an outer grey area known as penumbra or partial shadow. In the umbra region, the light from the source is completely blocked by the opaque body. In the penumbra region, the light is partially blocked by the opaque object. The inner region of the shadow receives less than the outer parts. Thus the penumbra becomes brighter from the umbra and outwards.

ECLIPSE

An eclipse is a result of a shadow cast by one heavenly body on another. The sun being a luminous body and it is in the middle while the earth and the moon revolves round the sun. If the moon is between the sun and the earth, the shadow of the moon will be cast on the earth's surface.

There are two types of the eclipse. Viz:

1. Eclipse of the sun (solar eclipse): here the moon comes between the sun and the earth in a straight line
2. Eclipse of the moon (lunar) eclipse: in this case, the earth comes in between the sun and the moon.

PIN HOLE CAMERA

It consists of a light proof box, one end of which has a small hole made with a pin or needle point. The opposite end has a screen made with tracing paper or ground glass. Light from an object in front of the pinhole passes through it and form an image on the screen. If the screen is replaced with a photographic paper or film, a picture of the object can be taken with the pinhole camera.

When using the pinhole camera to take pictures of an object, long exposure is necessary to allow sufficient light to enter the box through the pin hole. The image formed on the screen of the pinhole camera will be seen more clearly if external light is excluded by covering head and camera with a dark cloth.

The image formed on the screen of the pinhole camera is inverted

Linear magnification

Magnification is defined as the ratio of the size (or height) of the image to the size (or height) of the object

$$linear\ magnification = \frac{image\ size}{object\ size} = \frac{image\ distance}{object\ distance} \quad ---1$$

$$m = \frac{h_i}{h_o} = \frac{v}{u} \quad ---2$$

Reflection of Light waves

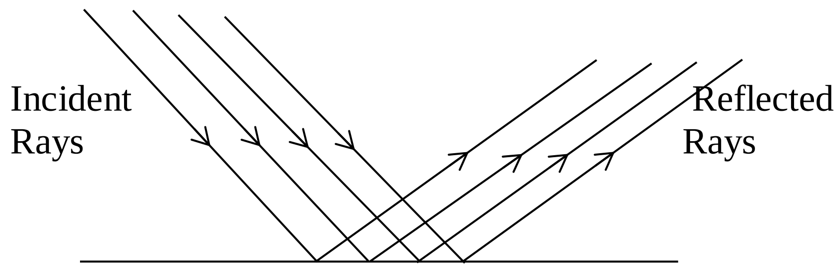
Reflection is the bouncing back of light waves when it strikes a surface.

Reflection of plane mirrors

There are two types of reflection:

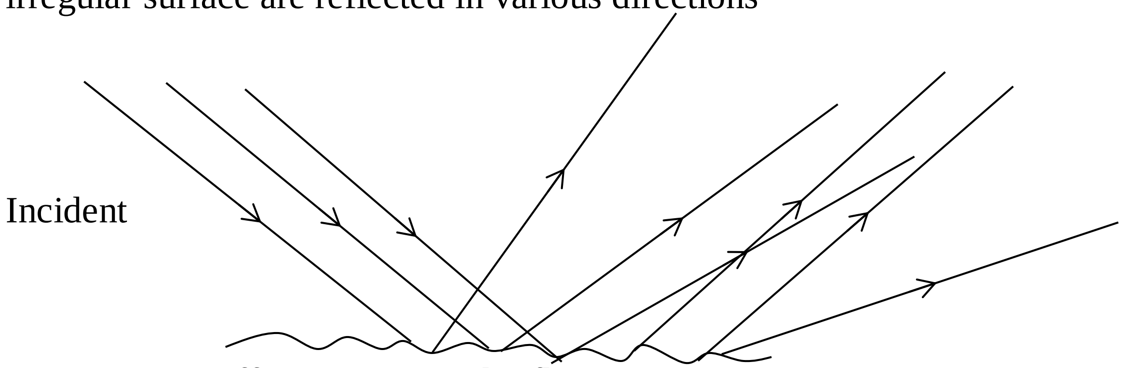
1. Regular Reflection
2. Diffuse Reflection or Irregular Reflection

In regular reflection, parallel rays of light incident on a smooth or polished surface are reflected as parallel rays in one direction.



Regular reflection

In diffused or irregular reflection, parallel rays of light incident on a rough or irregular surface are reflected in various directions



Diffuse or scattered reflection

LAWS OF REFLECTION

The first law of reflection states that the incident ray, the reflected ray and the normal at the point of incidence all lie on the same plane

The second law of reflection states that the angle of incidence (i) is equal to angle of reflection (r).

IMAGE FORMATION BY A PLANE MIRROR

CHARACTERISTICS OF IMAGE FORMED BY PLANE MIRROR

1. It is the same size as the object
2. It is virtual
3. It is laterally inverted
4. It is upright
5. It is far behind the mirror as the object is in front of the mirror

IMAGE

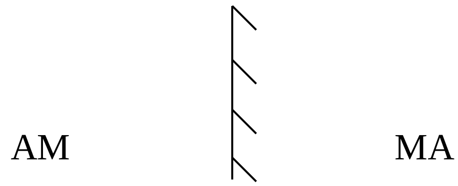
There are two types of image:

1. Real image
2. Virtual image

A real image is one that can be caught on a screen. Light rays actually pass through real image. A virtual image is one that cannot be caught on a screen. It is one through which rays do not actually pass but which is nevertheless visible to the eye.

LATERAL INVERSION

The effect on plane mirror on objects placed in front of it whereby the appearance of the image looks like a reversal of the object is known as lateral inversion



IMAGES FORMED BY INCLINED MIRROR

When two mirrors are placed at an angle to each other, the number of images formed is given by:

$$n = \frac{360}{\theta} - 1 \qquad \text{---3}$$

N = Number of images

Θ = Angle of inclination

When Θ = 180^0, the two mirrors will act as a single mirror and therefore formed only one image. When Θ = O, the two mirrors are parallel to each other and the image of object placed between them will be at infinity.

EFFECT OF MIRROR ROTATION ON REFLECTED RAY-MIRRO GALVANOMETER

If the direction of an incident ray on a mirror is kept constant and the mirror is rotated through twice that angle. This fact is utilized in mirror galvanometer (to measure very small electric current) and in the navigator’s sextant.

Example

The reflection of a narrow beam of light incident normally on a plane mirror falls on a metre rule parallel to the mirror and at a distance of 1m. Calculate the angle of rotation of the mirror if the reflected beam is displaced 21.26cm along the metre-rule when the mirror rotated.

Angle ONP = 2 Θ

$\tan 2\Theta = \frac{21.26}{100}$

$= 0.2126$

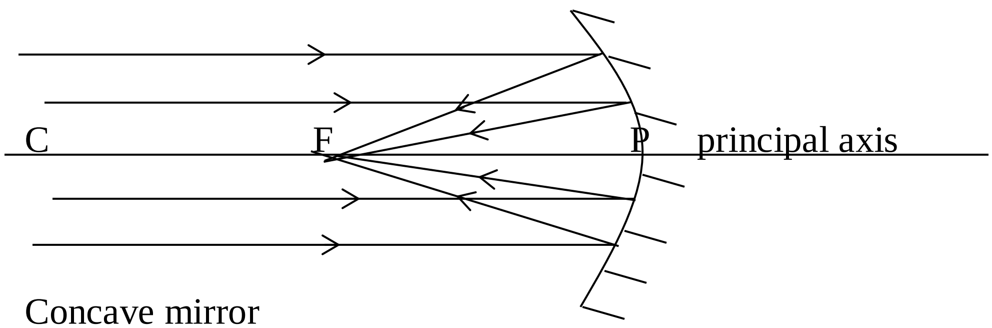
$2\Theta = \tan^{-1}(0.2126)$

$2\Theta = 12^0$

$\Theta = 6^0$

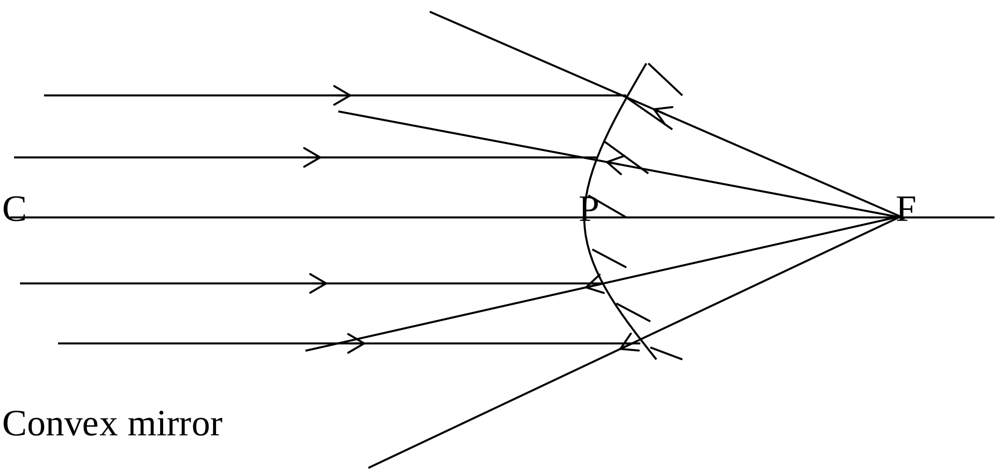
USES OF PLANE MIRROR
It is used in periscope
It is used in kaleidoscope
It is used in sextant
Reflection of curved mirrors
Curved mirrors differ in size, shape and direction of their curvature. In respect of shape, we have spherical and parabolic mirrors.
There are two types of spherical mirrors – concave and convex mirrors

1. Concave mirrors – the concave mirrors are hollowed-out toward the incident light like the inside surface of a spoon. It is also called a converging mirror.



Concave mirror

2. Convex mirrors – these mirrors bulge towards the incident light like he back of a spoon. Convergent mirrors are also referred to as divergent mirrors.



Convex mirror

Terms used with spherical mirrors

1. *The pole (p)* – this is the midpoint of the spherical mirrors
2. *The aperture* – this is the width or diameter of the mirror.
3. *The center of curvature (c)* – this is the centre of the large sphere from which the spherical mirror is carved out.

4. *The radius of curvature (R)* – this is the distance between the center of curvature and the pole of the mirror.
5. *The principal axis* – this is the imaginary line passing through the pole (p) and the center of curvature (c)
6. *The principal focus (f)* – this is the point on the principal axis where the incident rays converges (for concave mirrors) or appear to diverge (for convex mirror)
7. *Focal length (f)* – this is the distance between the focus and the pole of the spherical mirror. It is always half of radius of curvature

   $f = \frac{R}{2}$ ---4

   $R = 2f$ ---5

Spherical aberration

This is the phenomenon whereby a spherical mirror of wide aperture cannot bring all parallel rays to the same focus. In other to avoid this, spherical mirrors of small aperture are usually used. This is also why parabolic mirrors are used in place of spherical mirrors in searchlights and car headlamps.

Construction of ray diagrams

The following tips are used in constructing ray diagrams

i. Light rays parallel to principal axis are reflected through the focus
ii. A light ray passing through the center of the curvature is reflected back along the same path
iii. A light ray passing through the focus is reflected parallel to the principal axis.
iv. Light rays striking the mirror at the pole is reflected such that the angle of incidence is equal to the angle of reflection

Characteristics of image formed by concave mirrors

a. Object before center of curvature: the image formed is:
   - same size the object
   - between the center of curvature and the focus
   - inverted
   - real
b. Object at the center of curvature: the image formed is
   - same size the object
   - at the center of curvature
   - inverted
   - real
c. Object between the center of curvature and the focus: the image formed is
   - Magnified
   - Beyond the center of curvature

- Inverted
- real

d. Object at focus: the image formed is
   - Formed at infinity

e. Object between focus and the pole: the image formed is
   - Magnified
   - Behind the mirror
   - Virtual
   - Erect

f. Object at infinity: the image formed is
   - Diminished
   - Formed at the focus
   - Real
   - Inverted

Characteristics of image formed by convex mirrors

The image formed by a convex mirror is always virtual, erect and diminished in size; it is formed between the pole and the principal focus. This is unlike the case of the concave mirror which can produce either real or virtual images that may be inverted or erect, magnified or diminished in size according to the position of the object.

Linear magnification

This is defined as the ratio of the image size to the object size

$$linear\ magnification = \frac{image\ height}{object\ height} = \frac{image\ distance}{object\ distance}$$

$$m = \frac{h_o}{h_i} = \frac{v}{u} \qquad \text{---6}$$

Mirror formula

The focal length, *f*, object distance, *u*, and the image distance, *v*, can be related using the formula below:

$$\frac{1}{u} + \frac{1}{u} = \frac{1}{f} \qquad \text{---7}$$

From equation 6, we can have:

$$v = mu \qquad \text{---8}$$

$$u = \frac{v}{m} \qquad \text{---9}$$

Also, from equation 7, we can have:

$$f = \frac{uv}{u+v} \qquad \text{---10}$$

$$u = \frac{fv}{v-f} \qquad \text{---11}$$

$v = \frac{fu}{u-f}$ ---12

Sign convention

This is used to know and calculate by properly assigning sign to all the parameters used in mirror

i. The new Cartesian – here, all the distances measure to the left of the mirror from the pole are negative while distances measured to the right of the mirror from the pole are positive
ii. Real is positive and virtual is negative – this is the most widely accepted and used in calculations for mirrors and lenses. In this case:
    - All distances are measured from the pole of the mirror to either left or right
    - The distance of real objects and real images are positive
    - The distance of virtual objects and virtual images are negative
    - The focal length of a concave mirror is positive while the focal length of a convex mirror is negative

Example

1. An object which is 5.0cm high is placed 10.0cm in front of a convex mirror of focal length 15.0cm. Find the position, size and nature of the image produced.

   Solution

   Using "real is positive"

   Given that f=-15cm, u=10cm

$$\frac{1}{u} + \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v} + \frac{1}{10} = \frac{-1}{15}$$

$$\frac{1}{v} = -\left(\frac{1}{15} + \frac{1}{10}\right)$$

$$\frac{1}{v} = -\left(\frac{5}{30}\right)$$

$$V = -6.0cm$$

For magnification

$$m = \frac{v}{u}$$

$$m = \frac{-6}{10}$$

$$m = -0.6$$

$$Image\ size\ =\ magnification\ \times\ object\ size\ (height)$$

$Image\ size\ =\ 0.6 \times 5.0 = 3.0cm$

Thus, the image is formed 6.0cm behind the mirror and the height 3.0cm. it is erect, virtual, diminished

CLASSWORK 10

1. (a) What do you understand by the term lateral inversion? (b) write your first name in block form to buttress (a)
2. Differentiate between concave and convex mirror
3. Two plane mirrors inclining at an unknown angle, forms 11 images. Find the value of the angle
4. Mention three uses of plane mirrors

ASSIGNMENT 10
SECTION A

1. Which of the following abatement is true of virtual image (a) it is formed on the screen (b) it is formed by the intersection of actual rays (c) rays of light do not pass through it (d) all of the above (e) none of the above
2. An object is placed between two plane mirrors inclined at 60^0 to each other. How many images will the observer see? (a) 6 (b) 5 (c) 4 (d) 3 (e) 2
3. An object is place 15cm in front of a concave mirror of focal length 20cm, the image formed is (a) real, inverted and diminished (b) real, inverted and magnified (c) virtual, erect and diminished (d) virtual, erect and magnified (e) virtual, inverted and magnified
4. A concave mirror can be used to produce can be used to produce a parallel beam of light if a light bulb is placed (a) between its focus and the pole (b) at its focus (c) at its center of curvature (d) between its focus and the center of curvature (e) none of the above
5. When an image is formed in a plane mirror, the image formed will be (a) the same size as the object (b) smaller than the object (c) laterally inverted (d) always virtual (e) all of the above
6. Using the real is positive sign convention determine the sign of the focal length of a convex mirror (a) positive (b) negative (c) neutral (d) none of the above (e) options (a) and (b)
7. An object is placed in front of a concave mirror of radius of curvature 12cm. if the height of the real image formed is three times that of the object, calculate the distance of the object from the mirror (a) 24 cm (b) 16 cm (c) 12 cm (d) 8 cm (e) 4 cm
8. A magnified erect image four times the size of the object is formed by a concave mirror of focal length 12cm. what is the distance of the image from the pole of the mirror? (a) -36cm (b) -18cm (c) -24cm (d) -3.6cm (e) 24cm

9. A boy walks away from a plane mirror at a constant speed of $5.0ms^{-1}$ in a direction normal to the surface of the mirror. At what speed does his image move away from him? (a) $5.0ms^{-1}$ (b) $2.50ms^{-1}$ (c) $3.5.0ms^{-1}$ (d) $1.25.0ms^{-1}$ (e) $0.00ms^{-1}$
10. The image of an object is located 6cm behind a convex mirror. if its magnification is 0.6, calculate the focal length of the mirror (a) 3.75 cm (b) 6.60 cm (c) 10.00 cm (d) 15.00 cm (e) 20.00 cm

SECTION B

1. (a) Give the differences between real and a virtual image

   (b) A magnified, virtual image is formed 12cm from a concave mirror of focal length 18cm. calculate the position of the object and the magnification of the image
2. (a) Explain with the aid of diagram how the image of an object is formed by a plane mirror

   (b) State four characteristics of the image
3. (a) Define the following terms (i) principal focus (ii) radius of curvature (iii) principal focus

   (b) The screen of a pinhole camera is a square of side 160mm and it is 150mm behind the pole. The camera is placed 11m from a flag staff and positioned so that the image of the flag staff is formed centrally on the screen. The image occupies three-quarters of the screen. What is the length of the staff?

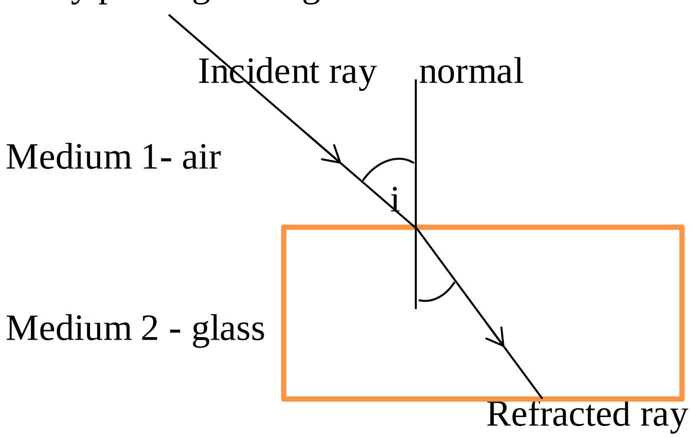
WEEK ELEVEN

REFRACTION OF LIGHT

- Refraction of light
- Refractive index
- Determination of Refractive index
- Total internal reflection
- Critical angle

Refraction of light

Refraction is the bending away of light from the normal as it passes from one medium to the other.
There is a change in the direction and speed of a ray of light when it passes from medium to another medium of different density. This change in the direction of the light of the light ray which is due to difference in the speed of light in different media is called refraction.
When a ray of light travels from optically less dense medium (air) to an optically dense medium (water, glass), it bends towards the normal.
A ray passing from glass or water to air is bent away from the normal



LAWS OF REFRACTION

1. The incident ray, refracted ray and the normal at the point of incidence; all lie on the same plane.
2. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant for a given pair of media.

The second law is known as Snell's law

$$n = \frac{\sin i}{\sin r}$$

The constant, *n*, is known as the refractive index of the second medium with respect to the first medium. It is a number which gives a measure of refraction or bending of light as it travels from one medium to another.

As the ray of light travels from air to glass, the refractive index can be written as:

$$_a n_g = \frac{\sin i}{\sin r}$$

From the principle of reversibility of light

$$_a n_g = \frac{1}{_a n_g}$$

Furthermore,

$$_a n_g = \frac{\boldsymbol{speed\ of\ light\ in\ air}\ (\boldsymbol{medium\ 1, incidence\ medium})}{\boldsymbol{speed\ of\ light\ in\ glass}\ (\boldsymbol{medium\ 2, refractive\ medium})}$$

Determination of Refractive index

EFFECTS OF REFRACTION

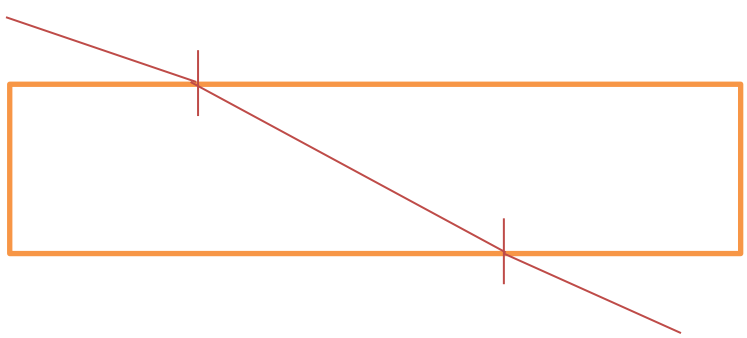
The phenomenon of refraction is responsible for the following

1 The bottom of a clear river or pond appears shallower than it really is

2 A rod or spoon appears bent or broken when it is partially immersed in water or any liquid

3 Letters in print seem to be nearer when we place a thick block of glass over them

REFRACTION THROUGH RECTANGULAR PRISM



The refractive index, n=sin(A/2+D/2)/sinA/2

Total internal reflection & Critical angle

When light passes at a small angle of incidence from a denser to a less dense medium e.g. from glass to air, there is a strong refracted ray. There is also a weak ray reflected back into the denser medium.

When the angle of incidence increases, the angle of refraction also increases. At a certain increase of the angle of incidence, the angle of refraction is 90^0. This angle of incidence in the denser medium for which the angle of refraction in the less dense medium is 90^0, is referred to as the critical angle (c). For angle of incidence greater than C, the refracted ray disappears and all the incident light is reflected back into the denser medium. At this point, the ray is said to experience total internal reflection. Example of total internal reflection is the mirage on the road, where the refractive density of warm air is less than that of cool air and light meets a layer at a critical angle, it suffers total internal reflection.

REAL AND APPARENT DEPTH

A thick slab of glass appears to be only two –third of its real thickness when viewed vertically from above. Similarly, water in a pond appears to be only three quarters of its real depth. Rays from a coin at the bottom of a bucket of water are refracted away when they leave water and enter the eyes. They appear as if coming from a virtual image, which is apparent depth while the actual depth of the bottom remains and is referred to as real depth

Refractive index=real depth/apparent depth

CLASSWORK 11

1. State the laws of refraction
2. The velocities of light in air and glass are 3.0 $x10^8$ m/s and 1.8 $x10^8$ m/s respectively. Calculate the sine of the angle of incidence that will produce an angle of refraction of 30^0 for a ray of light incident on glass

ASSIGNMENT 11

SECTION A

1. The direction of light ray changes as it passes from one medium to the other. The phenomenon is called (a) diffraction (b) reflection (c) dispersion (d) deviation (e) refraction
2. The horizontal floor of a reservoir appears to be 1.0m deep when viewed vertically from above. If the refractive index of water is 1.35, calculate

the real depth of the reservoir (a) 2.35m (b) 1.35m (c) 1.00m (d) 0.50m (e) 0.35m

3. Which of the following is an application of refraction (a) eye glasses (b) car headlamp (c) touch light (d) shaving mirror (e) none of the above
4. A ray of light is incident normally on an air-glass interface. What is its angle of refraction (a) 90^0 (b) 60^0 (c) 45^0 (d) 30^0 (e) 0^0
5. A transparent block 5.0cm thick is placed on a dot. The dot when viewed is seen 3.0cm from the top of the block. Calculate the refractive index of the material of the block (a) $\frac{2}{5}$ (b) $\frac{3}{5}$ (c) $\frac{3}{2}$ (d) $\frac{5}{3}$ (e) $\frac{5}{2}$

SECTION B

1. (a) What is: (i) refraction of a wave? (ii) Critical angle?

   (b) A water poured into a jar to a depth of 21cm. the bottom of the jar appears to be raised by 3cm when viewed vertically. Calculate the refractive index of the water
2. A ray of light incident at an angle of 30^0 at an air-glass interface (i) draw a ray diagram to show deviation of the ray in glass (ii) determine the angle of deviation

WEEK TWELVE

REVISION

WEEK THIRTEEN

EXAMINATION