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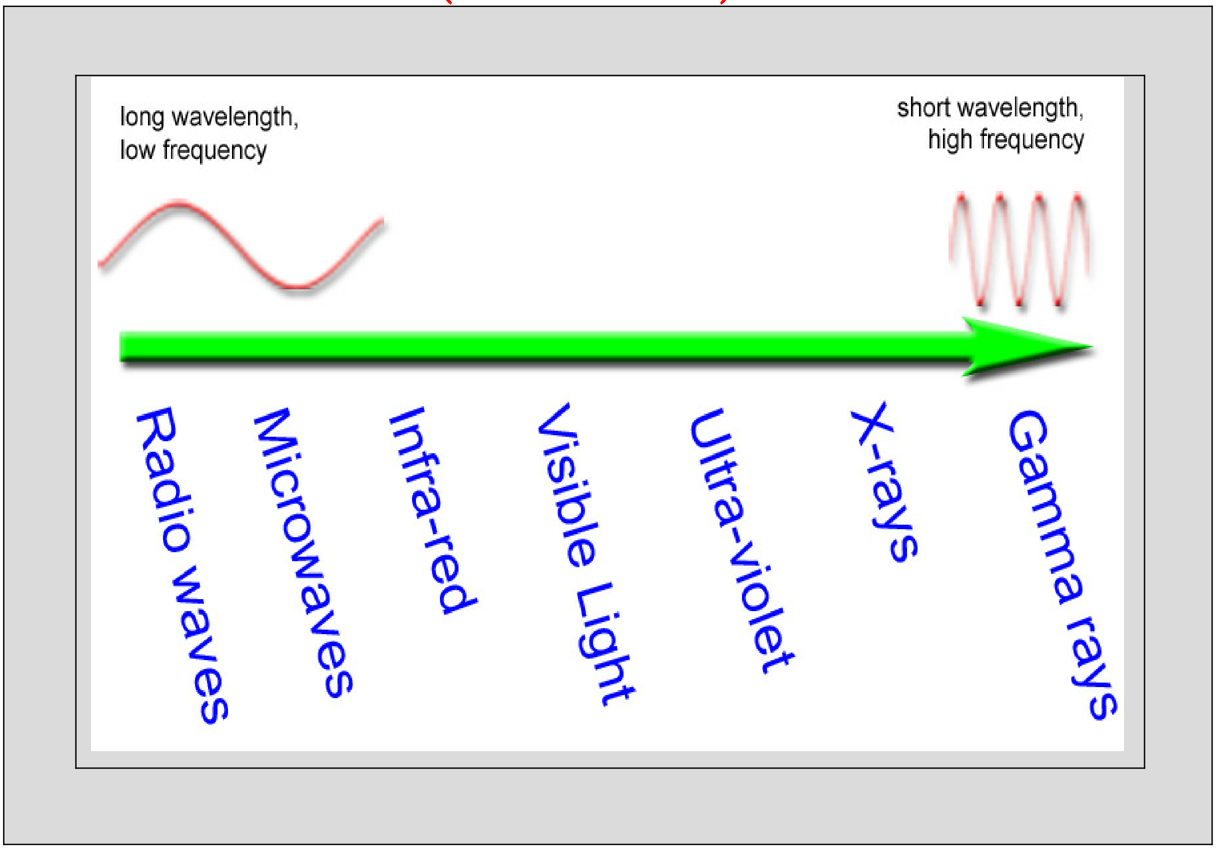
FORM FOUR PHYSICS HANDBOOK

[With well drawn diagrams, solved examples and questions for exercise]

(2015 Edition)



IN GOD WE EXCEL

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Acknowledgement

First and foremost I thank the Almighty God for the gift of life, energy, knowledge and skills to pursue this work.

I am very grateful to the entire Nyabururu Girls' High school fraternity for generously supporting me all round as I worked on this material. I must specifically appreciate the H.O.D Physics Nyabururu Girls' Mr. Albert O. Onditi for the support and encouragement.

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The care and best wishes I received from my mother Joyce Mokeira and my siblings deserve special attention. They were a great source of encouragement.

Lines that influence activities in my life

1. ***God is always there to assist provided you ask for Him.***
2. ***At its best, Physics eliminates complexity by revealing underlying simplicity.***
3. ***There is no method of changing your fate except through hard work.***
4. ***Cohesion with immediate neighbours and determination always betters your immediate environment.***

Chapter One **THIN LENSES**

Objectives

By the end of this lesson the learner should be able to:

a) Describe converging lenses and diverging lenses.

b) Describe using ray diagrams the principal focus, the optical centre and the focal length of a thin lens.

c) Determine experimentally the focal length of a converging lens.

d) Locate images formed by thin lenses using ray construction method.

e) Explain the image formation in the human eye.

f) Describe the defects of vision in the human eye and how they are corrected.

g) Describe the uses of lenses in various optical devises.

h) Solve numerical problems involving the lens formula and the magnification.

Introduction

Lens- Is a carefully molded piece of a transparent material that refracts light in such away as to form an image. They normally operate on **refractive property** of light.

- They are made of glass, clear plastic, or Perspex.
- They are found in cameras human eye, spectacles, telescopes, microscope and projectors e.t.c

Types of lenses

There are two major types of lenses, namely:

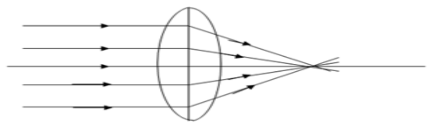
1. Convex (converging) - they are thickest at the middle and thinnest at the ends.
2. Concave (diverging) – they are thinnest at the middle and thickest at theends.

Convex lenses

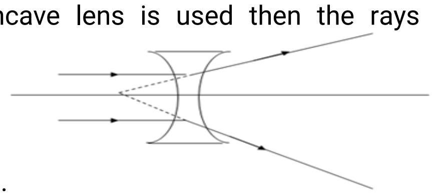
Effect of lenses on parallel rays of light.

A lens relies on the principal of refraction of light. Therefore when parallel rays are directed towards the lens the rays will be refracted either by being converged or by being diverged.

- When the convex lens is used the rays are converged.



- If a concave lens is used then the rays are



diverged.

Definition of terms

a) ***Centre of curvature –*** the centre of the sphere which the lens is part.

b) ***Radius of curvature (r) -*** the radius of the sphere of which the surface of the lens is part.

c) ***Principal axis –*** it is an the line joining the centres of curvature of its surfaces.

d) ***Optical Centre (O) -*** it is a point on the principal axis midway between the lens surfaces.

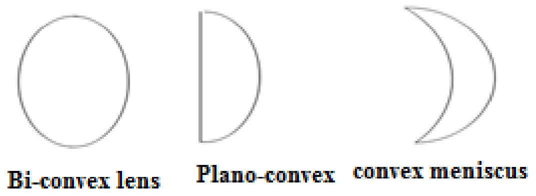
e) ***Principal focus (F) –*** For a convex lens, is a point on the principal axis where all rays converge after passing through the lens. While for a concave lens, is a point on the principal axis behind the lens from which rays seem to diverge from after passing through the lens.

f) ***Focal length (f) –*** it is the distance between the optical centre and the principal focus.

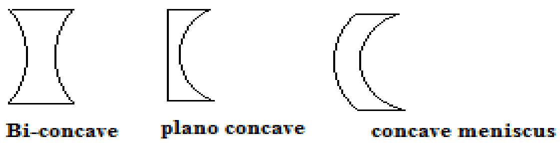
g) ***Focal plane –*** it is a plane perpendicular to the principal that all the rays seem to converge to or seem to appear to diverge from. The incident rays in this case are not parallel to the principal axis.

h) ***Paraxial rays-*** these are rays that are parallel and close to the principal axis.

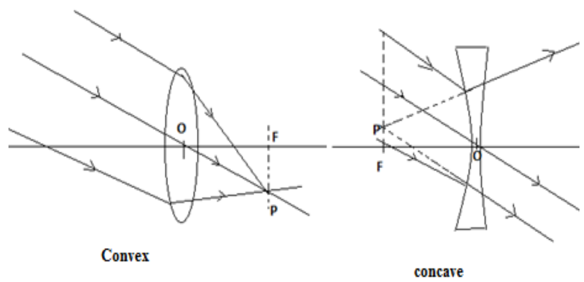
i) ***Marginal rays-*** these are rays that are parallel and

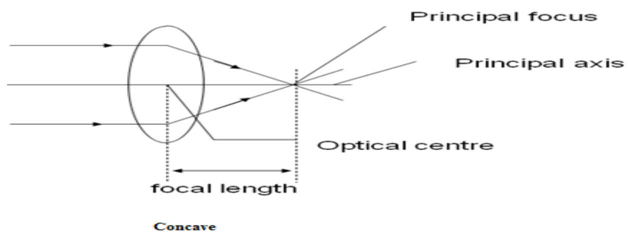


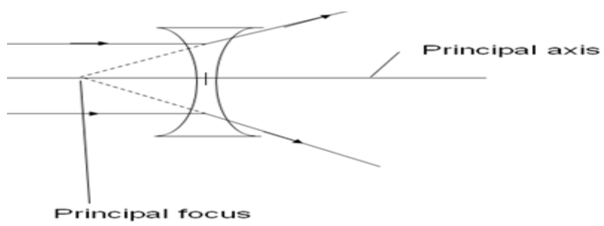
Concave lenses



far away from the principal axis.







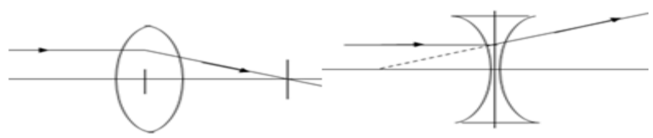
1.2 Ray Diagrams

For one to locate the image when using a lens, ray diagrams are of great importance. There are three major rays that are used in ray diagrams for the location of images formed by the lens.

These rays are;

(i) ***A ray of light parallel to the principal axis.***

This ray passes through the principal focus (for convex lens) or seem to appear to emerge from the principal focus (for concave lens) after refraction by the lens



(ii) ***A ray of light passing (or appearing to pass through) the principal focus***

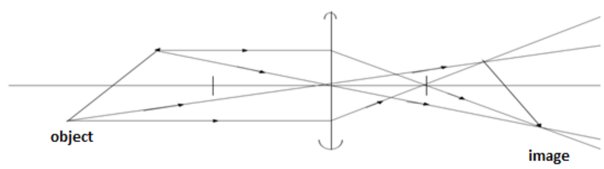
-the ray emerges parallel to the principal axis after refraction by the lens

1.3 Image Formation

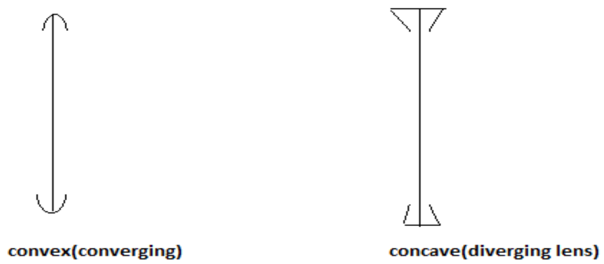
It is important to note:

- Real rays and real images are drawn in full lines.
- Virtual rays and virtual images are drawn in broken/dotted lines.
- To locate the image, two or three rays from the tip of the object are drawn.
- Should the foot of the object cross the principal axis, the method on 3 above is used to get the foot of the image. The top is joined to the foot to get the image.

Example



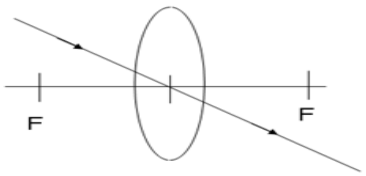
- Converging and diverging lenses are represented by the symbols shown below.



Characteristics of images formed by lenses

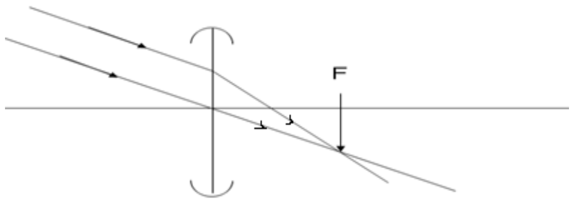
(iii) A ray of light through the optical centre

This ray passes on un-deviated



Converging lenses.

Object at infinity.



The image is

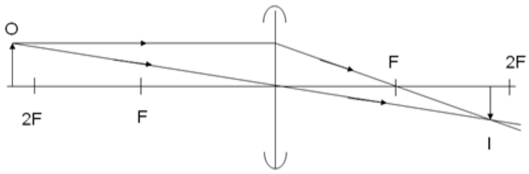
(i) Real

(ii) Inverted

(iii) Diminished

(iv) Formed at F

Object beyond 2F



The image is

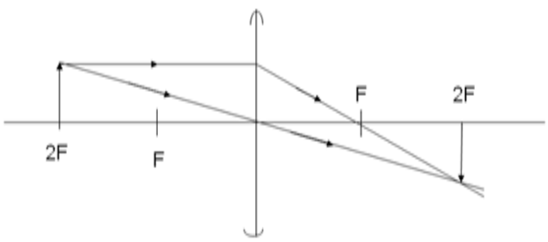
(i) Real

(ii) Inverted

(iii) Diminished

(iv) formed between F and 2F on the other side of the lens

Object at 2F



The image is

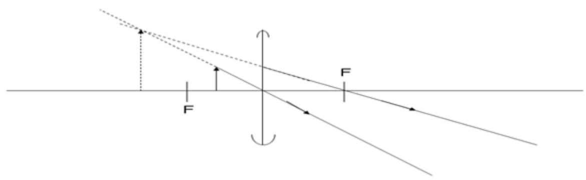
(i) real

(ii) Inverted

(iii) Same size as the object

(iv) Formed at 2F, on the other side of the lens

Object between F and lens



The image is

(i) Virtual

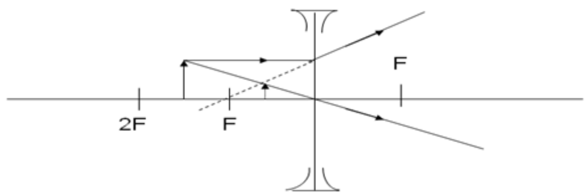
(ii) Erect

(iii)

(iv) Magnified

(v) Formed on the same side as object

Diverging lenses



The image is

(i) Virtual

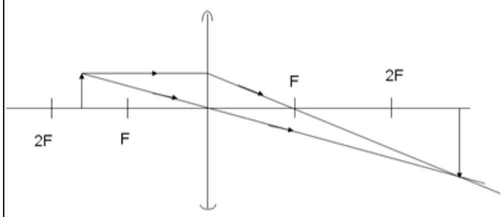
(ii) Erect

(iii) diminished

Linear Magnification

- Magnification is a measure of the extent to which

Object between F and 2F



The image is

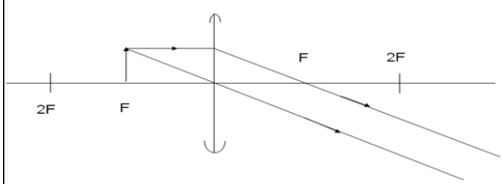
(i) Real

(ii) Inverted

(iii) Magnified

(iv) formed beyond 2F on the other side of the lens

Object at F



The image is at infinity

an optical system enlarges or reduces an image.

- Linear magnification is a ratio of height of image to the height of the object **OR** the ratio of the image distance to the object distance.

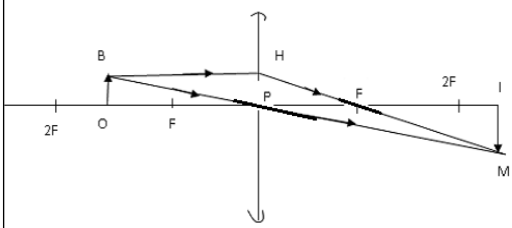
$$\text{magnification} = \frac{\text{height of image}}{\text{height of object}}$$

Or $\text{magnification} = \frac{\text{image distance}}{\text{object distance}}$

Therefore, $m = \frac{V}{u} = \frac{h_i}{h_o}$

The lens formula

Consider an image formed by converging lens as shown below.



PO is the object distance, u, PI is the image distance, v, and PF the focal length, f.

OB=PH

Triangles POB and PIM are similar. Therefore;

$$\frac{OB}{IM} = \frac{PO}{PI} = \frac{u}{v} \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Similarly, triangles PFH and IMF are similar. So;

$$\frac{PH}{IM} = \frac{PF}{IF} \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

But, PF=f

IF = PI - PF;   IF = v - f

Substitute these values in equation (2);

$$\frac{OB}{IM} = \frac{f}{v - f} \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Combining equations (1) and (3);

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

$$uv - uf = vf$$

$$uv = vf + uf$$

$$uv = f(v + u)$$

$$\frac{uv}{f} = v + u$$

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

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

This is called the lens formula and holds for both converging and diverging lens.

Examples

(i) An object 0.05m high is placed 0.15m infront of a convex lens of focal lenght 0.1m.find the position and size of the image.what is the magnification?

Solution

$\mathbf{h_o = 0.05m, u = 0.15\ m, f = 0.1\ m, v = ?, h_i = ?}$

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

$$\frac{1}{0.1} = \frac{1}{0.15} + \frac{1}{v}, \quad v = 0.3\ m$$

$$\frac{h_i}{h_o} = \frac{v}{u} = m \ \Rightarrow \mathbf{h_i} = \frac{v}{u} \times \mathbf{h_o},$$

(ii) An object placed 6m from a converging lens forms an erect image that is five times larger.State the type of the image formed.Find the focal lenght of the lens.

Solution

The image is virtual since it is upright and magnified.

From $\frac{v}{u} = m, \frac{v}{u} = 5 \Rightarrow v = 5u, u = 6m, v = 5 \times 6 = 30m$

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}, \ \frac{1}{f} = \frac{1}{6} + \frac{1}{30}, f = 5\ m$$

Relationship between magnification and focal length

We have;

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

Multiply both sides by v;

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

But, $\frac{v}{u} = m$ and $\frac{v}{v} = 1$, therefore,

$$\frac{v}{f} = m + 1$$

Re-arranging;

$$m = \frac{v}{f} - 1$$

To determine u and v, real-is –positive sign convention is adopted. According to this convention:

I. All distances are measured from the optical centre.

II. Distances of real objects and real images are positive whereas distances of virtual objects and images are negative.

III. The focal length of a converging lens is positive while that of diverging lens is negative.

Exercise

1. An object is placed 12cm from a converging lens of focasl lenght 18cm. Find the position of the image.
2. An object is places 10cm from a diverging lens of focal lenght 15cm. Find the nature and the position of the image.
3. The focal lenght of a converging lens is found to be 10cm.how far should the lens be placed from an illuminatated object to obtain an image which is magnified five times on a screen?

$h_i = \frac{0.3}{0.1} \times 0.05 = 0.015m$, $m = \frac{0.3}{0.1} = 3$	

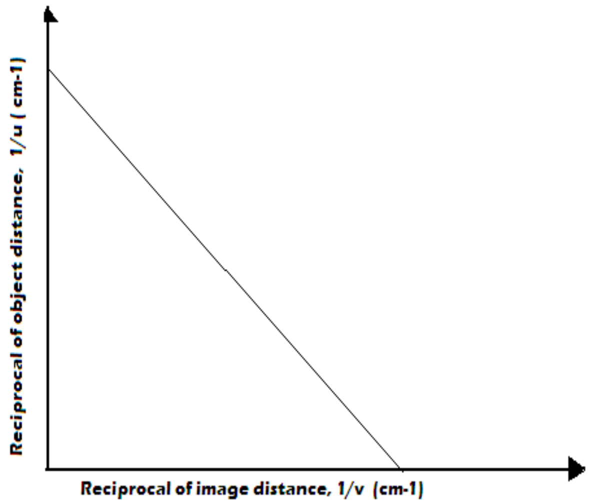
Graphical interprentation of the lens formula	***Exercise***
CASE1:	Interprete a graph of:

A graph of $\frac{1}{v}$ against $\frac{1}{u}$;

From the lens formula, $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

Re - write the equation in the form $y = mx + c$

$\frac{1}{V} = -\frac{1}{u} + \frac{1}{f}$ Hence, slope = -1 and $\frac{1}{v}$ - intercept = $\frac{1}{f}$



CASE 2

A graph of uv against u + v

From the lens formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$, $\frac{1}{f} = \frac{v + u}{uv}$

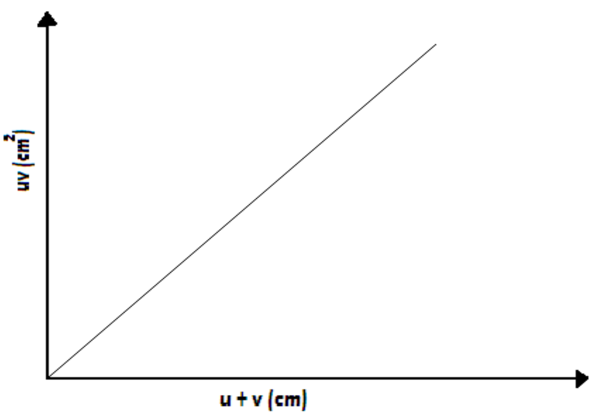
$$uv = (u + v)f$$

In the form $y = mx + c$

$uv = f(u + v) + 0$

Thus gradient = f and uv intercept = 0

It is a graph of a straight line passing through the origin.



(i) $\frac{1}{u}$ against $\frac{1}{v}$

(ii) u + v against uv

CASE 3:

Graph of u against $\frac{1}{m}$

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

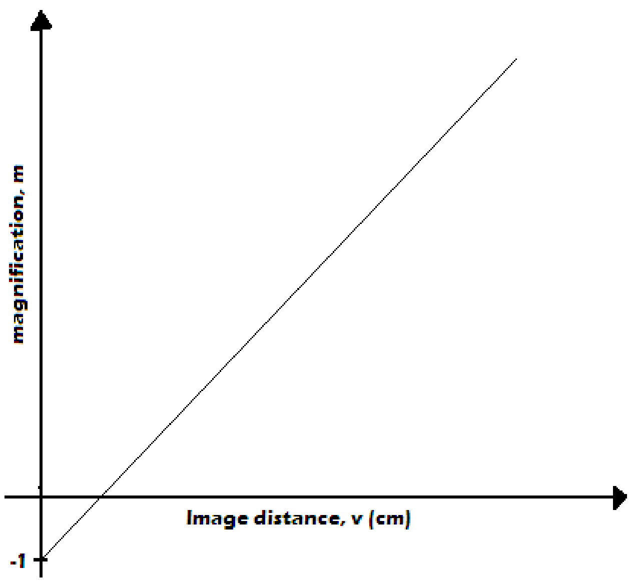
$\frac{u}{f} = \frac{u}{u} + \frac{u}{v}$

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

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

Implying that f = slope and u - intercept = f

It is a straight line that cuts the vertical axis at f.



Exercise

Interpret a graph of:

(i) m against v

(ii) V against m

Experimental Determination Of The Focal Length Of A Converging (Convex) Lens

Method (1):

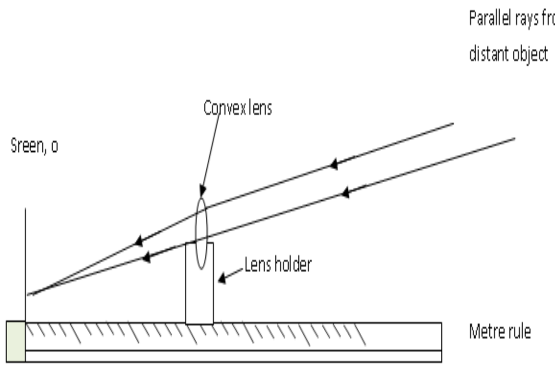
Focusing A Distant Object

Apparatus

Metre rule, lens, a lens holder, screen

Procedure

1. Mount a convex lens on a lens holder and fix a metre rule on a bench using plasticine as shown below.



2. Place a white screen at one end of the metre rule.
3. Move the lens to and fro along the metre rule to focus clearly the image of a distant object, like a tree or window frame.
4. Measure the distance between the lens and the screen.

Focal length——————cm

Note: The distance between the lens and the screen gives a rough estimate of the focal length of the lens. This is because parallel rays from infinity are converged at the focal point on the screen.

Method (2):

Using an Illuminated Object And Plane Mirror/Reflection Method

Procedure

1. Set the lens in its holder with a plane mirror behind it so that light passing through it can be reflected back as shown below.
2. Adjust the position of the lens holder until a sharp image of the object is formed on the screen alongside the object itself.
3. Record the distance between the lens and the screen.

Focal length——————cm

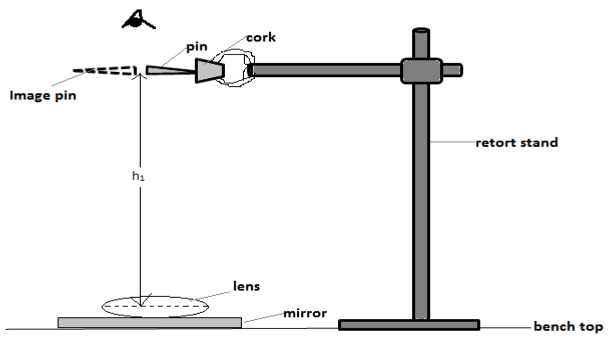
NOTE:

Under these conditions, rays from any point on the object will emerge from the lens as parallel rays. They are therefore reflected back through the lens and brought to a focus in the same plane as the object. The distance between the lens and the screen now give the focal length of the lens.

Method (3):

Using A Pin And Plane Mirror/No Parallax Method

1. Set up the apparatus as shown below.



2. Adjust the position of the pin up and down till its tip is at the same horizontal level as the centre of the lens. A position is found for which there is no parallax between it and the real image formed. For best results, attention should be given to the tilt of the plane mirror so that the tip of the image of the object pin appears to touch at the same level as the centre of the lens.
3. The distance between the pin and the lens will then be equal to the focal length of the lens.

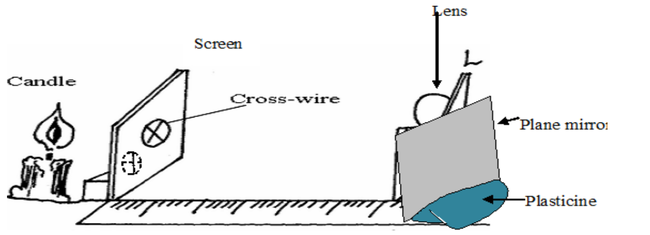
Focal length=——————cm

The power of a lens

Is a measure of refractive property of a lens. It is given by

$$\text{power} = \frac{1}{\text{focal length in metres}}$$

The unit of power of a lens is dioptres (D)



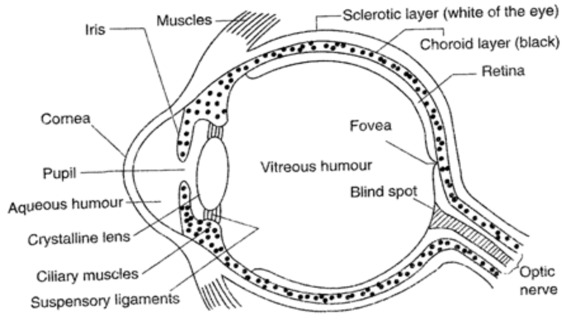
USES OF LENSES IN OPTICAL DEVICES

Due to their ability to converge or diverge light rays, lenses are widely used in optical devices. The devices include;

- Human eye
- Simple microscope
- Compound microscope
- The camera

The human eye

It is a natural optical instrument



1. ***Sclerotic layer*** – hard shell that encloses the eye and is white.

   The front part is transparent and spherical known as the cornea.

   Most bending of light entering the eye occurs at the cornea.

2. ***Aqueous Humour*** – clear liquid between the cornea and the lens. It helps the eye maintain shape.

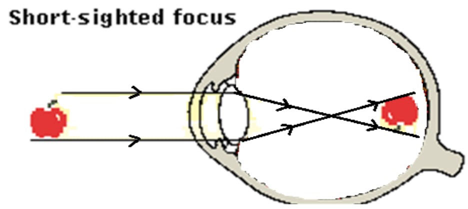
3. ***Iris*** – it is the colouring of the eye. It has pupil which regulates the amount of light entering the eye.

4. ***Crystalline lens***- it is a converging lens. It can change its focal length by the action of Ciliary muscles

5. ***Vitreous humour*** – transparent jelly like substance filling another chamber between the

Defects of vision

Short sightedness (myopia)

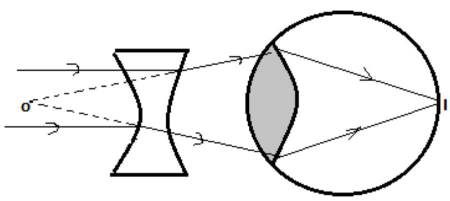


- Can only clearly see near objects
- Rays of near objects are focused on the retina but those for distance objects are focused in front of the retina

Causes

- Short focal length of the eye lens
- Long eyeball

Corrected by diverging lenses as shown

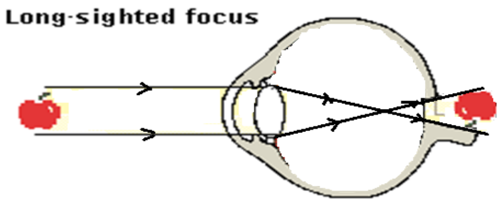


Long sightedness (hypermetropia)

- Can see distant objects but not near ones
- The images of near objects are formed behind the retina

Causes are:

- Too long focal length of the eye
- Too short eyeball

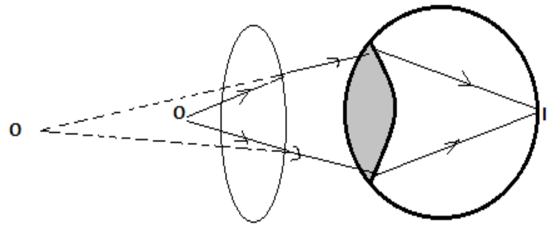


lens and the retina

6. ***Retina*** – it is where the image is formed and Made of cells that are light sensitive
7. ***Fovea*** – central part of the retina that exhibits best details and colour vision at this place.
8. ***Blind spot*** – this contains cells that are not light sensitive.
9. ***Ciliary muscles*** – these are muscles that support the lens. They control the shape of lens by contracting or relaxing. In relaxing the muscles it enables the lens to increase hence focus distance objects. In contraction the muscles reduce tensions in the lens to increase its focal length thus focus near objects. This process is known as ***accommodation.***

Near point – closest point which the normal eye can focus. ***Far point*** - furthest point that a normal eye can focus.

- It is corrected by using converging lenses



Camera

- The camera has ***lenses*** that focus light from the object to form an image of the object on the film.
- Focusing is done by adjusting the distance between the lens and the film .the diaphragm controls the amount of light entering the eye.
- ***The shutter*** allows light to reach the film only for a precise period when the camera is operated.
- The inside is blackened to absorb any stray light.

Similarities between the eye and the camera

Eye	***Camera***
Has crystalline convex lens	Has a convex lens
Choroid layer is black	Box painted black inside
The retina where images are formed	Light-sensitive film where images are formed.
Iris which controls the amount of light entering the eye	Diaphragm which controls the amount of light entering the camera.

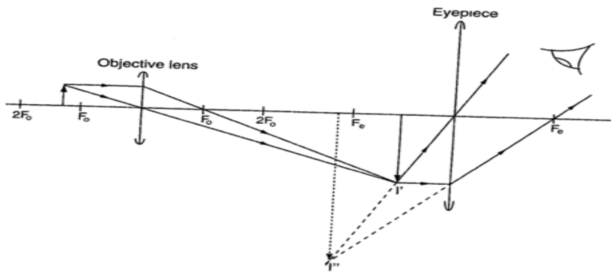
Compound microscope

There are two cases under which a converging lens can produce magnified images;

When the object is between F and 2F.

When the object is between the lens and F.

A compound microscope combines the above two cases. It consists of converging lenses of short focal length .The focal length next to the object is called **objective lens** and the one next to the eye is called **the eyepiece or ocular**. The objective lens is of short focal length.



The eye piece is also of short focal length but longer than that of the objective lens. A compound microscope overcomes the limitations of a simple microscope by use of objective lenses with many lenses and an eyepiece with more than one lens.

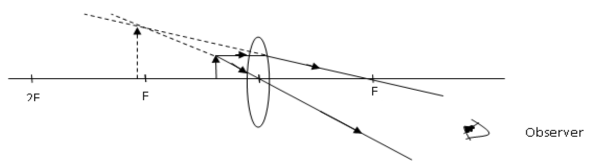
Total magnification produced by a compound microscope is given by;

Differences between the eye and the camera

Eye	Camera
Varable focal length	Fixed focal length
Constant image distane	Variable image distance
Constantly changing pictures	Only one photograph can be taken at at time

Simple microscope

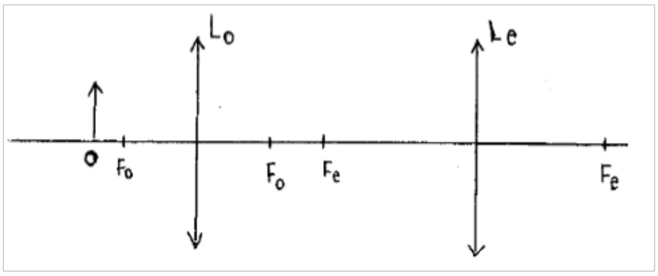
It is sometimes referred to as a magnifying glass. When the object is placed between a convex lens and its principal focus, the image formed is virtual, erect and magnified.



$\left(\frac{V_e}{f_e}-1\right)\left(\frac{v_o}{f_o}-1\right)$ Where v_o is the image distance from I and V_e the image distance from I'.

REVISION QUESTIONS

1. The diagram below shows an arrangement of lenses, L_o and L_e used in a compound microscope F_o and F_e are principal foci of L_o and L_e respectively.



Draw the rays to show how the final image is formed in the microscope

Chapter Two

UNIFORM CIRCULAR MOTION

Specific Objectives

By the end of this topic, the learner should be able to:

- *Define angular displacement and angular velocity*
- *Describe simple experiments to illustrate centripetal force*
- *Explain the application of uniform circular motion*
- *Solve numerical problems involving uniform circular motion*

Content

- *The radian, angular displacement, angular velocity*
- *Centripetal force;* $F = \frac{mv^2}{r}$, $F = mr\omega 2$ *(derivation of formulae not required) (experimental treatment is necessary)*
- *Applications of uniform circular motion*
- *Centrifuge, vertical, horizontal circles banked tracks (calculations on banked tracks and conical pendulum not required)*
- *Problem solving (Apply* $F = \frac{mv^2}{r}$, $F = mr\omega 2$*)*

Definition of Terms

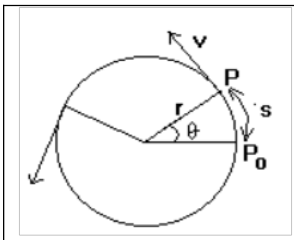
(A) Angular Displacement, θ

It is the angle swept through a line joining to the centre of circular path. It is measured in radians.

Convert the following into radians:

a) 80^0C

b) 120^0C



It is calculated as angular displcement = $\frac{\text{arc length}}{\text{radius}}$

$$\theta = \frac{s}{r}$$

Radian

Is defined as an angle of sector of the circumference whose length is equal to its radius or is the ratio of arc length to the radius of a circular.

$$\text{radian} = \frac{\text{arc length}}{\text{radius}}$$

$$\text{radian} = \frac{s}{r}$$

$$\text{radian} = \frac{2\pi r}{r}$$

$$= 2\pi$$

$$2\pi^r = 360^0$$

Relationship between angular displacement, θ and angular velocity.

$V = \frac{\Delta S}{\Delta t}$ -- (i)

$\Delta\theta = \frac{\Delta S}{\Delta r}$ --- (ii)

For small change in equation (ii)

$\Delta\Theta = \frac{\Delta S}{r}$ --- (iii)

Dividing equation (iii) by Δt

$$\frac{\Delta\theta}{\Delta t} = \frac{\Delta s}{r\Delta t}$$

$$\omega = \frac{v}{r} \rightarrow \mathbf{v = \omega r}$$

Anybody in circular motion has both linear velocity

(b) ***Angular Velocity***

It is the rate of change of angular displacement. It is denoted by Greek letter omega (ω).

$$\omega = \frac{\theta}{t}$$

Is measured in radian per second

Example

1. A particle moving in a circular path covers one revolution in ten seconds. Calculate its angular velocity.

Period/Periodic Time

Is the time taken to complete one revolution.

$$\text{periodic time} = \text{angle covered in one}\frac{\text{revolution}}{\text{angular velocity}}$$

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

Frequency (f)

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

$\frac{1}{f} = \frac{2\pi}{\omega} \rightarrow \mathbf{\omega = 2\pi f}$

Centripetal Acceleration

- An object going through a circular path is said to accelerate.
- If the velocity of such object is constant the object still accelerates because there is continuous change in velocity as the object continuously changes direction. From Newton’s second law of motion, the body experiences a resultant force as it moves rounds path .This resultant force is directed towards the circular path.
- Acceleration of this body is in the direction of force applied to it i.e. it accelerates towards the centre of the circular of the circular path. This acceleration is called centripetal acceleration.

The centripetal acceleration is given by the following equation.

in m/s and angular velocity in rads/s.

Examples

1. A turn table rotates at the rate of 60 revolutions per minute. What is its angular velocity in rads/s
2. A model car moves around a circular path of radius 0.6m at 25 Rev/s. Determine its;

   (a) period

   (b) Angular velocity (ω)

   (c)Speed (v)
3. The car moves with uniform velocity of 3m/s in a circle of radius 0.2m. Find its angular velocity and frequency.
4. Distinguish between angular and linear velocity.

Centripetal acceleration $a = \frac{v^2}{r}$

But $v = \omega r$

$a = \omega^2 r$

Centripetal Force

Is a force that is required to keep a body moving in a circular path and is directed towards the centre of the circular path.

If an object moving through a circular path is released suddenly it flies off tangentially.

Factors Affecting Centripetal Force.

1. **Mass of the object, m**- the heavier the object the more the centripetal force needed to maintain it in circular path.

2. **Angular velocity of the object, ω** - an increase in centripetal force needed to maintain the object in circular path.

3. **Radius of the path r**-the shorter the radius of the path the larger the centripetal force required to maintain the object in circular path.

Example

The figure below shows the diagram of set up to investigate the variation of centripetal with the radius r, of the circle in which a body rotated

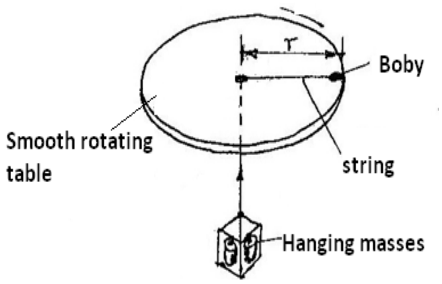
Examples of Uniform Circular Motion

A car rounding a level circular bend

When a car is going round in a circular path on a horizontal road, the centripetal force required for a circular motion is provided by the frictional force between the tyres and the road

Therefore- $F_r = \frac{mv^2}{r}$

If the road is slippery then frictional force may not be sufficient so to provide centripetal force



Describe how the set up can be used to carry out the investigation

- Keep angular velocity ω constant;
- Centripetal force provided by mg;
- Fix the mass m and measure of m;
- Repeat for different values of m;

The above factors are proofed using a turntable.

The turntable has the following features

- Increase in speed of the turn table increases length of the spring (increase in centripetal force)
- When using a shorter spring there is more extension of the spring than using along spring.
- When using a heavier metal bar will produce more extension than using a lighter ball.

This is a proof to the above factors.

The graph of force against the square of angular velocity is a straight line through the origin.

$$F \propto \frac{MV^2}{r}$$

$$F = \frac{KMV^2}{r}$$

When k=1, $F = \frac{MV^2}{r}$, but $v = \omega r$

Hence, $F = \frac{m\omega^2 r^2}{r}$, thus, $F = mr\omega^2$

To prevent skidding the car should not exceed certain speed limits referred to as the **critical speed**

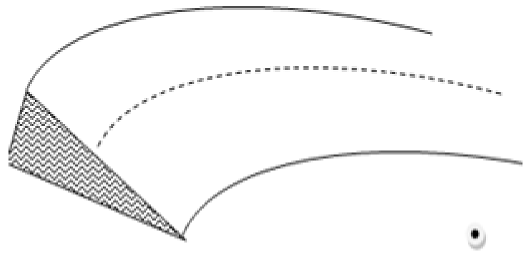
This critical speed depends-

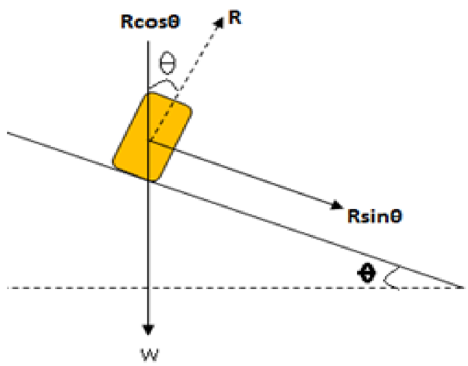
Radius of the bend i.e. one may negotiate the a bend at higher critical speed the radius of the bend is big

Condition of the tyre and the nature of the road surface this will produce the frictional force need to negotiate the bend

Banked tracks

Condition in which a road is raised gradually from the inner side of the bend.





$R\sin\theta$ *-Is the horizontal component which is responsible for providing centripetal force.*

BY principle of moments

$R.x = F_r y$

$R\cos\theta$ -Is the vertical component that is responsible for balancing the weight of the vehicle.

If a vehicle of mass m is travelling a long a circular path of radius r at uniform speed v, then

$$R\sin\theta = \frac{mv^2}{r}\text{.........................(i)}$$

$$R\cos\theta = mg\text{...............................(ii)}$$

Divide (i) by (ii)

$$\frac{R\sin\theta}{R\cos\theta} = \frac{mv^2}{r} \times \frac{1}{mg}$$

$$\frac{\sin\theta}{\cos\theta} = \tan\theta$$

Hence $\tan\theta = \frac{v^2}{rg}$

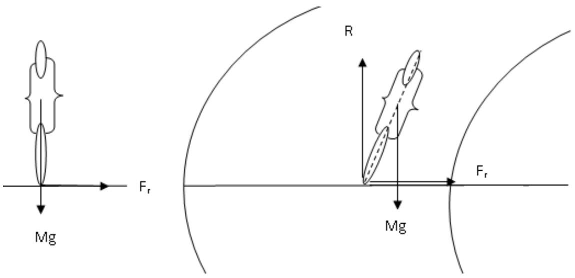
The maximum speed required for a body moving in a circular path whose angle of banking is θ is given by;

$$v^2 = rg\tan\theta \text{ Hence,} v = \sqrt{rg\tan\theta}$$

A cyclist moving round a circular track

Frictional force (Fr) is provided by centripetal force which is directed towards the car however if frictional force is not sufficient to provided centripetal force skidding takes place. To avoid skidding the cyclist leg inwards so that normal reaction of frictional force produces the turning effect to the clockwise and anticlockwise directions.

Taking moments about G



$$\frac{x}{y} = \frac{mv^2}{rmg}$$

$$\frac{x}{y} = \frac{v^2}{rg}$$

$$\tan\theta = \frac{v^2}{rg}$$

Making v the subject of the formula

$$v = \sqrt{rg\tan\theta}$$

$$\tan\theta = \frac{F_r}{mg}$$

Mg tan θ = F_r

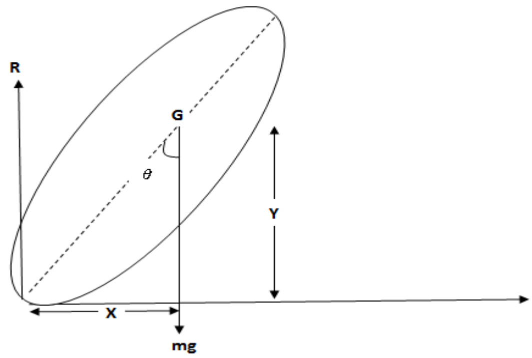
Fr = μR

Mg tan θ = μ mg

Tan θ = μ

Where μ is coefficient of friction

Skidding occurs when tan θ is greater than μ

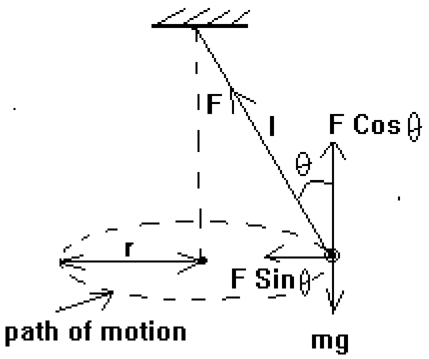


Conical pendulum

If a pendulum bob moves in such a way that the string sweeps out a cone, then the bob will describe a horizontal circle.

Example:

(a) The figure below shows an object at the end of a light spring balance connected to a peg using a string. The object is moving in a circular path on a



As it can be clearly seen, there are two forces acting on the pendulum bob;

(i) its weight (mg)

(ii) The tension in the string.

Centripetal force is provided by the horizontal component of the tension (**F** Sinθ). Hence from Newton's second law;

$\mathbf{F}\,\mathrm{Sin}\,\theta = \frac{mv^2}{r}$........................(1) (Where symbols have their usual meaning). Since there is no vertical acceleration

$$\mathbf{F}\,\mathrm{Cos}\,\theta = m\mathbf{g}\text{............................}(2)$$

Again, from the two equations; $\mathbf{Tan}\,\theta = \frac{\mathbf{v^2}}{\mathbf{rg}}$

Note that this equation is similar to the one we got earlier for banked tracks.

When the angular velocity W the cork rises hence Q increases. This concept is applied in merry go round and speed governors.

Motion in a Horizontal Circe

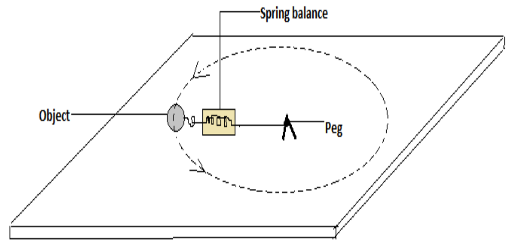
The tension in the string provides the centripetal force.

$$\mathbf{T = F_C}$$

$$\mathbf{T = \frac{MV^2}{r}}$$

Where the length of the string = radius of rotation

smooth horizontal table with a constant speed.



(i) What provides the force that keeps the object moving in the circular path?

(ii) Indicate with an arrow on the figure the direction of centripetal force .

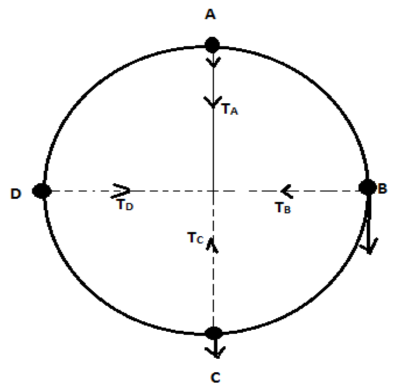
(iii) The speed of the object is constant, why is there acceleration?

(iv) Although there is force acting on the object, NO, work is done on the object. Explain.

(v) Given that the mass of the object is 0.5kg and it is moving at speed of 8m/s at a radius of 2m.Determine the reading on the spring balance.

(vi) State what happens to the reading if the speed of rotation is reduced.

Motion in Vertical Path



Tension on the spring changes its magnitude depending on the position of the ball.

When the ball is at A, the **sum of tension T_A and weight Mg acting in the same direction provide centripetal force.**

$\frac{MV^2}{r} = T_a + Mg$ -- (i)

When the ball is at A it attains minimum speed because $T_a = 0$

$\frac{MV^2}{r} = mg$

$V_{min} = \sqrt{rg}$

At B, tensional force T_B provides centripetal force.

$$T_B = \frac{MV^2}{r}$$

At C, tension and weight acts in different direction and hence the resultant force between the two forces provides the centripetal force

$\frac{MV^2}{r} = T_c - Mg$ -- (ii)

$T_a = \frac{MV^2}{r} - Mg$ -- (iii)

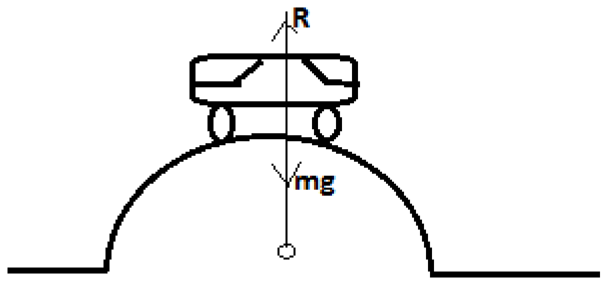
$T_c = \frac{MV^2}{r} + Mg$-- (iv)

$$\text{At D, } T_D = \frac{MV^2}{r}$$

1. A pilot not stripped to his seat in a loop manoeuvre without falling.
2. A bucket of water whirled in a vertical without water spilling.
3. A ball bearing 'looping the loop' on a rail lying in vertical plane.

Example

A car travels over a humpback bridge of radius of curvature 40m. Calculate maximum speed of the car if its wt are to staying contact with bridge. g =10m/s^2



$\frac{mv^2}{r}$=mg-R

R=0

Mv^2 =mg

$$V^2 = rg$$

V= $\sqrt{rg}$

= $\sqrt{40 \times 10}$

= 20 m/s

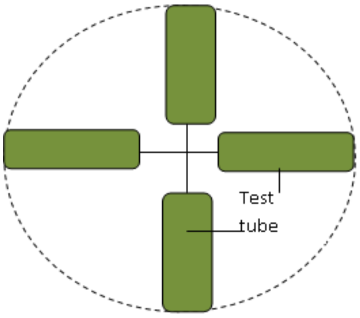
Examples of Centripetal Force

Example	Source(what provides centripetal force)
Cyclist moving along a circular path	Frictional force between the tyre and the road
Car moving a long a banked road	Horizontal component of reaction force
Electron orbiting around the nucleus of an atom	Electrostatic force of attraction between the proton and the electron
Electron moving in a magnetic field	Magnetic field
Satellite orbiting around the earth	Gravitational force exerted by the earth
A string whirled in a horizontal track	Tensional force

Application of Circular Motion

1. Centrifuges

It is used to separate particles in suspension in liquids of different densities. It consists of small metal containers tubes that can be rotated.



Centripetal will be too great according to the equation $F = mr\omega^2$

And r will thus be smaller for lighter particles and longer for heavier particles.

2. Satellites

Two bodies with mass m_1 and m_2 at a distance r from each other experience a force of attraction. $F = \frac{GM_1M_2}{R^2}$ G is equal to universal gravitational constant

Attraction between earth and satellite gives centripetal Force$M_1v^2 = \frac{GM_{1M_2}}{R^2}$

Where M_1 is mass of satellite and m_2 mass of the earth $v^2 = \frac{GM_2}{R^2}$

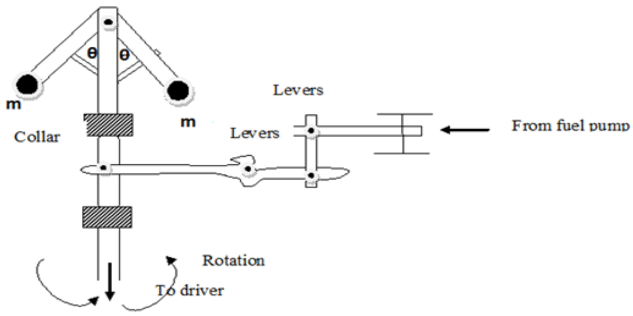
$$v = \sqrt{\frac{GM_2}{r}}$$

The velocity of the satellite increases with decrease in the radius of the orbit.

If periodic time of the satellite is equal to that of the earth the satellite appear stationary as seen from the earth surface such satellite are said to be in **parking orbit and are used in weather forecasting and telecommunications**.

3. Speed Governors

Principle of conical pendulum is used in operating the speed governors.



As the angular velocity of the drive shaft increases .the masses m rises and moves the collar up as the angle θ increases. The up and down movement of the collar is transmitted through a system of levers to the device that controls the fuel intake. Since the angular velocity of the drive shaft increases with speed of the vehicle, the fuel supply will cut off when the speed exceeds a certain limit.

Chapter Three — SINKING AND FLOATING

Specific objectives

a) state Archimedes" principle

b) verify Archimedes principle

c) state the law of flotation
d) define relative density
e) describe the applications of Archimedes" principle and relative density.
f) Solve numerical problems involving Archimedes" principle.

Content

- *Archimedes" principle,*
- *Law of flotation (experimental treatment)*
- *Relative density*
- *Applications of Archimedes" principle and relative density.*
- *Problems on Archimedes" principle*
- ***Project Work-** Construct a hydrometer.*

Upthrust force

Upthrust is an upward force acting on an object floating or immersed in a fluid. An object immersed or floating in a fluid appears lighter that its actual weight due to upthrust force (**force of buoyancy).**

Archimedes principle.

T***he principle states: When a body is totally or partially immersed in a fluid it experiences an up thrust equal to the weight of displaced fluid.***

To verify Archimedes' principle

Apparatus

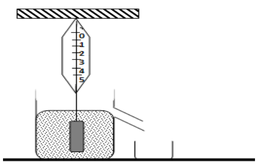
- An overflow can
- A metal block
- A beaker
- A spring balance
- A string
- Water

Procedure

(i) Weigh the block in air.

(ii) Note the weight of the block in air as **W_1.**

(iii) **Immerse** the block in water in the overflow can as shown in the diagram below

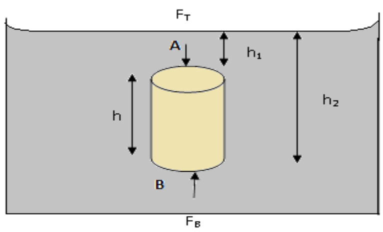


- Note the weight of the block when fully immersed as **W_2**

Precisely: Upthrust = Real weight –Apparent weight.

Cause of upthrust

Consider the figure below.



Pressure at the bottom > pressure at the top

$P_B = P_a + h_2\rho g$

$P_T = P_a + h_1\rho\, g$

Force = pressure x area

$F_B = P_BA = (P_a + h_2\,\rho\, g)\, A$

$FT = P_TA = (P_a + h_1\rho g)\, A$

Resultant force = $F_B - F_T$

$U = (Pa + h_2\,\rho\, g)\, A - (Pa + h_1\rho\, g)\, A$

$U = (h_2 - h_1)\,\rho g A$

$U = h\rho g A$ But $A\,h = v$

Hence, $U = V\rho g$

Upthrust therefore depends on:

(i) Volume of fluid displaced.

(ii) Density of fluid displaced.

- Measure the volume of water displaced and calculates its weight as **W_3**
- Apparent loss of weight=**$W_1 - W_2$**
- The upthrust **$U=W_3$**
- **Upthrust=apparent loss of weight;$U = W_1 - W_2$**

Example

A stone of weight 3N in air and 1.2N when totally immersed water. Calculate:

(a) Volume of the stone

(b) Density of the stone

Upthrust = Real weight- Apparent weight

= 3N – 1.2N

= 1.8 N

But $U = V\rho g$

1.8 = V x 1000 x 10

V= 0.00018 m^3

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

$$= \frac{0.3}{0.00018} \ kg/m^3$$

=1,666.67 kg/m^3

QUESTIONS

1. A Solid of density 2.5g/cm^3 is weight in air and then when completely immersed in water in a measuring cylinder the Level of water rises from 40cm^3 to 80cm^3. Determine

(a) Volume of the solid

(b) Its apparent weight.

2 a)State the Archimedes' principle

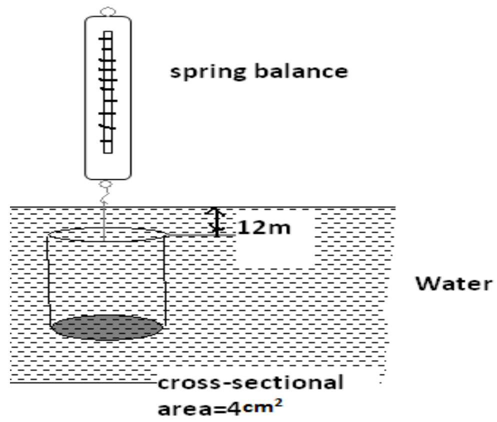
b) A right angled solid of dimensions 0.02m by 0.02m by 0.2m and density 2700kgm^{-3} is supported inside kerosene of density 800kgm^{-3} by a thread which is attached to a spring balance. The long side is vertical and the upper surface is 0.1m below the surface of kerosene.

(i) Calculate the force due to the liquid on:

(ii) The lower surface of the solid

3.(a) Distinguish between pressure and up thrust force.

(b) A solid metal block of density 2500kg/m^3 is fully immersed in water, supported by a thread which is attached to the spring balance as shown below.



(i) Calculate the force due to the liquid on the top face of the block.

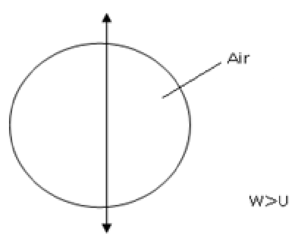
(ii) If the upward force on the bottom face is 1.5N, calculate the volume of the block.

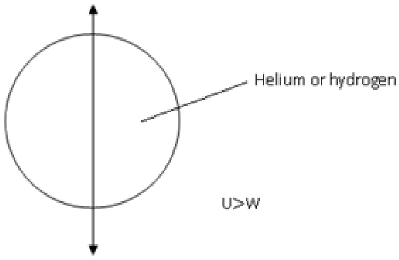
(iii) Calculate the apparent weight of the block in water.

Up thrust in gases

Gases exert small upthrust on objects because of their low density.

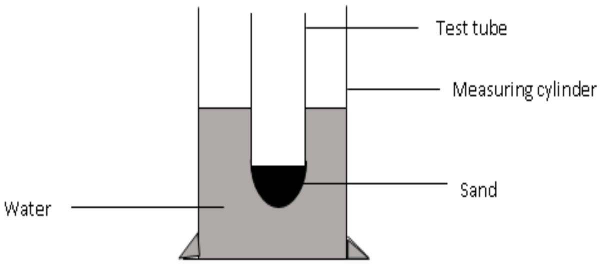
A balloon filled with hydrogen or helium rises up because of low density.



(iii) The upper surface of the solid (iv) Calculate the upthrust and hence or otherwise determine the reading on the spring balance.	

In the figures above the balloon filled with air will not float because the weight of the balloon fabric and air is greater than the weight of air displaced (upthrust) i.e. W>U. The balloon filled with helium or hydrogen floats because the weight of the balloon fabric and helium or hydrogen is less than the weight of the air displaced(upthrust) i.e. U>W

Law of Flotation



In this case we consider the floating object and weight of the fluid displaced.

A comparison of the weight of the object and that of fluid displaced.

Experimentally this can be done by:

- ½ fill measuring cylinder with water and record the reading.
- Place a clean dry test tube into the beaker and add some sand in it so that it floats upright.
- Records the new level of the liquid determine the volume of displaced water
- Measure its weight (dried) and content.
- Calculate the weight of displaced water.

It is observed that the weight of the test tube and its consent is equal to weight of displaced water.

OR

Apparatus:

weight of block in air. They are equal (same).

Therefore we conclude that **a floating object displaces its own weight of the fluid in which it floats. This law of flotation.**

Explanation

When a body is submerged in water, there are two forces acting on the body;

(i) The weight of the body acting downwards

(ii) Upthrust on the body due to displaced liquid acting upwards.

Case 1

If the weight of the body is greater than upthrust, the density of the body is greater than the density of the displaced liquid, the body sinks.

Case2

If the weight of the body is equal to upthrust, the density of the body is equal to the density of the liquid, the body remains in equilibrium.

Case3

If the weight of the body is less than the upthrust, density of the body is less than the density of the liquid, the body floats partially in the liquid.

Example:

A boat of mass 2000kg floats on fresh water. If the boat enters sea water. Determine the volume that must be added to displace the same volume of water as before.(Fresh water-=1000kg/m^3, sea water= 1030 kg/m^3)

Weight of fresh water = 2000kg

Displaced Volume of fresh water =$\frac{2000}{1000}$

=2m^3

A block of wood, A spring balance, Thin thread, Overflow can, A small measuring cylinder and Some water.

Using the apparatus above, describe an experiment to verify the law of floatation.

- Using the spring balance, weigh and record the weight of the block in air
- Fill the eureka completely with water
- Place the measuring cylinder under the spout
- Lower the block of wood slowly into water until the string slackens (the block floats)
- Collect the displaced water using the measuring cylinder
- Repeat the procedure to attain more results
- Compare the weight of displaced water with the

Mass = Density x Volume

= 1030 x 2

= 2060 kg

= 2060- 2000

= 60kg

2. A sphere of radius 3 cm is floating between liquid A and B such that ½ is at A and ½ at B. If of liquids A and B are 0.8g/cm^3 and 1.0g/cm^3 respectively determine mass of the sphere.

Mass of sphere= volume x density

Volume = $\frac{4}{3}\pi 3^3$

= 113.14 cm^3

Volume of liquid A displaced = ½ x 113.14

56.57 cm^2

Mass displaced of A = 56.57 x 0.8

45.256g

Mass of liquid B displaced = 56.57g

Total mass of sphere displaced = 45.256 + 56.57

<u>**101.826g**</u>

3. A stone eights 2N in air and 1.2N when totally immersed in water Calculate

(a) Volume of the stone

(b) Densities of the stone

(a) Up thrust = weight of water displaced

= 2-1.2

=0.8N

Upthrust and Relative Density

Relative density **is the ratio of the mass of any volume of a substance to the mass of an equal volume of water** <u>OR</u> **the ratio of the density of a substance to the density of water.**

To find relative density of a solid or a liquid several methods or formulas are used.

$$\textbf{Relative density} = \frac{\text{density of a substance}}{\text{density of water}}$$

Relative density of a solid.

If equal volumes of the substance and water are considered,

$$\textbf{Relative density} = \frac{\text{Mass of solid}}{\text{Mass of equal volume of water}}$$

Because mass is directly proportional to the weight the relative density of a solid may be given as:

$$\textbf{Relative density} = \frac{\text{weight of solid}}{\text{weight of equal volume of water}}$$

$$\textbf{Relative density} = \frac{\text{weight of solid}}{\text{weight of displaced water}}$$

$$\textbf{Relative density} = \frac{\textbf{weight of solid}}{\textbf{up thrust in water}}$$

Relative density of solid which sinks in water

If the weight of the substance in air is W_1 and in water is, W_2, Mass of water displaced = 0.8/10

= 0.08kg

$$\text{volume} = \frac{\text{mass}}{\text{density}}$$

$= \frac{0.08}{1000} \text{kgm}^{-3}$

1000 kg/m^3

= 0.00008m^3

Volume of stone = 0.00008m^3

(b) Density = $\frac{\text{mass}}{\text{volume}} = \frac{0.2}{0.00008}$

= 2500 kg/m^3

then $\text{R.D} = \frac{W_1}{W_1 - W_2}$

Relative density of solid which floats in water

The sinker is used as follows:

Weight of the sinker in water=W_1

Weight of the sinker in water + weight of floating object in air= W_2

Weight of the sinker +weight of floating object in water=W_3

Weight of floating object in air =$W_2 - W_1$

Weight of floating object in water=$W_3 - W_1$

Up thrust of the floating object in water=$(W_2 - W_1) - (W_3 - W_1)$

Up thrust of the floating object in water=$W_2 - W_1 - W_3 + W_1$

Up thrust of the floating object in water=$W_2 - W_3$

$$\textbf{Relative density} = \frac{\textbf{weight of solid}}{\textbf{up thrust in water}}$$

$$\textbf{Relative}\ \text{density of floating object} = \frac{W_2 - W_1}{W_2 - W_3}$$

Relative density of a liquid

To find relative density of the liquid we determine:

a) Weight (w_1) of solid in air.

b) Weight (w_2) of the same solid when totally immersed in water.

c) Weight (w_3) of the same solid when totally immersed in a liquid whose relative density is to be determined.

$$\text{R.D of liquids} = \frac{\text{mass of liquid}}{\text{mass of equal volume of water}}$$

Or

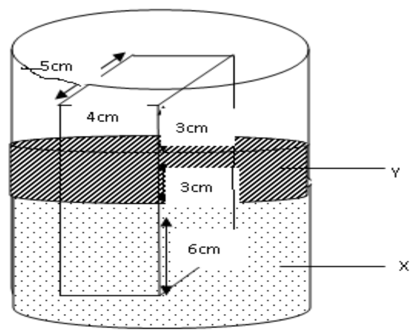
R.D of liquids

$$= \frac{\text{weight of displaced liquid}}{\text{weight of equal volume of water displaced}}$$

Or

$$\textbf{R.D of liquids} = \frac{\textbf{upthrust in the liquid}}{\textbf{upthrust in water}}$$

$$\text{R.D of liquids} = \frac{w_1 - w_2}{w_1 - w_3}$$



Volume of y displaced = 4 x 5 x 3

= 60 cm^3

= 0.00006 m^3

Up thrust in = vρg

= 800 x 0.00006 x 10

= 0.48N

Volume of x displaced = 0.04 x 0.05 x 0.06

= 0.00012 m^3

Up thrust in x = vρg

Or

Example

1. A solid of mass 800g is suspended by a string is totally immersed in water. If the tension in the string is 4.8N. Calculate

(a) Volume of solid

(b) Relative density of the solid.

Weight of solid = 8N

W_1 = 8N

W_2= 4.8N

Up thrust = 3.2N

Volume of water displaced = $\frac{0.32}{1000}$

= 0.00032 m^3

Volume of the solid = 0.00032m^3

1. The wooden block below floats in two liquids x and y if the densities of x and y are 1g/cm^3 and 0.8g/cm^3 respectively determine:

(i) Mass of the block

(ii) Density of the block

= 0.00012m^3

= 1.2N

Total up thrust = 1.2 x 0.48

= 1.68N

Weight of block = total up thrust

= 1.68N

= 0.168 kg

(b) density = $\frac{\text{mass}}{\text{volume}}$

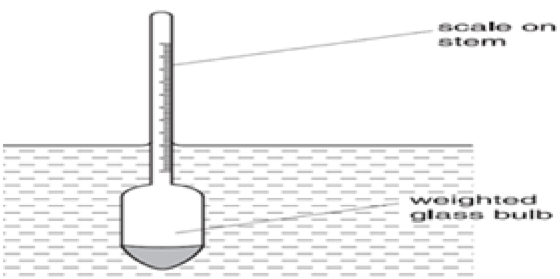
= 0.168

= 0.04 x 0.05 x 0.12

=700 kg/m^3

Applications of Archimedes's Principle and Relative Density

(a) The hydrometer



(b) Balloons

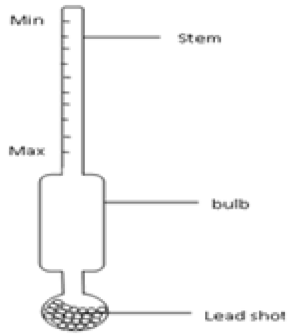
Used by metrologists where a gas which is less dense than air like hydrogen is used. The balloon moves upwards because up thrust force is greater than weight of the balloon. It rises to some height where density is equal to that of the balloon. At this point the balloon stops rising because up thrust is equal to weight of the balloon and therefore resultant force is equal to zero.

(c) Ships

They are made of steel which is denser than water but floats because they are hollow thereby displacing a large volume of water than the volume of steel which provides enough up thrust to support its weight.

The average density of sea water is greater than the average density of fresh water. Due to this difference, ships are fitted with primsol lines on their sides to show the level that a ship should sink to when on various waters.

(d) Sub-marine

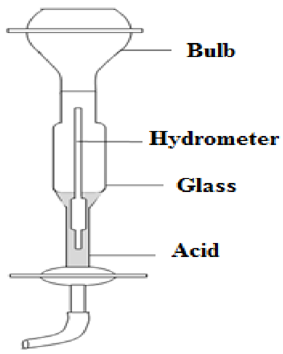


It is an instrument used to find relative densities of density of liquids. It applies the law of flotation in its operation.

It has a wide bulb to displace large volume of liquid that provide sufficient up thrust to keep hydrometer floating.

Lead shots at the bottom- to make hydrometer float upright.

Narrow stem- to make hydrometer more sensitive.



Hydrometers are designed for specific purposes lactometer range 1.015 – 1.0045 so as to measure density of milk.

The bulb is squeezed and released so that the acid is drawn into the glass tube.

It can sink or float. It is fitted **with ballast tanks** that can be filled with air or water hence varying its weight .To sink, ballast tanks are filled with water so that its weight is greater than up thrust.

To float compressed air is pumped into the tank displacing water so that up thrust is greater than weight of the submarine.

Examples

1. A hydrometer of mass 20g floats in oil of density 0.7g/cm^3.with 5cm of its stem above the oil. If the cross sectional area of the stem is 0.5cm^2. Calculate:-

(a) Total volume of the hydrometer

(b) Length of the stem out of water if it floats in water.

Solutions to questions

(a) Volume of oil displaced = $\frac{\text{mass of oil displaced}}{\text{density of oil}}$

$= \frac{20}{0.8}$

= 25 cm^3

Volume of hydrometer above oil = 5 x 0.5

= 2.5 cm^3

Total volume = 25 + 2.5

= 27.5 cm^3

(b) Mass of hydrometer = 2 x 10 - 2 kg

Weight of hydrometer = 2 x 10 - 1N

Weight of water displaced = 2 x 10 - 1N

Mass of water displaced = 2 x 10^{-1}

= 20g

Volume of water displaced = $\frac{20g}{1}$g cm^3

= 20cm^3

Volume of 1.00g/cm^3 liquid displaced = m/ρ = 165/1 = 165 cm^3;

Volume of 1.10g/cm^3 displaced = 165/1.1 = 150 cm^3;

*Change in volume displaced = 165 – 150 = **15 cm^3** ;*

Volume = Area x Height ;

*0.75 x h ; therefore h = **20 cm.***

(ii) State two ways of improving the sensitivity of the

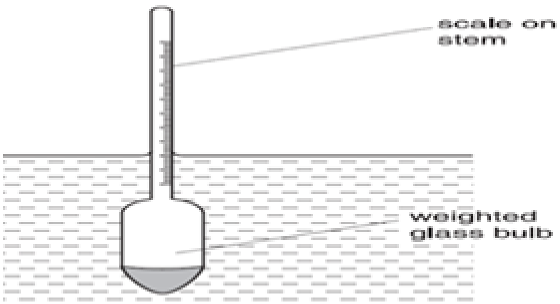
Volume of hydrometer above water = 27.5 - 20

$= 7.5cm^3$

$$\text{Length} = \frac{\text{volume}}{\text{Area}}$$

$$= \frac{7.5}{0.5} = 15cm$$

The densities of liquids may be measured using hydrometers. The hydrometer in the figure consists of a weighted bulb with a thin stem.



The hydrometer is floated in the liquid and the density is read from a scale on its stem.

The hydrometer in the figure is designed to measure densities between 1.00 g cm^{-3} and1.10 g cm^{-3}.On the diagram, mark with the letter M the position on the scale of the 1.10 g cm^{-3} graduation. The hydrometer has a mass of 165 g and the stem has a uniform cross-sectional area of 0.750 cm^2.Calculate;

(i) The change in the submerged volume of the hydrometer when it is first placed in a liquid of density 1.00 g cm^{-3} and then in a liquid of density 1.10 g cm^{-3}.

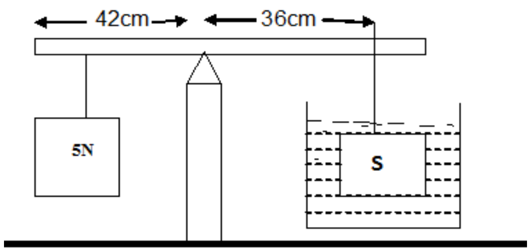
above hydrometer.

-Using a hydrometer with a narrow stem.

- Using a hydrometer with a large bulb

2. When a body of mass 450g is completely immersed in a liquid, the upthrust on the body is 1.6N. Find the weight of the body in the liquid.

3. The figure below shows a lever arrangement with the rod balanced by a knife edged at as centre of gravity. The 5N weight on one side balances the solid S (volume $100cm^3$) which lies immersed in a beaker of water on the other side.



The beaker of water is then removed and while keeping the 42cm distance constant, the position of solid **S** is adjusted to obtain balance conditions again.

a) Determine the new position of **S**.

b) What would be the new position of S if it was immersed in a liquid of relative density 0.8?

Chapter Four	ELECTROMAGNETIC INDUCTION
Specific objectives	***Content***
By the end of this topic, the learner should be able to: *a) Perform and describe simple experiments to illustrate electromagnetic induction* *b) State the factors affecting the magnitude and the direction of induced emf* *c) State the laws of electromagnetic induction* *d) Describe simple experiments to illustrate mutual induction explain mutual induction* *e) Explain the working of an alternating current*	➢ *Simple experiments to illustrate electromagnetic induction* ➢ *Induced emf:* • *Faraday's law* • *Lens's law* ➢ *Mutual induction* ➢ *Alternating current generator, direct current generator*

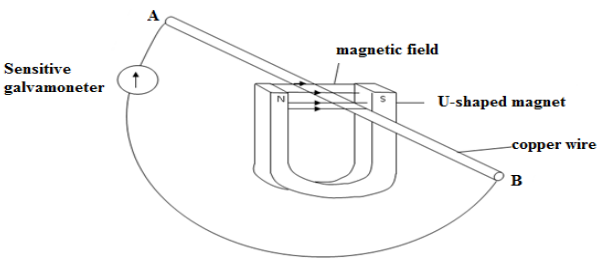
(a.c) generator and a direct current (d.c) generator f) Explain the working of a transformer g) Explain the application of electromagnetic induction h) Solve numerical problems involving transformers	➢ Fleming's right hand rule ➢ Transformers ➢ Applications of electromagnetic induction • Induction coil • Moving coil transformers

Introduction

Electric current passing through a conductor has an associated magnetic field. The reverse is also true in that a change in magnetic field induces an electric current in a conductor a phenomenon known as **electromagnetic induction.**

This is attributed to Michael Faraday and has led to production of electrical energy in power station.

Experiment to Show Induced Electromotive Force (Emf)



The galvanometer reflects when conductor AB cuts the magnetic field.

- There is no flow of current when the conductor is stationary.
- The magnitude of induced current increases with the angle of which conductor cuts magnetic field.
- The direction of deflection reverses when the direction of motion is reversed.

FACTORS AFFECTING MAGNITUDE OF INDUCED E.m.f.

(i) The magnitude or strength of magnetic field.

(ii) The rate of change of flux linkage/rate of relative motion between the conductor and magnetic field.

(iii) The number of turns of coil/length of the conductor

(iv) The nature of the core

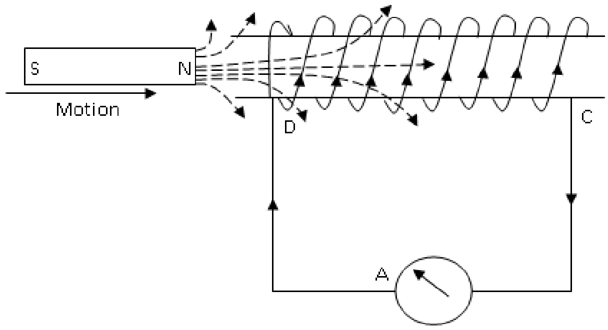
Magnetic Flux

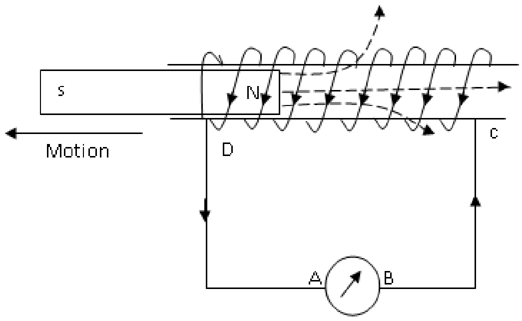
It is the product of magnetic field strength and perpendicular area covered by the field lines.

The direction of induced emf by a conductor is predicted by **two laws of electromagnetic induction**;

***Faraday's law*-The magnitude of induced e.m.f. is directly proportional to the rate of change of magnetic flux linkage.**

Lenz's law – **direction of induced e.m.f. is such that the induced current which it causes to flow produces a magnetic effect that opposes the change producing it.**





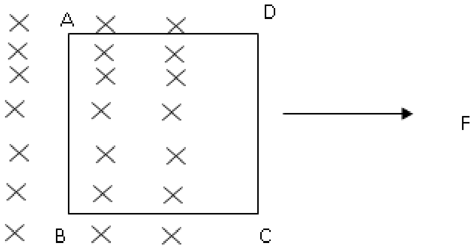
The mechanical energy of a moving magnet inside a coil is converted to electric energy inform of induced current. The person pushing the magnet towards the coil must exert force to do work against repulsion of induced pole of coil magnet.

Fleming Right Hand Rule (Dynamo Rule)

If the thumb and first two fingers of the right hand are held manually at right angle with 1st finger pointing direction of magnetic field, the thumb pointing in the direction of motion then the second finger points in direction of induced current.

Example

(i) A square looped conductor is pulled at speed across a uniform magnetic field as shown below.



Determine direction of induced current in

(a) AB – from B to A

(b) AD - no induced current

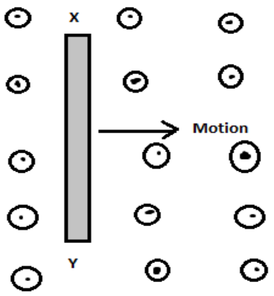
(c) CD-C to D

(d) BC- no induced current

Question

(a) State Faraday's laws of electromagnetic induction.

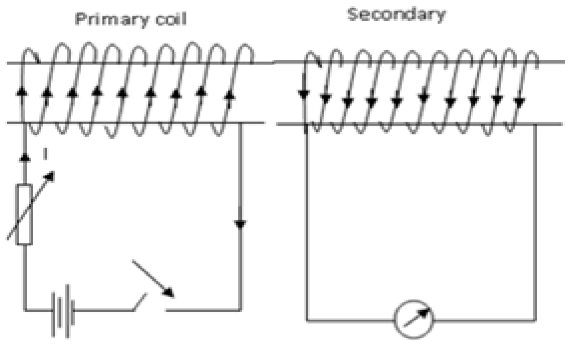
(b) The figure below shows a conductor XY moving in a region of uniform magnetic field.



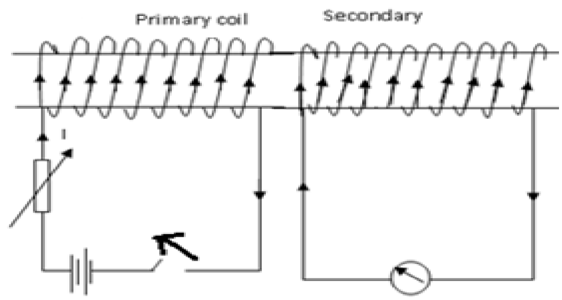
(i) State the direction of the induced current in the conductor and the rule used in arriving at the answer.

Mutual Induction

It occurs when change of current in one coil induces a current in another coil placed close in to it. The **changing magnetic flux** in the first coil (Primary) links to secondary coil inducing an EMF in it.



(a)



(b)

When a switch is closed, current in the primary coil increases from zero to a maximum current within a very short time. The magnetic flux in the primary coil linking with the secondary coil increases from zero to a maximum value in the same interval of time inducing an e.m.f. in the secondary coil. Current flows hence the reflection on the galvanometer.

Likewise when the switch is opened the current in the primary takes a very short time to fall from maximum value to zero. The magnetic flux in primary coil linking secondary also falls from maximum value to zero inducing an **e.m.f.** on the secondary coil.

The induced e.m.f. in the secondary coil is higher when current in the primary coil is switched off than when it is switched on because the current in the circuit takes a much shorter time to die off than build up. The above explanation is called **mutual induction**. The induced e.m.f. in the secondary coil can be increased by:

(i) Having more turns in the secondary coil.

(ii) Winding the primary and secondary coils on a soft iron rod.

(iii) Winding both primary and secondary coils on a soft iron ring in order for the magnetic flux in the primary to form concentric loops within it thus reaching the secondary point. Soft iron concentrates magnetic flux in both coils that is

(ii) Suggest one way of increasing the magnitude of the induced current in the conductor.	why it is used.

Application of Electromagnetic Induction

It is applied in many areas some of these are:

(i) Transformer

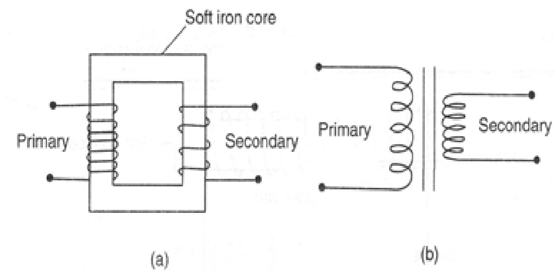
A transformer transfers electrical energy form one circuit to another by mutual induction.

It consists of a primary coil where an alternating current is the input and secondary coil forming the output.

The coils are wound on a common soft iron.

Types of Transformers

Step down transformers



It has more turns in primary coil (N_P) than in the secondary coil (N_S)

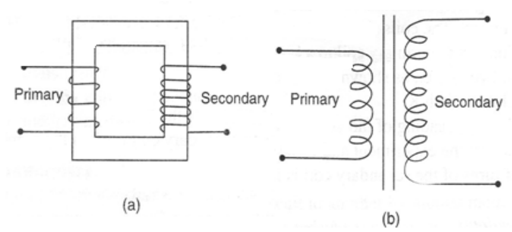
$\frac{V_S}{V_P}$ = n(Turns ratio)

Turns ratio is less than one

Step up transformer

It has less turns in primary coil and more in the secondary coil.

The turn's ratio is greater than one.



NOTE – In a step-down transformer current in the in the secondary coil is greater than in the primary coil while in the step-up transformer current in the

Useful transformer equations

From experiment;

$$\frac{\text{Secondary voltage}}{\text{Primary voltage}} = \frac{\text{no. of secondary turns}}{\text{no. of secondary turns}}$$

This is called **turns rule**.

Mathematically;

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

Assuming negligible resistance

Power = Voltage x current

$$P = VI$$

$$\text{Power input} = \text{Primary voltage x primary current}$$

$$P_{Input} = V_P I_P$$

Power output= secondary voltage x secondary current

$$P_{Output} = V_S I_S$$

$$\text{Efficiency (\%)} = \frac{\text{Power output}}{\text{Power input}} \text{x } 100$$

$$\eta = \frac{V_S I_S}{V_P I_P} \times 100\%$$

For ideal transformer there is no energy lost and therefore efficiency is 100%

$$100 = \frac{V_S I_S}{V_P I_P} \times 100$$

$$V_P I_P = V_S I_S$$

$$I_P = \frac{V_S I_S}{V_P}$$

$$\frac{I_P}{I_S} = \frac{V_S}{V_P} = \frac{N_S}{N_P}$$

Examples

1. A transformer is to be used to provide power of 24V ceiling bulb from a.c. supply of 240. Find the number of turns in secondary coil if the primary coil has 1000 turns.

primary coil is greater than in the secondary coil.

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

$$\frac{24}{240} = \frac{N_s}{1000}$$

1000

= 100 turns

2. A power station has an output of 10KW at a p.d of 500v. The voltage is stepped up to 15 KV by transformer T_1, for transmission along a grid of resistance 3 k and thin stepped down to p.d 240v by transformer T_2 at the end of grid for use in a school. Given that efficiency of T1 is 95% and T2 90%, find:

   (i) The power output of T_1

   (ii) The current in the grid.

   (iii) The power loss in grid.

   (iv) The input voltage of T_2

   (a) The maximum power and current available for use in school

   (b) Why is it necessary to step up the voltage at power station?

3. Power station has an output of 33K at a p.d of 5k V a transformer with a primary coil of 2000 turns is used to stop up the voltage of 132 KV for transmission along a grid. Assuming there s no power loss in the transformer calculate

   (a) Current in the primary coil

   (b) Number of turns of secondary coil

   (c) Current in the secondary coil.

Energy Losses in a Transformer

There are four main causes of energy losses in a transformer.

Flux Leakage

All magnetic flux produced by the primary may not link up with the secondary coil hence reducing e.m.f induced in secondary. Flux leakage is reduced by efficient design of transformers to ensure maximum flux leakage.

The secondary coil is wound over the primary coil or

Resistance of Coils (Copper Losses)

This can be prevented by use of thick copper wire to reduce heating effect.

Eddy Currents in the Core

Eddy currents have associated fluxes that tend to oppose the flux change in primary. This reduces power transfer to the secondary. To reduce eddy currents the core is laminated (using thin sheets of insulated soft iron plates) causes minimal heating effect.

Hysteresis Loss

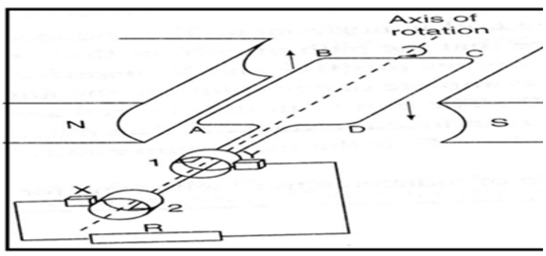
It is energy losses inform of heat in magnetizing and demagnetizing the soft iron core every time the current reverses. It can be minimized by using a core of soft magnetic material which magnetized and demagnetize easily.

Practical Transformer

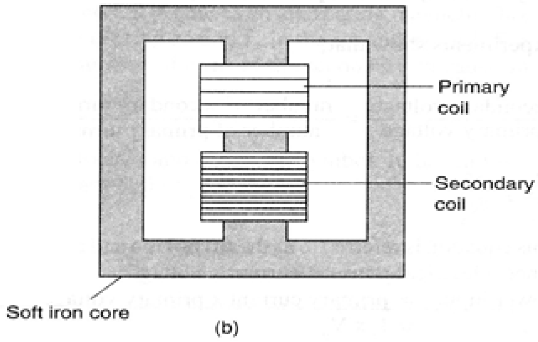
A transformer used in power stations and along transmission lines generates a lot of heat. **They are therefore cooled by oil which does not easily evaporate.** Small transformers are cooled by use of air. A well-designed transformer can have an efficiency of up to 99%.However; the presence of air reduces its efficiency.

(i) Alternating current generator

It converts mechanical energy into electrical energy. It has a rectangular curved permanent magnet poles, two slip rings and carbon (graphite) brushes.



The poles of the magnet are curved so that magnetic coils are wound next to each other on a common core.



field is radial. Induced Current enters and leaves the coil through the brushes which presses against the slip-rings. The brushes are made of graphite because:

(i) It is a good conductor of electricity-

(ii) It is slippery and therefore can act as a lubricant.

When coil rotates in clockwise direction side AB moves up and CD downwards. The two sides are cutting the magnetic field perpendicularly and produce maximum induced e.m.f (E) when the coil is horizontal.

Applying Fleming's right had rule, the flow of induced current is in the direction ABCD

The current flow through the external circuit via the slip – ring 2 and brush x. Brush Y and slip-ring 1 complete the circuit. Brush x is thus positive terminal which Y is negative. When coil rotates from horizontal to vertical position the angle at which the sides of the coil cuts magnetic field reduces from 90^{o} to 0^{o}

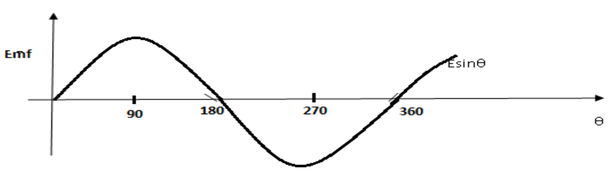
Likewise the induced emf reduces from maximum to zero. When the coil rotates past the vertical position side AB moves downwards as side CD moves upwards. The angle Θ at which the sides of the coil cuts the magnetic field increases from 0^{o} to 90^{o} when coil is horizontal. The induced emf increases from zero to maximum value and direction of current in the coil reverses from D C B A brush Y now becomes positive and X negative.

The magnitude of induced e.m.f obeys the sinusoidal equation

$E= E_o \sin \Theta$

Where E_o is maximum e.m.f and Θ is the inclination of the coil to the vertical.

The graph below shows the variation of induced emf with time for one revolution of the coil starting with the coil in vertical position.

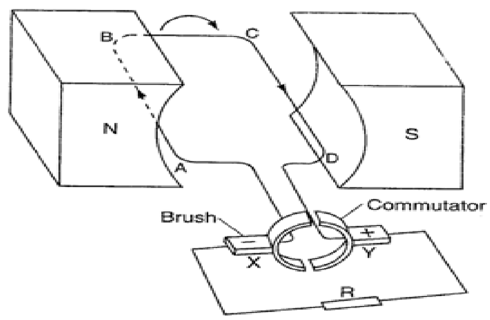


By Ohm's law $I = \frac{E}{R}$

$E = E_0 \mathrm{Sin}\Theta$

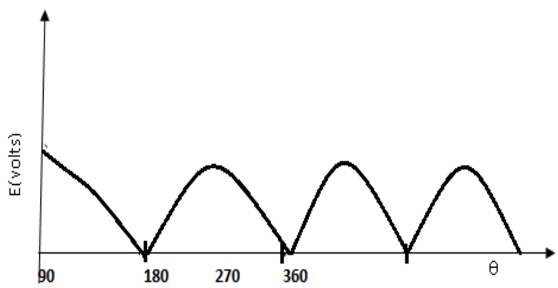
(ii) Direct Current Generator

Direct current (d.c) generator differs from an a.c generator in that it has a split-ring (commutator) while in ac generator has slip-ring.



If the coil rotates into the vertical position induced current and e.m.f though resistor R decreases from maximum value to zero. The polarity of brush Y is **positive** and X is **negative**. The brushes touch the gaps within the commutators

The vertical position ensures that rings exchange brushes since the induced current change direction but direction of current through the external resistor remains the same. The polarity does not change and output of d.c generator is shown below.



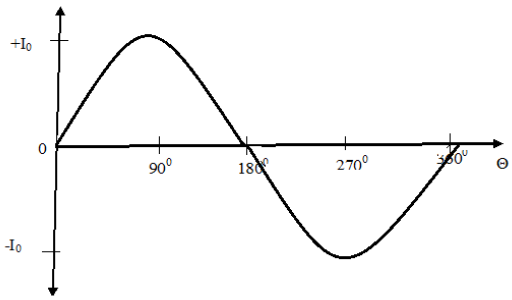
The induced e.m.f or current of both a.c and d.c generator can be increased by;

(i) Increasing speed of rotation of coil.

$$IR = I_0R\sin\Theta$$

$$I = I_0\sin\Theta$$

The graph of induced current against the angle of inclination is similar to one above.

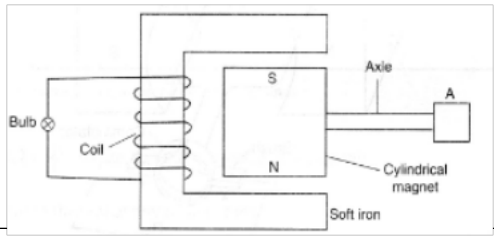


(ii) Increasing no of turns of coil.

(iii) Increasing the strength f the magnetic field.

(iv) Winding the coil on a laminated soft iron core.

In a bicycle dynamo the magnet rotates while coil remains stationary. It has advantages over other generators because there are no brushes which get worn out.



(iv) Moving Coil Microphone

Sound waves from the source set diaphragm in vibration which in turn causes the coil to move to and from cutting the magnetic field.

Induced e.m.f of varying magnitude sets up varying current in coil so that coil is perpendicular to it for maximum flux linkage.

An amplifier is used to increase the amplitude of this current before it is fed into the loudspeaker to be converted back to sound.

(iv) The Induction Coil

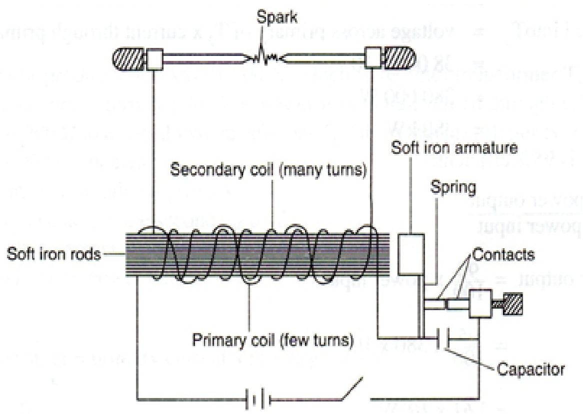
It is used to ignite petrol-air mixture in a car engine.

When the switch is closed the soft iron rod is magnetized due to current on the primary coil and attracts the soft iron armature.

The armature opens the contact and cuts off primary currents reducing magnetic field to zero. This is turn induces a large emf in the secondary coil by mutual induction. The spring pulls the armature back to make the contact again and process repeats itself.

The induced emf in the secondary coil is higher when primary current is switched off than when it is switched on. This is because current takes a longer time to increase from zero to maximum than to decrease from maximum to zero.

Sparking occurs at the contact due to magnetic field of the primary. A capacitor is therefore connected across the contacts to minimize sparking effects by decaying magnetic flux to zero. Sparks forms across gap between the ends of secondary coil and can be used to ignite petrol-air mixture in a car engine.



Assignment to the student.

Do the exercise at the end of the topic in KLB.

Chapter Five	MAINS ELECTRICITY

Specific Objectives

By the end of this topic the learner should be able to:

a) State the sources of mains electricity
b) Describe the transmission of electricity power from the generating station
c) Explain the domestic wiring system
d) Define the kilowatt hour
e) Determine the electrical energy consumption and cost
f) Solve numerical problems involving electricity

Content

- *Sources of mains electricity*
- *Power transmission (include dangers of high voltage transmission)*
- *Domestic wiring system*
- *Kw-hr, consumption and cost of electrical energy*
- *Problems on mains electricity*

Sources of Mains Electricity

1. Water in high dams
2. Geothermal energy
3. Coal or diesel
4. Winds
5. Tidal waves in the seas
6. Nuclear energy

The type of power generation chosen for a given location depends on the most abundant source of energy available in that area.

Power Transmission

The National Grid System

- It is a system of power cables connecting all the stations in a country to each other and to consumers.
- **Advantage of national grid system**

  Ensures that power is available to

Advantages of A.C Voltage over D.C Voltage

(i) Can be transmitted over long distances with minimum power loss.

(ii) Can be stepped up to very high voltage.

Electrical Power

$$\text{Electrical potential energy} = \text{voltage} \times \text{charge}$$

$$\text{work done} = VQ$$

$$\text{Electrical power} = \frac{\text{work done}}{\text{time}}$$

$$P = \frac{VQ}{t}$$

but $Q = It$

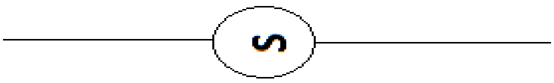
$$\text{Thus, } P = \frac{V \times I \times t}{t}$$

$$\Rightarrow P = VI$$

Power loss during transmission

consumers even when one of the power stations fails.

- Most power stations generate electricity in form of alternating current (a.c) at voltage between 11kV and 25kV.The voltage is then stepped up between 132kV to 400kV for transmission so as to minimize power loss.
- The electrical energy is then transmitted over long distance to substations where the voltage is stepped down to 11kV.
- The power can be stepped down to appropriate value for domestic and other users. In Kenya domestic applicant operate at 240V.
- An a.c source voltage is represented by the symbol shown below:



Power dissipated in a circuit is given by P = VI.

But V = IR (Ohm's law)

Thus $P = I^2 R$

The above equation shows that when current is high power loss is also high

Power loss is therefore low when transmitted at high voltage and low current.

Example

1. A generator produces 100kW power which is transmitted through a cable of resistance 5Ω .if the voltage produced is 5,000V,calculate;

(i) The current transmitted

(ii) Power loss through the cables

(iii) Power received by the consumer

During transmission power loss can be minimized by:

(i) Stepping up output voltage from power station.

(ii) Use of thick and good conductor transmission cable to minimize resistance.

In most cases aluminium is preferred because:

(a) Good conductor of electricity

(b) It is light

(c) It is cheap and available

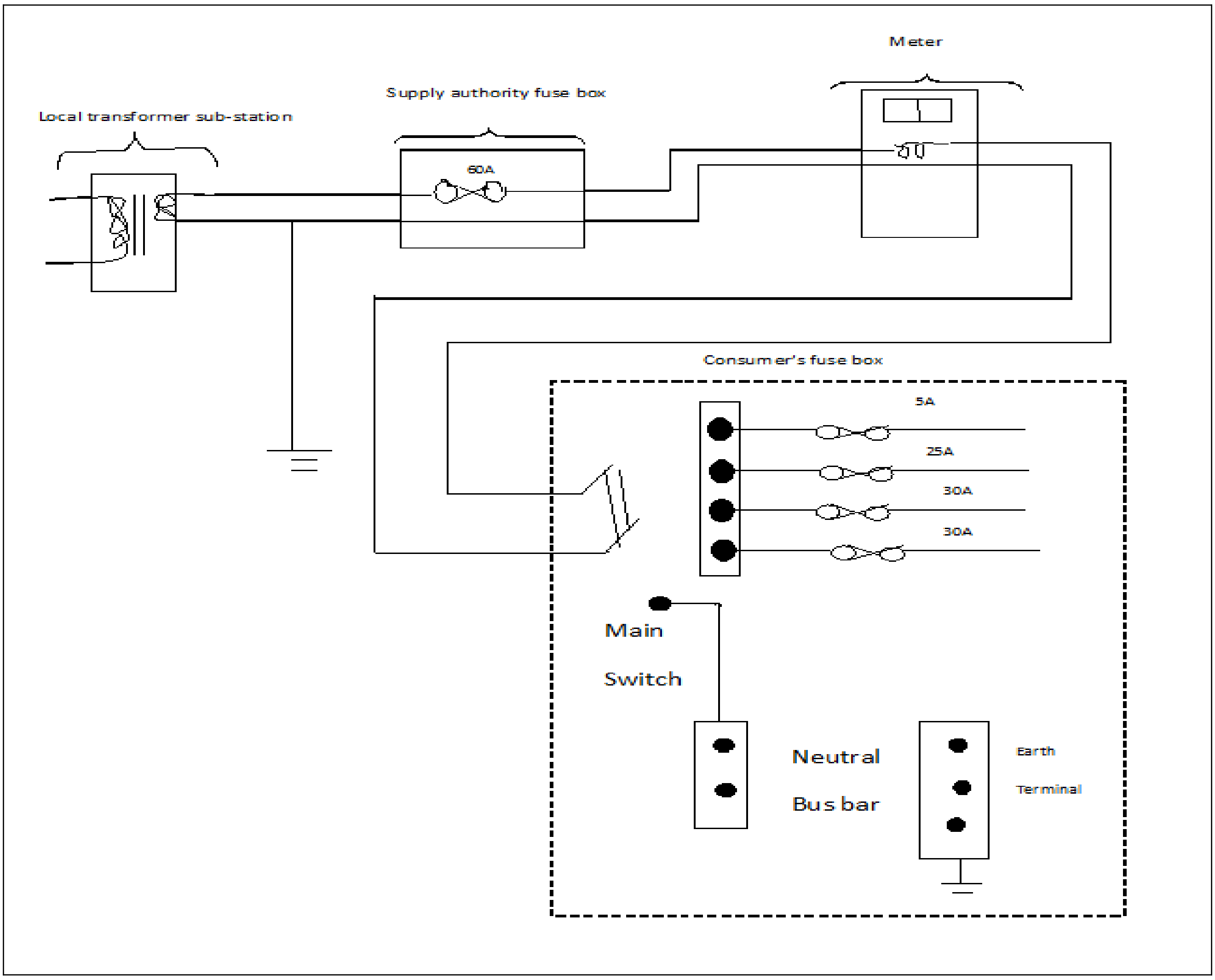
Dangers of high voltage transmission.

(i) Harmful effects of strong electric fields.

(ii) The risk of fire on nearby structures and vegetation when cables get too low.

(iii) The risk of electric shock in case the poles collapse or hang too low.

Domestic Wiring



Electrical power is usually supplied at 240V from a step-down transformer.

This power is connected to the house using two wires;

Neutral cable which earthed at zero potential.

Live cable which is at full potential

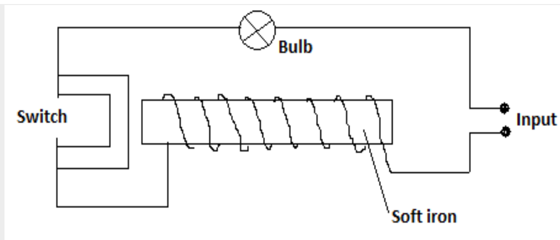
The life cable is connected to a higher fuse value. The cables are then connected to a meter where energy consumed is registered. From meter cable passes on to consumers fuse box.

Consumer fuse box consist of:

Main switch

It disconnects both live and neutral wires simultaneously.

Live bus bar



Example

House has a lighting circuit operated from 220V mains. Nine bulbs rated at 120W 240V are switched on at the same time. What is the most suitable fuse for this circuit?

P = VI

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

It is connected to live wire and the fuse.

Neutral bus bar

It is connected to all neutral wires

Earth Terminal

It is earthed through a thick copper bar buried deep in the earth or through water piping.

Fuse

- ❖ Fuse is a thin wire (made alloy of copper and tins) which melts when current exceeds its rating.
- ❖ Its function is to safeguard components against excess current in the circuit.
- ❖ It has low melting point.
- ❖ It is usually connected on a live wire because live wires are at full potential

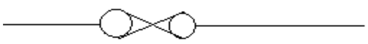
The fuse can blow due to the following:

(i) Overloading the circuit

(ii) Short circuiting

(iii) Use of wrong fuse rating

The fuse is normally represented by any of the following symbols:



or

Circuit Breakers

Is an electronic device which disconnects the circuit when current exceeds a certain value by electromagnetism. It is more efficient than a fuse in that it can be reset when power goes off unlike a fuse which must be replaced with a new one.

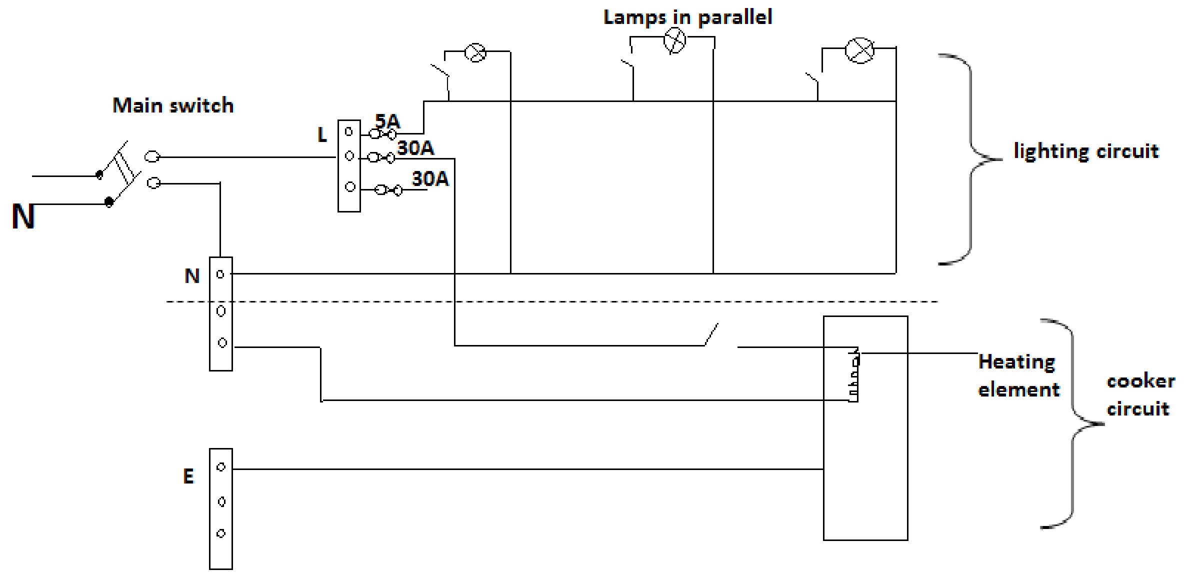
Total current $I = \frac{9P}{V}$

$= \frac{9 \text{ X } 120}{220}$

= 4.91A

The suitable fuse is a 5A fuse

Lighting and Cooking Circuits



For lighting circuit the lamps are connected in parallel so that:

(i) They are operated independently.

(ii) To reduce the effective resistance.

(iii) They can be operated at the same potential

The cables are relatively thin because lamps consume small amount of current.

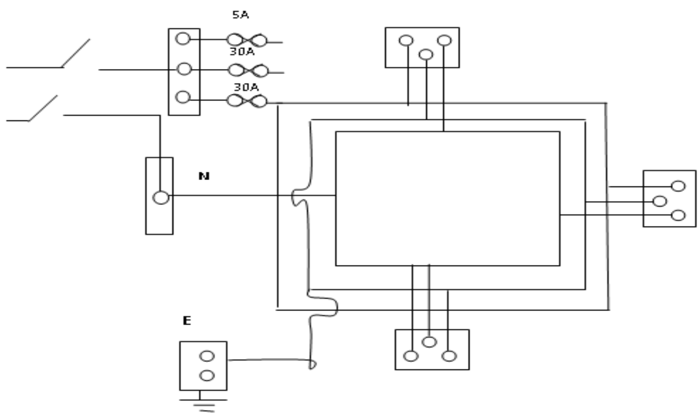
For cooking circuit, power is taped from the rings mains circuit.

These circuits are earthed and their wires are relatively thicker than those for the lighting circuit, since they carry large currents.

The Rings Mains Circuit

Is a circuit where power in various rooms tapped at convenient point from a loop.

The arrangement of the cable enable double path for current arrangement also increases the thickness of wires used reduces the risk of overloading when several sockets are used.

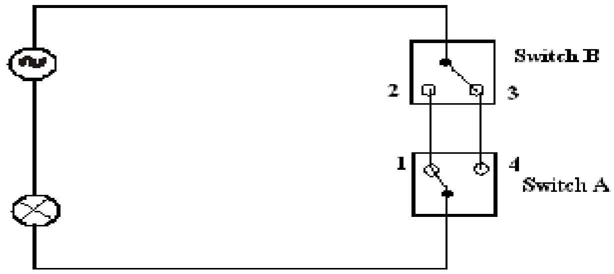


Two Way Switch Circuit	The insulation on the three cables are coloured so that they link correctly when connected to

Is used to put off on lights by one switch and put off by the other.

Example

The diagram below shows staircase double switches.

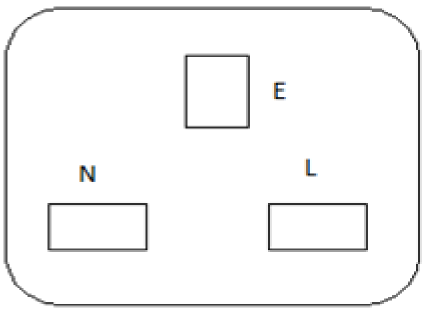


On the table given below write down whether the lamp will be ON or OFF for various combinations of switch positions.

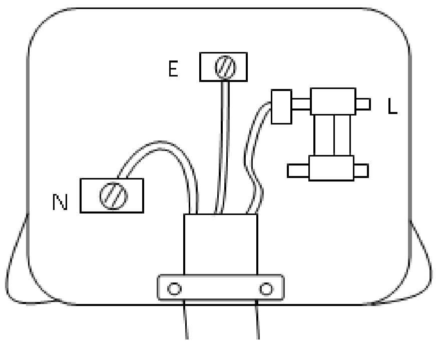
Position of switch A	Position of switch B	Lamp ON/OFF
1	3	
1	2	
4	3	
4	2	

A Three – Pin Plug

Socket for three-pin plug



Three -pin plug



power circuit.

Live lead – red/brown

Neutral – Black/ blue

Earth – Green/green with yellow stripes

Fuse is used to safeguard appliance from damage due to excessive

The value of the chosen fuse should be slightly above the value of the operating current of the appliance.

The earth pin is longer so as to open valves or shutters of the live and neutral pins.

This protects the user from shock. Three pin-plugs have the earth pin which provides the path for excess current.

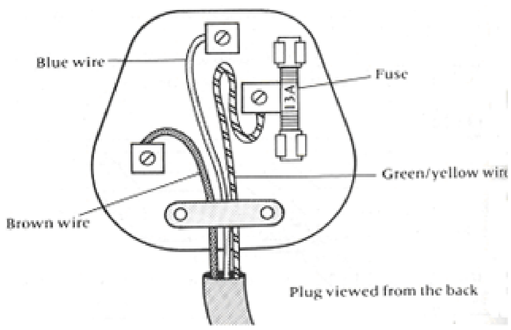
Question

The figure shows a three-pin plug

Identify the mistakes in the wiring

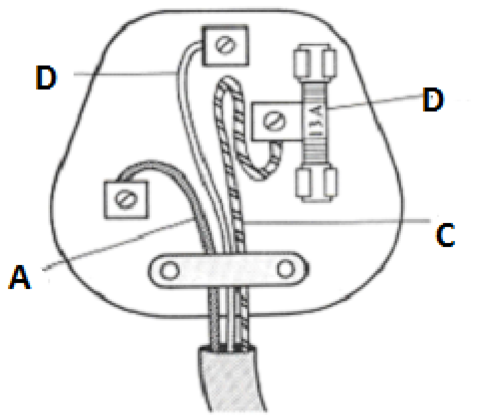
What would happen if this plug was connected to mains socket.

Why is the earth pin normally longer than the other two pins



a)Study the figure below:-

Electrical Energy Consumption and Costing



(i) What name is given to the fitting in the diagram?

(ii) Identify the parts labelled.

A -

B -

C -

D -

iii) State the colours A, B and C.

A -

B -

C -

Commercial companies charge for electrical energy supplied to consumers.

Amount of energy used by consumers depends on:

Power rating of appliances

Time for which they have been in use.

Energy = Power x time

The unit is used for costing 1 unit = 1kWh

Kilowatt – hour (KWh) is amount of electrical energy spent in one hour at rate of 1000 J/S (watts).

A consumer has the following components in his house for the times indicated in one day.

Appliance	Time
Two 40w bulbs	30min
One 3kw electric heater	4hrs
One 500w fridge	15hrs

Calculate;

Total power the components use

Total cost of power consumed in 30 days if one unit costs Ksh 6.50

(2 x 40) + (3000) + (500)

= 3580W

Chapter Six **ELECTROMAGNETIC SPECTRUM**

Specific Objectives

By the end of this topic. The learner should be able to:

a) Describe the complete electromagnetic spectrum

b) State the properties of electromagnetic waves

c) Describe the methods of detecting electromagnetic radiations

d) Solve numerical problems involving $c = \lambda f$

Content

- *Electromagnetic spectrum*
- *Properties of electromagnetic waves*
- *Detection of electromagnetic (emf) radiations*
- *Application of e.m radiations (include green house effect)*
- *Problems involving* $c = \lambda f$

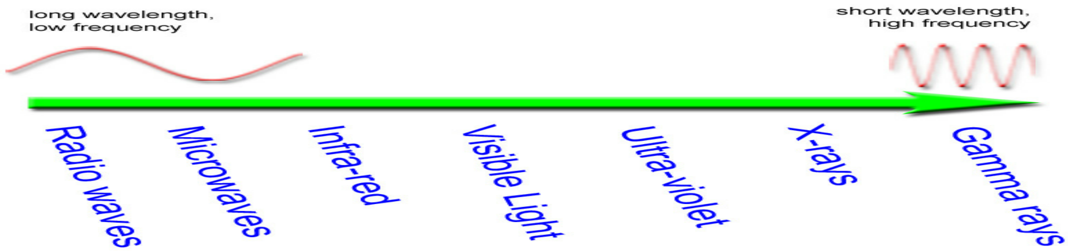
Electromagnetic Spectrum - this is the arrangement of the electromagnetic waves according to their frequencies or wave length.

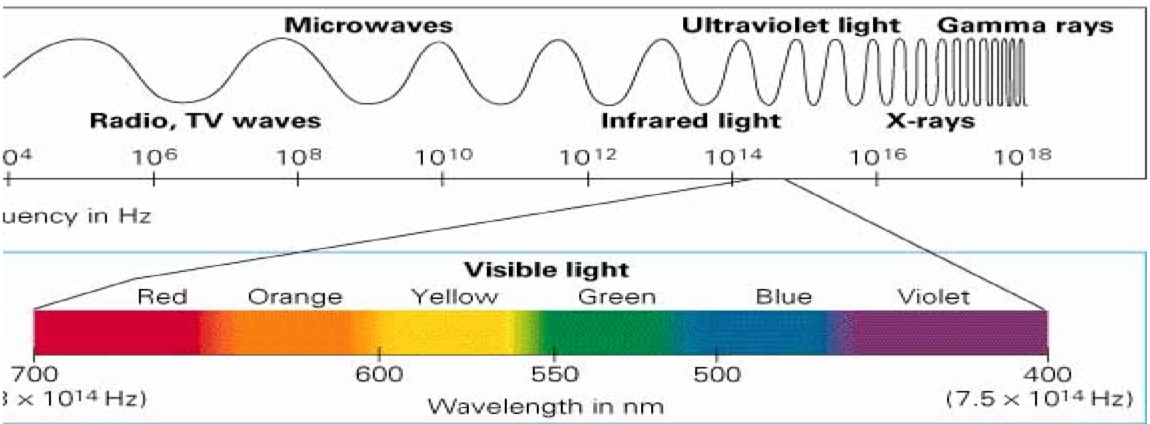
Electromagnetic Waves

Are transverse waves which results from oscillating electric and magnetic fields at right angle to each other.

Examples of E.M Waves

They include light, x-rays, ultra violet, infrared and gamma rays when this wave is arranged in terms of wavelength or frequency .They form electric magnetic spectrum. The wavelength range from about 1 x 10^{6} m to 1 x 10^{-14}m.





Properties of Electromagnetic Waves	***Example***
(i) They are transverse in nature. (ii) They do not require a medium for transmission. (iii) They travel through space (vacuum) with the speed of light (3 x10^8 m/s) (iv) They carry no charge hence not affected by electric or magnetic fields. (v) They undergo interference, reflection, and diffraction, refraction and polarization effects. (vi) They possess energy in different amounts. According to $E = hf$ where h is planets constant (6.63 x 10^{-34} Js) and f is frequency. (vii) They obey the wave equation $c = f\lambda$	Green light has a wavelength of $5\,x10^{-3}$m.Calculate the energy it emits. A radio is tuned into a radio station 144 km away. (a) How long does it take a signal to reach the receiver? (b) If the signal has a frequency has a signal of 980 kHz, how many wavelengths is the station away from your receiver?

Production and Detection of Electromagnetic Waves.

EM wave	Production	Detection
Radio waves	oscillating electrical circuits and transmitted through aerials or antennae	Diodes and earphones.
Microwaves	Special vacuum tubes called magnetrons in microwave ovens or with a mass.	Dry crystal detectors or solid state diodes.
Infrared Radiation	the sun or any hot body	Heating effect produced on the skin, thermopile, bolometer and thermometer with blackened bulb.
Visible light	Sun is the major source other sources are hot objects, lamps and laser beams.	the eye, photographic film and photocell
Ultraviolet (u.v) rays	By the sun, sparks and mercury vapour due to large energy chances in the electrons of an atom.	by photographic films, photocells, fluorescent materials (quinine sulphate) and paper lightly smeared with Vaseline
X-rays	action of beam of fast-moving electrons hitching a metal target	Using fluorescent screen or photographic film.
Gamma Rays	By radioactive substances in the nucleus of an atom	Detected by photographic plates and radiation detectors e.g. The G.M tube.

Application of Electromagnetic Waves

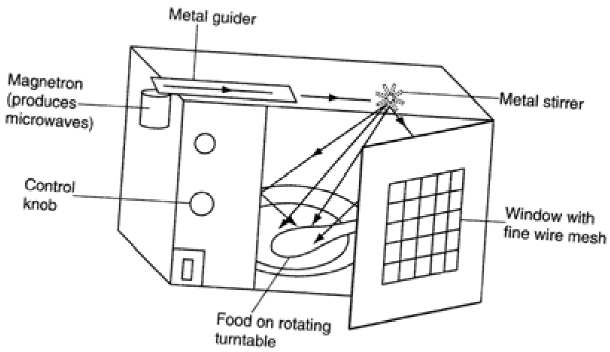
Properties	**Type of radiation**	**Uses**
Highest frequency Highest energy content	**Gamma rays**	In medicine used to kill cancerous tissues Sterilize medical equipment and pests
High energy Content	x-rays	Crystallography, study fractures and detect forgeries in art and flaw in metals
Low energy content	**U.V radiations**	In medicine they supply vitamin D treatment of skin cancer mineral analysis and detecting forgeries
Easily reflected have average wavelengths	visible light	Seeing, photography, Fibre optics, lasers (light amplification by the stimulated emission of radiations)
Long wavelength high heating effect	Infrared and microwave	Used in cooking heating and drying
Long medium wavelength penetrates the atmosphere easily	TV waves	In communication with the aid of satellite,
Longest wavelength, shortest frequency, Easily diffracted	Radio waves	Widely used in radio communication.

Diffraction of TV Radio Waves

Large wavelengths and low frequency radio waves are easily diffracted. They are also easily detected by receivers in deep valleys and behind hills. Radio waves of longer wavelength, amplitude modulation (AM) are reflected easily by ionosphere. Shorter wavelength waves (frequency modulations (FM) are transmitted over short distances and received directly from the transmission.

Microwaves

In cooking microwaves produces magnetron at a frequency of about 2500 MHZ. These waves are directed to a rotating metal shiner which reflects them to different parts of the oven. In the oven food is placed in a turntable where it absorbs the waves evenly. The wave's heat cooks it. The wire mesh on the door reflect the microwave back inside. The device is switched off before opening the door. Microwaves of shorter wavelength are used in radar communication.



Micro waves which have shorter wave lengths are used for radar (Radio detection and Ranging) communication. This communication is useful in locating the exact position of aero planes and ships.

Radio Waves

They have varying range of wavelength which makes their application wide. Medium and short wavelength is used in radio transmission signals. Amplitude modulation (AM) radio transmission has a longer range because of reflection by the ionosphere. TV and frequency modulation (FM) radio waves are received all a shorter wavelength than normal radio broadcasts. Very high frequency (VHF) transmission (Used in TV and FM radios are transmitted over short distance and received direct from the transmission.

Green House Effect (Heat Trap)

Hazards of Some Electro-Magnetic Waves.

UV rays and gamma rays carry high energy which damages cells, skin burn of effect eyes when absorbed. There are delayed effect of radiation such as cancer, leukemia and hereditary effects in children.

Minimising the Hazards

(i) Reduce dosage by minimising exposure time.

(ii) Keep a safe distance from the radiations

(iii) Use shielding materials such as lead jackets.

Transparent glass allows visible light of short wavelength radiations emitted by the sun to pass through. On the other hand glass cannot transmit the long wavelength given out by cooler objects. Heat from the sun is therefore trapped inside the green house. This makes inside of the green house warmer than outside.	

Chapter Seven CATHODE RAYS AND CATHODE RAY OSCILLOSCOPE

By the end of this topic, the learner should be able to:

a) Describe the production of cathode rays
b) State the properties of cathode rays
c) Explain the functioning of a cathode Ray oscilloscope (C.R.O)and of a Television tube (T.V tube)
d) Explain the uses of a cathode Ray Oscilloscope
e) Solve problems involving Cathode Ray Oscilloscope

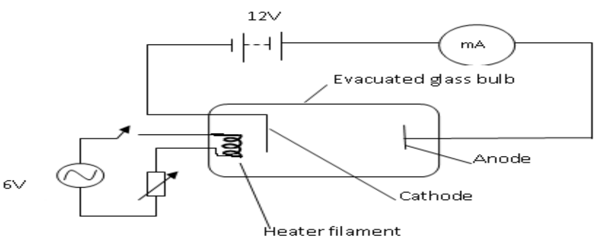
Content

- *Production of cathode rays, cathode ray tube.*
- *Properties of cathode rays.*
- *C.R.O and T.V tubes.*
- *Uses of C.R.O.*
- *Problems on C.R.O.*

Cathode Rays

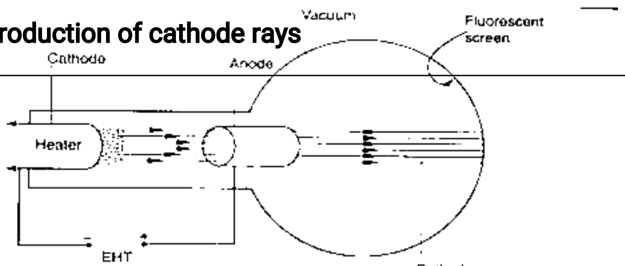
They are streams of high velocity electrons emitted from the surface of a metal when a cathode (negative electrode) is heated inside a vacuum tube by thermionic emission. Electrons are able to leave the metal surface because they gain enough kinetic energy to break loose from the force of attraction of the nuclei.

Thermionic emission is the process of emitting electrons from a metal surface due to heat energy. See the figure below:



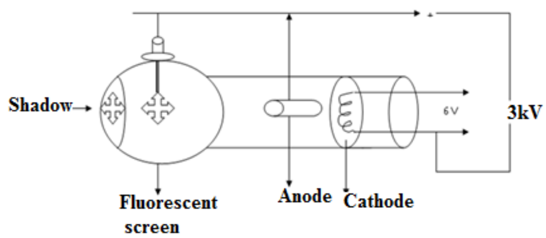
Before the heater current is switched on, no current is registered by the milliameter. When the switch is put on, the cathode is heated and emits electrons which complete the gap between the electrodes and a current is registered at the milliameter.

Production of cathode rays



Properties of Cathode Rays

(i) They travel in a straight line in absence of magnetic or electric fields. Hence form sharp shadows of objects put on their way.



ii) Cathode rays cause fluorescence in some substances e.g. zinc sulphide (phosphor).

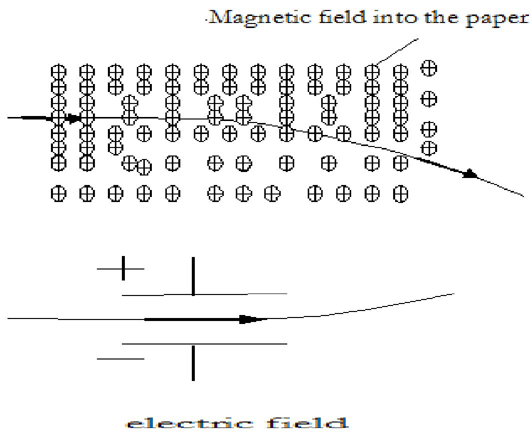
iii) They possess kinetic energy. The kinetic energy of the emitted electrons is converted into light energy by a process called fluorescence. This is the main reason why the screen is not heated.

iv) They are charged because they are deflected

In the above discharge tube electrons produced at the cathode by thermionic emission are accelerated towards fluorescent screen by an anode of an extra high tension (EHT) source. The tube is evacuated so that the emitted electrons do not collide with air molecules which would ionise them making them lose kinetic energy. Ionisation is a process where electrons are completely removed from atoms of an element. The cathode is coated with barium and strontium oxides to give a ready and continuous supply of electrons.

by both electric and magnetic fields (not waves).

v) The path of cathode rays in a magnetic field is **circular** so that the force acting on them is perpendicular to both the magnetic field and the direction of current.



vi) cathode rays have momentum and energy given by MeV and $\frac{1}{2}MeV^2$ respectively

kinetic energy of the electron
= work done by the electric field on the electron

$$\frac{1}{2}m_e v^2 = eV$$

vii) cathode rays produce x rays when they strike a metal target

viii) Cathode rays slightly ionise gases.

ix) Affect photographic papers.

Cathode Ray Oscilloscope (C.R.O.)

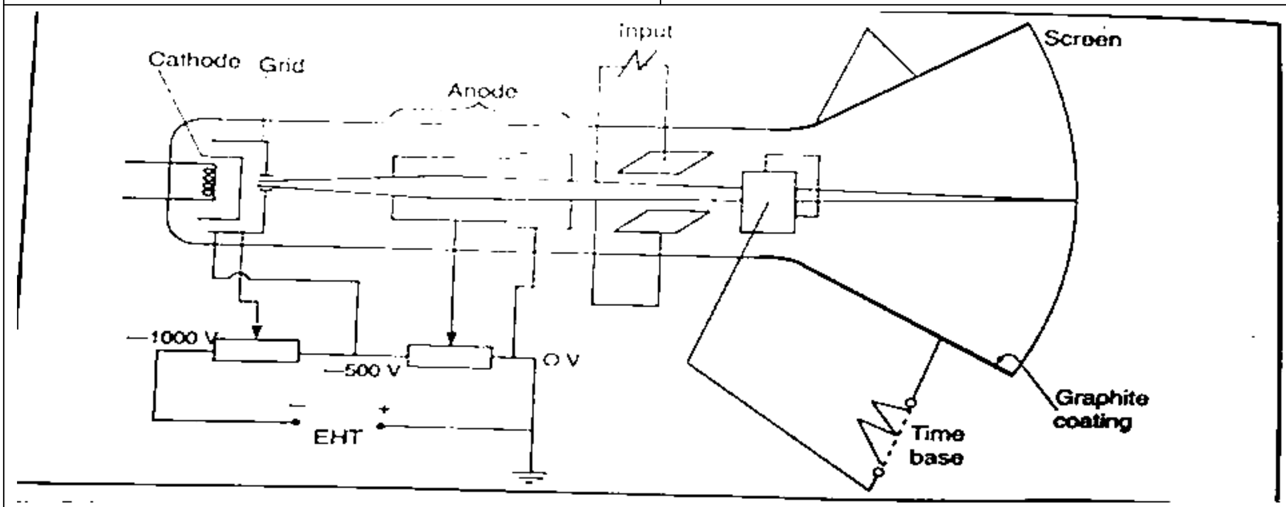
It is an electrical instrument used to display and analyse wave forms as well as to measure electrical potentials i.e. voltages that vary with time.

It consists of the following parts;

(a) Electron gun.

(b) Deflecting system.

(c) Display system



Electron Gun

- If the grid is made more negative with respect to

(a) It produces an electron beam which is highly a concentrated stream of high speed electrons.

(b) It has the following components;

-Cathode

-Cylindrical grid

-Two anodes

Function of Cathode

To emit electrons by thermionic emission (when heated). It is coated with oxides of thorium and strontium (the two are preferred because they have low work functions hence can emit electrons easily)

Function of Cylindrical Grid.

- Controls the rate of flow of electron hence the brightness of the spot on the screen.
- The negative voltage on grid can be varied to control the number of electrons reaching the anode.

the cathode, the number of electrons per second passing through the grid decreases and the spot becomes darker. The effect is reversed if the grid is made more positive in potential with respect to the cathode.

Anodes

The two anodes have positive potentials relative to cathode. Anode 1 is at a higher potential than anode 2. The difference in potential between the two anodes creates an electric field. The electric field converges the diverging beam from anode 2.

Functions

(a) Attract electrons from cathode.

(b) They accelerate the electrons by providing enough energy to cause emission of light as they hit the screen.

(c) They focus electron beam by converging electrons to a sharp point on the screen.

Deflecting System

Function of the deflection system

To determine position of electron beam on the screen

Types of deflections

(i) Vertical deflection (by Y-plate)

(ii) Horizontal deflection (by X-plate)

Vertical deflection(Y-plates)

- It deflects electron beam vertically across the screen in the following ways when the time base(X-plates) is switched off;
- When d.c potential across the two plates is zero a spot is produced on the screen i.e. no deflection.
- When d.c. voltage is applied across the y-plate with top plate positive the electrons are deflected upwards and a spot therefore appears on the upper part of the screen.
- When lower plate is positive a spot appears on the lower part of the screen.
- If a.c voltage is applied cross y plate the spot oscillate up and down depending on frequency such

Display System (screen).

Inside of the screen is coated with phosphor (zinc sulphide) which fluoresces or glows when electrons strike it hence producing a bright spot on the screen.

The inside of the tube is coated with graphite which has the following functions;

- Earthing – conduction of electrons to the earth.
- It is used to shield the beam from external electric field.
- It accelerates electrons towards the screen since it is in the same potential as the anode.

Uses of CRO

- It is used as a voltmeter.
- Time base of switched off, the x-plates earthed and the voltage to be measured connected across the y-plates. The voltage is calculated using the formula:

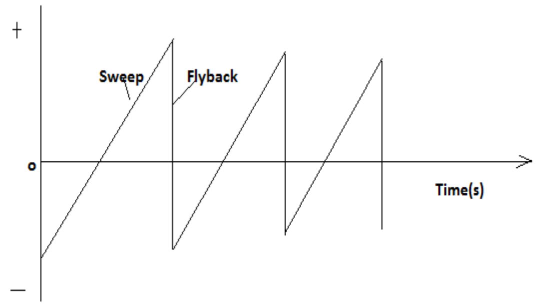
$$\text{Voltage} = \text{displacement} \times \text{sensitivity(volts per division)}$$

Advantages of CRO over voltmeter

that what is seen on the screen is a vertical straight line if the frequency is very high.

Horizontal deflection (x -plates)

X-plates are internally connected to the time-base circuit, which applies a saw-tooth voltage to the x-plates. The voltage increases uniformly to a peak (sweep) and drops suddenly (fly back). The speed with which the electron beam is "sweep" can be adjusted with the help of the time base knob.



When a d.c voltage is applied to the input(Y-plates) of the cathode ray oscilloscope and the time base on, then the horizontal line is seen to move toward the positive plate.

When an a.c voltage is applied to the input of a CRO and time base on, then due to interaction of the saw-tooth voltage at the x-plates and a.c voltage at the y-plates, a 'sine-curve' is seen on the screen.

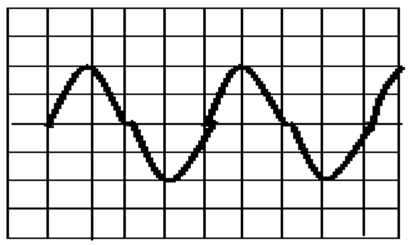
The purpose of time-base is to move electrons across the screen at a particular speed enabling the study of variation between voltages with time.

- Can measure large voltages without being destroyed.
- It responds instantaneously unlike ordinary meter whose pointer is affected by inertia.
- Can measure both a.c and d.c voltages.
- It has extremely high resistance and does not therefore alter current or voltage in the circuit to which it is connected.
- Measuring the frequency of a wave(a.c signal)

The signal is fed into the y-plates of a C.R.O. with the time base on. The time base control is then adjusted to give one or more cycles of the input signal on the screen. The time T of the signal is then determined by relating the trace of the signal on the screen with the time base setting. The frequency can be calculated as $f = \frac{1}{T}$

Examples

1. The figure below shows a display of an a.c signal on the CRO screen. Determine the frequency, given that the time base setting is 200ms/div.



2. On the grid provided below, show the display on the CRO screen of an a.c signal, peak voltage 300v and frequency 50Hz when time base is on (Take-gain at 100 V/div, time base setting at 10ms/div).

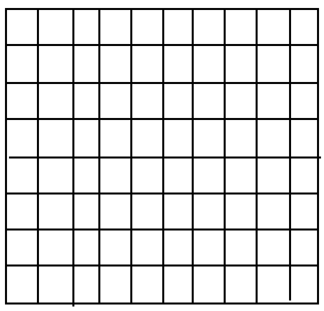
$$\text{maximun vertical divisions} = \frac{300}{100}$$

$$= 3$$

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

$$T = \frac{1}{50}$$

$$T = 0.02 \text{ seconds}$$

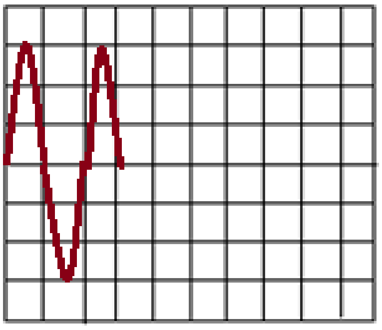


4. The control knobs of CRO have been adjusted to get a bright electron 'spot' on the screen. Explain how you get the following traces:

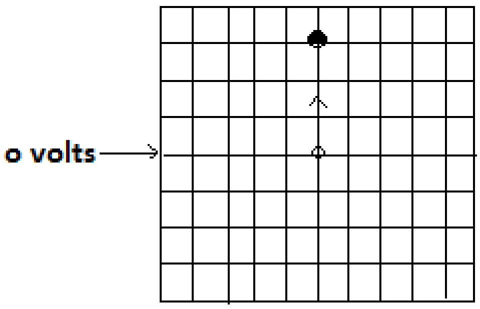
   (i) A horizontal line at the centre.

Number of horizontal divisions per complete cycle

$= \frac{0.02}{0.01} = 2$



3. A.d.c voltage of 50v when applied to the Y-plates of a CRO causes a deflection of the spot on the screen as shown.



(i) Determine the sensitivity of the Y-gain.

(ii) Show what will be observed on the screen if an a.c of peak voltage 40v is fed onto the Y-plates

(ii) A vertical line at the centre.

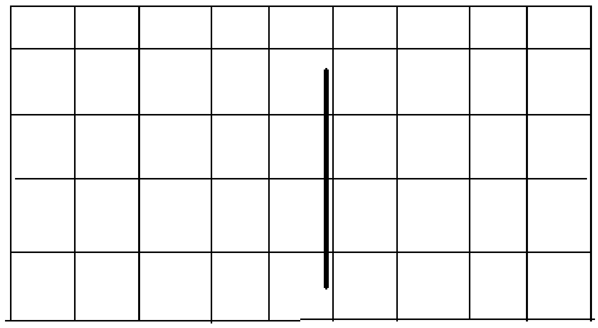
(iii) A sine curve

5. The time base on a CRO is set at 1ms/cm and Y-gain at 100v/cm.When an alternating voltage is applied to the input terminals, the beak value of the sine curve on the screen is 2.9cm.calcuate:

(i) The amplitude of the ac voltage.

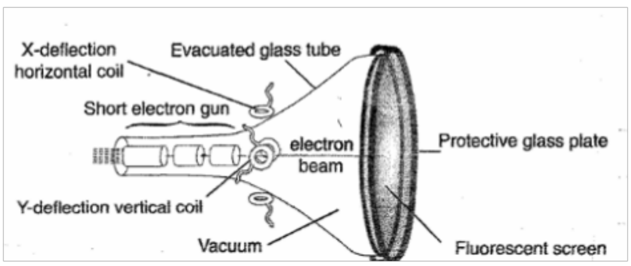
(ii) The frequency of the ac input signals, if two full waves are formed in a length of 5cm on the screen.

6. The figure below shows the deflection of a spot by alternating voltage signal



If the sensitivity is 30v/division .Find the voltage of the signal

TV Tube or Computer Monitor



- In TV tube **magnetic coils** (fields) are used instead **of electric field** because they provide

Question

1. The figure below shows the main parts of a television receiver tube with the electron guns deflection coils and the fluorescent screen labelled.

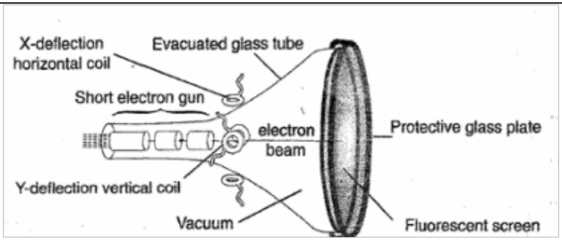
wider deflection to light the whole screen.

- The tube has two tiny plates which combine to light the entire screen instead of just a line.
- In a colour –TV 3 electron guns are used each producing one primary colour (red, blue and green) screen is coated with different chemicals to produce the colours.

Coils are mounted outside the neck of the tube so that they can be treated and adjusted while set is being assembled and tested.

Differences between TV screen and CRO

TV	CRO
Deflection is by magnetic field	Deflection is by electric field
It has two time base	It has one time base
Electrons lights the whole screen	Electrons produce a line or a dot
There are 625 lines per second	There are 25 lines per second



(i) Name the parts of the electron gun

(ii) Why are magnetic fields in the coils preferred in the television set instead of electric fields?

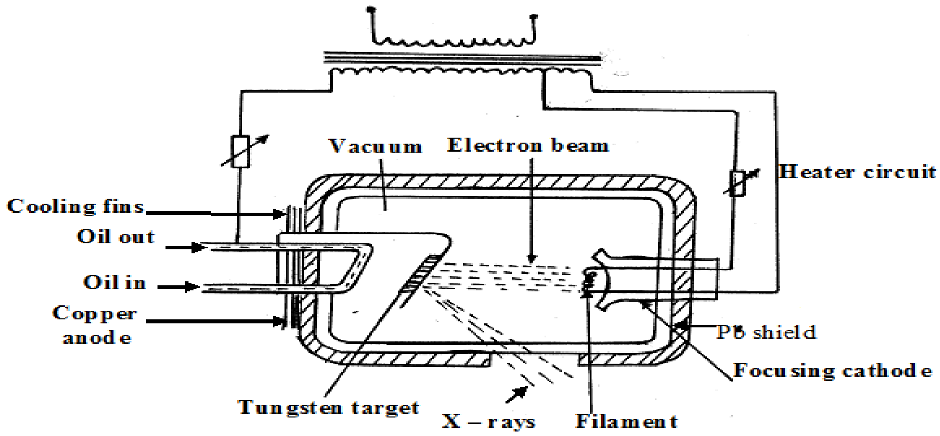
(iii) Name a suitable substance used to coat the screen.

Chapter Eight	X-RAYS
Specific Objectives *By the end of this topic, the learner should be able to:* *a) Explain the production of X-rays* *b) State the properties of X-rays* *c) State the dangers of X-rays* *d) Explain the uses of X-rays* *e) Solve numerical problems involving x-rays*	*Content* • *Production of X-rays X-ray tube* • *Energy changes in an X-ray tube* • *Properties of X-rays, soft X-rays and hard x-rays*

- *Dangers of X-rays and precautions*
- *Uses of x-rays*
- *Problems on x-rays*

✓ X-rays were discovered by W. Roentgen in 1895 when he was conducting a research of cathode rays. He called them x-rays because their nature was unknown at the time of discovery. X-rays are produced when fast moving electrons are suddenly stopped by matter.

Production Of X-Rays.



✓ When a Cathode is heated, it produces electrons by thermionic emission. Emitted electrons are accelerated to the anode (target) by high potential difference i.e. 100kv between cathode and anode.

✓ When first moving electrons are stopped by the anode (target) part of their kinetic energy is converted to x-rays.

✓ An x-ray tube is really a high voltage **diode** valve.

✓ Cathode is concave so as to focus electron beam to the tungsten target.

✓ The cathode is coated with oxides of low work function so that electrons are easily emitted from its surface when it is heated.

✓ The anode target has a high melting point to withstand a lot of heat generated e.g. tungsten or molybdenum

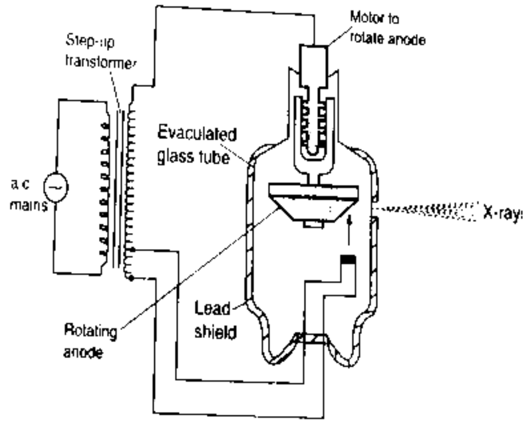
✓ Most of kinetic energy of electrons is converted to heat energy but about 0.5% is transferred to x-rays radiation.

✓ Anode is made of good conductor of heat i.e. copper for efficient (fast) dissipation of heat energy. However, oil circulation and fins enhances cooling process.

✓ Lead shielding has high density so as to

✓ Modern x-rays have a rotating target during operation to change the point of impact thereby reducing the wear and tear on it.

✓ The target is set at an angle (45^0) to direct x-rays out of the tube through a window on the lead shield. See the figure below:



prevent x-rays from penetrating into undesirable targets.	

Properties of X-Rays	***Applications of x-rays (uses)***
1. Travel in straight line at a speed of light in a vacuum. 2. X-rays are dangerous, they can cause cancer. 3. X-rays penetrate substances but are absorbed by dense solids e.g. bones or lead. 4. X-rays affect photographic films. 5. X-rays ionise gases, so that the gases become conductors. 6. X-rays can cause photoelectric emission. 7. X-rays cause fluorescence in certain substances. 8. X-rays are not deflected by a magnetic or electric fields. 9. X-rays can be diffracted and plane polarised so they are waves. 10. X-rays are electromagnetic waves of very short wavelengths and hence obey the wave equation $c = \lambda f$ and energy equation $E = hf$. ***Types of X-Rays*** ***Hard x-rays*** ✓ Have high frequency (short wavelength) hence high penetrating power. This is achieved by increasing the anode voltage, in order to give the cathode rays more kinetic energy. ✓ These x-rays penetrates the flesh but are absorbed by the bones. ***Soft x-rays*** ✓ The soft x-rays are produced by electrons moving at a lower velocity compared to those producing hard x-rays. This is achieved by lowering the accelerating voltage. ✓ These x-rays are used to show malignant growth in tissues because they only penetrate the soft tissues. ✓ Quality and type of x-rays produced is determined by the accelerating potential. ***Intensity (Quantity) of x-rays***	***(i) In medicine (Radiography and Radiotherapy).*** ✓ Due to the penetrating property of x-rays, fractured bones and dislocated joints can be seen from x-ray photograph called radiograph. Foreign objects like swallowed coins or pins can also be located. ✓ Hard X-rays can treat cancer, tumours and other skin diseases by destroying the infected cells. ***(ii) Science/ Crystallography*** ✓ Study of crystal structure which explains the arrangement of atoms in different materials. Incase there are fractures in the structure of the material, they can easily be revealed by the X-rays ***(iii) In industry*** ✓ Inspect cracks/flaws in metal casting. ✓ Sterilize surgical equipment before packaging. ***(iv) Security e.g. in Airports.*** ✓ To inspect luggage for any weapon hidden in them. ***Dangers of X–ray*** ✓ Because of their ionizing property, X-rays can cause serious damage to the body cells. Excess exposure of living tissue to X-ray can lead to damage or killing of the cells. ✓ The penetrating property can also cause genetic changes and even produce serious diseases like cancer if one is exposes to them for a long time. ***<u>Precautions when using x-ray machine</u>*** (i) X-ray machines have lead shield to protect the operator from stray X-rays. (ii) The rooms of operation have concrete walls to absorb any leaking radiations (X-rays).

- ✓ The Intensity of x-rays is controlled by amount of heating current.
- ✓ The greater the heating current, the greater the number of electrons produced hence **more x-rays**. To give a more intense beam of x-rays, the cathode is made hotter, to give more electrons leading to **more x-rays.**

NOTE: The strength of the X-rays depends on the accelerating potential difference between the anode and the cathode.

(iii) Reduce exposure time.

ENERGY OF X-RAYS

Energy of an electron can be calculated by the formula E = hf where h is Plank's constant and f frequency.

But from c = fλ; $f = \frac{c}{\lambda}$ thus $E = \frac{hc}{\lambda}$

But E = eV where e is the electron charge and V is the accelerating potential difference.

Thus $eV = \frac{hc}{\lambda}$

The energy of the electron is maximum when the wavelength is shortest.

Calculations

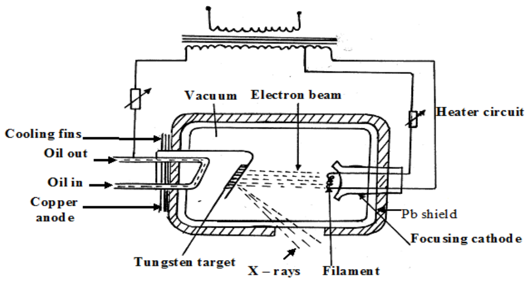
1. Calculate the wavelength of x-rays whose frequency is given by 2.0×10^{20}Hz.
2. Find the energy of x-rays whose wavelength is 10^{-10}m in a vacuum ($c = 3.0 \times 10^{8}$m/s, and $h = 6.63 \times 10^{-34}$Js).
3. An x-ray tube is operated with anode potential of 50kV and current of 15mA,calculate;
   - (i) The rate at which energy is converted at the target of the x-ray tube.
   - (ii) Kinetic energy of the emitted electrons before hitting the target.
   - (iii) The maximum velocity of the electrons.
   - (iv) The frequency of the x-rays produced if 0.5% of the energy is converted into x-rays.
   - (v) The number of electrons hitting the anode after one second.
4. An x-ray tube operates at a potential of 80kV. Only 0.5% of electron energy is converted to X-rays at the anode at a rate of 100J/s.

Determine;

(i) The tube current.

(ii) The average velocity of electrons hitting

4. The figure below shows the essential components of an X – ray tube



a) (i) Briefly explain electrons are produced by the cathode

b) (ii) How are the electrons produced accelerated towards the anode?

(iii) Why is the target made of tungsten?

(iv) How is cooling achieved in this kind of X – rays machine.

(v) Why would it be necessary for the target to rotate during operation of this machine?

(vi) Why is the tube evacuated?

(vii) Why is the machine surrounded by a lead shield?

(a) If the accelerating voltage is 100 kV calculate;

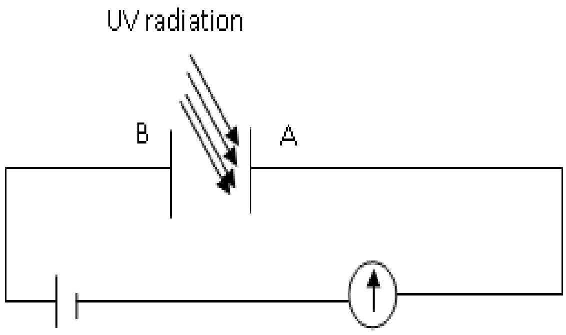
the target. (iii) The minimum wavelength of x-rays 5. An x-ray tube operating at 50kV has a tube current of 20mA. (Take $m_e = 9.1 \times 10^{-31}$kg,$e = 1.6 \times 10^{-19}$C,$c = 3.0 \times 10^8$) .How many electrons are hitting target per second. (i) If 0.5% of energy of electron is converted to x-rays, estimate the quantity of heat energy produced per second. (ii) Find x-ray power output. ***More*** 1. State one agricultural use of x-rays. 2. Name the property of x-rays that determines the type of x-rays produced. 3. An ex ray-tube is operated at 125kV potential and 10mA. If only 1% of the electrical power is converted to x-rays, at what rate id the target being heated? If the target has 0.3kg and is made of a material whose specific heat capacity is $150 Jkg^{-1}K^{-1}$,at what average rate would the temperature rise if there were no thermal loses?	(i) Kinetic energy of the electrons arriving at the target ($e = 1.6 \times 10^{-19}$ C). (ii) If 0.5 % of the electron energy is converted into X – rays determine the minimum wavelength of the emitted X- rays ($h = 6.63 \times 10^{-34}$ JS, and $C = 3.0 \times 10^{8}$ ms^{-1}) .

Chapter Nine	PHOTOELECTRIC EFFECT
Specific Objectives *By the end of this topic, the learner should be able to:* *a) Perform and describe simple experiments to illustrate the photoelectric effect* *b) Explain the factors affecting photoelectric emission* *c) Apply the equation E=hf to calculate the energy of photons* *d) Define threshold frequency, work function and the electron volt* *e) Explain photoelectric emission using Einstein equation* *f) ($hf + hf_0 + ½ mv^2$)* *g) Explain the applications of photoelectric effects* *h) Solve numerical problems involving photoelectric emission*	***Content*** ✓ *Photoelectric effects, photons, threshold frequently, work function, planks constant, and electrons-volt.* ✓ *Factors affecting photoelectric emission.* ✓ *Energy of photons.* ✓ *Einstein equation* $hf = hf_0 + \frac{1}{2} m_e v^2$ ✓ *Applications of photoelectric effects:* • *photo emissive,* • *Photo conductive* • *Photo voltage cells* ✓ *Problems on photoelectric emissions*

When an electromagnetic radiation of sufficient frequency is radiated on a metal surface electrons are emitted. These electrons are called **photoelectrons** and the phenomenon is called **photoelectric effect**. Photoelectric effect is therefore a phenomenon in which electrons are emitted from the surface of a solid when illuminated with electromagnetic radiation of sufficient frequency. A material that exhibits photoelectric effect is said to be **photo- emissive.**

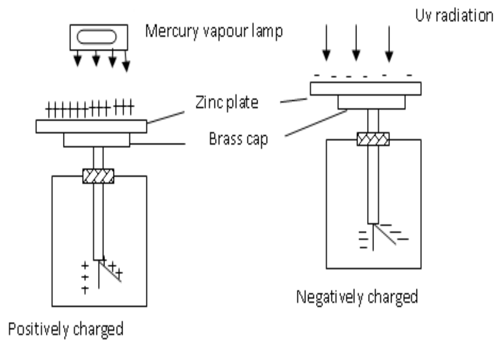
Photoelectric effect can be demonstrated by:

(a) **Using neutral plates**



When UV falls on plate A, the galvanometer deflects showing flow of current, when UV is blocked no deflection on the galvanometer i.e. no current flowing. When UV falls on the metal, some electrons acquire sufficient kinetic energy from the UV and are dislodged from the surface. The electrons are attracted to plate B. The electrons complete the gap between the plates allowing current to flow in the circuit hence deflection on the galvanometer.

(b) **Using charged electroscope**



When freshly cleaned zinc plate is irradiated with UV radiations, electrons are emitted from its surface. Photoelectrons emitted from the positively charged zinc plate do not escape due to attraction by positive charges on the zinc plate hence **divergence remains the same**. Photoelectrons emitted from the negatively charged zinc plate are repelled and the electroscope becomes discharged as a result of which the **leaf divergence decreases**. If a glass (which absorbs UV radiations) is placed between zinc plate (negatively charged) and the UV source no effect is seen on the leaf of the electroscope.

If the zinc is not freshly cleaned, the electrons might not be liberated from the zinc.

If the electroscope is uncharged, its leaf rises steadily showing that it is being charged. When tested it is found to be positively charged. This is because; electrons are removed from the zinc plate which in turn attracts electrons from the leaf of the electroscope leaving it with positive charges.

Definition of terms

1. Threshold frequency, f_0

Minimum frequency of a radiation for which can cause electron(s) to dislodge from a metal surface.

When visible light is incident on the freshly cleaned zinc plate, the leaf of a negatively charged electroscope does not decrease in divergence. This shows that visible light does not have enough energy to dislodge electrons from the surface of zinc plate. For any given surface there is a minimum frequency of radiation below which no photoelectric emission occurs. This frequency is called threshold frequency,f_0

$1eV = 1.6 \times 10^{-19}J$

Examples

1. Calculate the energy of a photon of frequency 5.0×10^{14}Hz in:

   (i) Joules

   (ii) Electron volts

2. The wavelength of orange light is 625nm.calculate the energy of a photon emitted by orange light in electron volts.

2. Work function, W_o -the minimum amount of energy needed to completely remove (dislodge) an electron from the surface of a metal. Work function varies from one metal to another. Unit for work function is electron-volt(eV) or joule(J) **Note: 1 eV = 1.6 x 10^{-19} J**

3. Threshold wavelength, λ_o – is the maximum wavelength beyond which no photoelectric emission will occur.

Light energy and the quantum theory.

In 1901, Max Planck, a scientist came up with the idea that light energy is propagated in small packets of energy. Each packet is called **quantum** (quanta-plural). In light this energy packet is called **photons.**

Energy possessed by a photon is proportional to the frequency of the radiation. $E = hf$

Where **f** is the frequency of radiation and **h** is Plank's constant = 6.63 x 10^{-34} Js

In general wave equation $c = f\lambda$ or $f = \frac{c}{\lambda}$

Therefore $E = h\frac{c}{\lambda}$

Since h and c are constants, a wave with larger wavelength has less energy.

1. **Electron-volts**-is the work done of energy gained by an electron when it moves through a potential difference of 1 volts.

$$\text{work done} = QV$$

Work done = eV For an electron

$$= 1.6 \times 10^{-19}C \times 1V$$

$$= 1.6 \times 10^{-19}J$$

Einstein's Equation of Photoelectric Effect.

- When a photo strikes an electron all its energy is absorbed by the electron and some energy is used to dislodge the electron while the rest become the kinetic energy of the electron. i.e.

Energy of photon = (Energy needed to dislodge an electron from the metal surface) + (maximum K.E gained by the electron)

- If the frequency (f) on any radiation is less than f_o, the energy will be less that W_o and therefore no emission will occur. If the frequency (f) is greater than f_o then $hf > W_o$ and excess energy is utilized as K.E of emitted electrons.

- Thus,$\mathbf{hf = w_0 + M_e v^2}$ where M_e is mass of electron and

V- Velocity of emitted electron. ***This is Einstein's photoelectric equation.***

$$hf = hf_0 + \frac{1}{2}M_e v^2$$

$$hf = \frac{hc}{\lambda_o} + \frac{1}{2}M_e v^2$$

Example:

1. The minimum frequency of light that will cause photoelectric emission from potassium surface is 5.37 x10^{14} Hz. When the surface is irradiated using a certain source photoelectrons are emitted with a speed of 7.9 x 10^5ms^{-1} calculate

(a) Work function of potassium.

(b) Maximum K.E of the photoelectrons.

(c) The frequency of the source of irradiation

solution

(a) $\mathbf{W_o = hf_o}$

$$= 6.63 \times 10^{-34}\text{ Js} \times 5.37 \times 10^{14}S^{-1}$$

$$= 3.56 \times 10^{-19}\text{ J}$$

(b) $\mathbf{K.E_{maximum} = \frac{1}{2}M_eV^2}$

$$= \frac{1}{2}\, 9.11 \times 10^{-31} \times (7.9 \times 10^5)^2$$

$$= 2.85 \times 10^{-19}J$$

(c) $\mathbf{hf = W_o + K.E_{maximum}}$

$$hf = 3.56 \times 10^{-19} + 2.84 \times 10^{-19}$$

$$hf = 6.4 \times 10^{-19}$$

Energy radiation/frequency of radiation used.

Frequency of the radiation and the energy of the photoelectrons can be examined using the following circuit

$$f = \frac{6.4 \times 10^{-19}}{6.63 \times 10^{-34}}$$

$$f = 9.65 \times 10^{14}\ Hz$$

2. Sodium has work function of $2.3 eV$. Calculate:
   (i) Its threshold frequency.
   (ii) The maximum velocity of the photoelectron produced when its surface is illuminated by light of wavelength $5.0 \times 10^{-7} m$ .determine the stopping potential of this energy.
3. When light of wavelength $1.0 \mu m$ **is irradiated** onto a metal, it ejects an electron with a velocity of $3.0 \times 10^{5} m/s$.calcualate the:
   (i) Work function of the metal.
   (ii) Threshold frequency of the metal
4. The minimum frequency of light which will cause photoelectric emission from a metal surface is $5.0 \times 10^{14} Hz$. if the surface is illuminated by light of frequency $6.5 \times 10^{14} Hz$, calculate:
   (i) The work function of the metal surface.
   (ii) The maximum K.E. (in e.v) of the electron emitted.
   (iii) The maximum speed of the electrons

Factors Affecting Photoelectric Effect

Note: Three factors determine the emissions of electrons on metal surfaces by incident radiation are:

(i) Intensity of the radiation.

(ii) Energy of the radiation

(iii) Type of metal.

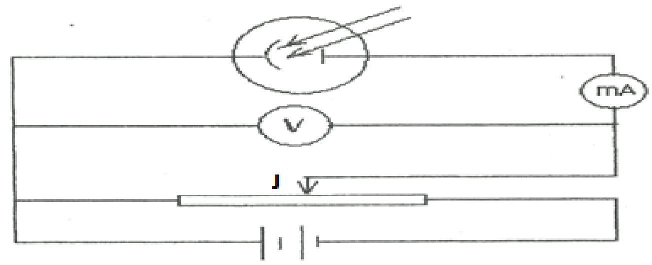
Intensity of radiation used.

This is the rate of energy flow per unit area when the radiation is perpendicular to the area. i.e.

$$\text{Intensity} = \frac{work\ (W)}{area\ (A) \times time\ (t)} \rightarrow I = \frac{W}{At}$$

but $\frac{W}{t}$ =P thus Intensity, $I = \frac{P}{A}$

When the intensity of the radiation is increased and the distance between the source and the and the frequency (wavelength) is varied using different colour filters placed in the path of the source of white light. For each colour, J is moved until no current is registered.



Note that, the battery is connected in such a way that it opposes the ejection of the photoelectrons by attracting them back to the cathode. The voltmeter records the stopping potential for a given frequency.

From Einstein's photoelectric equation,

$$hf = W_0 + \frac{1}{2} M_e v^2$$

$$\Rightarrow hf = W_0 + ev_s$$

If frequency is increase but work function held constant, then the stopping potential increases.

The table below shows some colours and their frequencies and stopping potentials.

Colour	Frequency f ($\times 10^{14}$ Hz)	(Stopping potential V_s)
Violet	7.5	1.2
Blue	6.7	0.88
Green	6.0	0.60
Yellow	5.2	0.28
Orange	4.8	0.12

For further learning, see the attached leaflet taken from KLB PG 158-59.

Type of metal/work function of the metal

Each metal has its own threshold frequency below which NO photoemission takes place, no matter how intense the radiation is. At constant incident energy, if the work function of the metal is high, then the kinetic energy of the emitted electrons is low.

surface is decreased, the number of photoelectrons emitted increases. Therefore, the number of photoelectrons produced is directly proportional to the intensity of the radiation.	

Examples

1. In an experiment to find the relationship between frequency of radiation and the kinetic energy of photo electrons in a photo electric device, the following results were obtained.

Frequency ($f \times 10^{14}\ H_3$)	7.4	6.8	6.1	5.3	4.7
Stopping potential (V_s)	1.7	1.6	1.26	0.8	0.74

On a graph paper **plot a graph** of stopping potential (V_s) against frequency (Hz)

From the graph **find;**

(i) The threshold frequency.

(ii) The planks constant (h)

(iii) The work function of the metal in Joules

2. (a) Define threshold wavelength

(b) The table below shows the sopping voltage, V_s, for a metal surface when illuminated with light of different wavelength, λ of constant intensity.

λ (x10^{-7}m)	3.00	3.33	3.75	4.29	5.00
V_s (V)	2.04	1.60	1.20	0.78	0.36

(i) Plot a suitable graph of K.E against frequency.

(ii) From the graph determine

(a) Planck's constant

(b) Threshold frequency

(c) Work function for the metal surface

3. **Interpret the following graphs;**

A graph of incident frequency against the kinetic energy of the photoelectrons

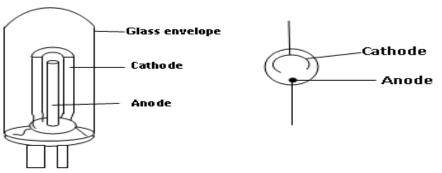
A graph of $\frac{1}{\text{wavelength}}$ kinetic energy of emitted electrons.

Application of Photoelectric Effect.

(a)Photo- emissive cell.

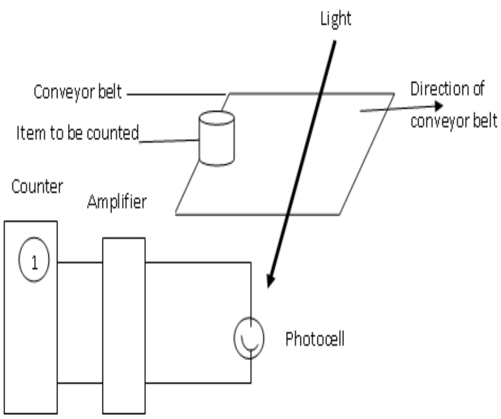
It has the cathode and the anode.

When light falls on the cathode, photoelectrons are emitted and attracted by the anode causing a current to flow in a given circuit



The cells are used in:

(i) Counting vehicles or items on a conveyor belt in factories



(ii) Burglar alarms

(iii) Opening doors.

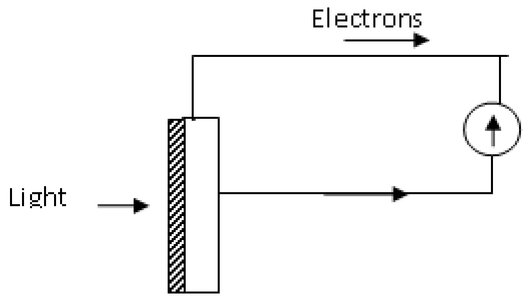
Photo emissive cell can also be used to reproduce sound from film.

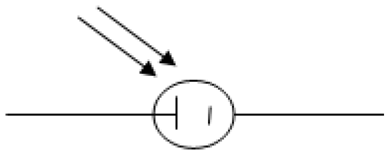
In exciter lamp focuses light through sound track along the side of moving film onto a photocell.

Light passing to the cell. The cell creates varying current in line with current obtained from the microphone when the film was made. Varying p.d across the resistor is amplified and converted to sound.

(b)Photovoltaic cell

It produces current as a result o photoelectric effect. It consists of a copper oxide and copper bar

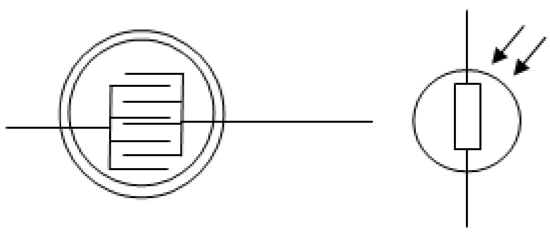




When light strikes the copper oxide surfaces, electrons are knocked off. Copper oxide becomes negatively charged and copper positively charged. This allows current to flow.

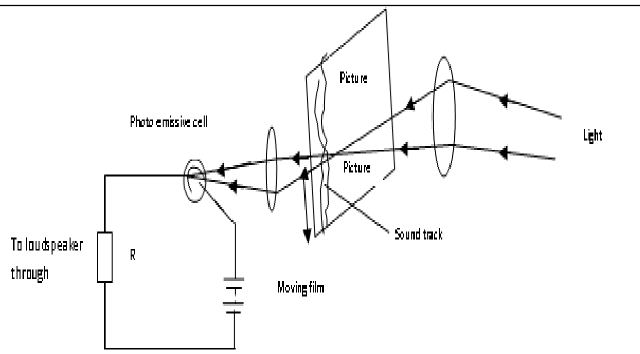
(c)Photoconductive cell or light- dependent resistor (LDR).

It is made of a semiconductor material called cadmium sulphide.



Light energy reduces the resistance of the cell from 10 MΩto1kΩ in bright light. Photon lets the electrons free increasing conduction. They are used in fire alarms and exposure meters of cameras.

Other photo electric devices are the solar cell and the photodiode.



Chapter Ten — RADIOACTIVITY

By the end of this topic the learner should be able to:

a) Define radioactive decay and half life
b) Describe the three types of radiations emitted in natural radioactivity
c) Explain the detection of radioactive emission
d) Define nuclear fission and fusion
e) Write balanced nuclear equation
f) Explain the dangers of radioactive emission
g) State the application of radioactivity
h) Solve numerical problems involving half life

Content

- ✓ *Radioactive decay*
- ✓ *Half-life.*
- ✓ *Types of radiations properties of radiations.*
- ✓ *Detectors of radiation.*
- ✓ *Nuclear fission, nuclear fusion.*
- ✓ *Nuclear equations.*
- ✓ *Hazards of radioactivity, precautions.*
- ✓ *Applications.*
- ✓ *Problems on half –life (integration not required)*

Radioactivity is the disintegration of an unstable nucleus with emission of radiation in order to attain stability.

Structure of the atom

- ✓ Consists of a tiny nucleus and energy levels(shells).The nucleus is very small in size, as compared to the overall size of the atom. The nucleus contains **protons** and **neutrons**. The number of **electrons** in the shells is equal to the number of **protons** in the nucleus making the atom **electrically neutral**.

The atomic number

- ✓ The number of protons in the nucleus of an atom.

Mass (nucleon) number

- ✓ The sum of protons and neutrons in the nucleus of an atom.

Isotopes

- ✓ Atoms of the same element that have the same atomic number but different mass numbers.

Radioactive decay

- ✓ Process by which a radioactive nuclide undergoes disintegration to emit a radiation. The emitted radiations can be alpha particles, beta particles and this is accompanied by release of energy in form of gamma radiations.

Types of Radioactive Decay

Alpha Decay –is represented by ${}^{4}_{2}\mathrm{He}$ ***and denoted by*** α

- ✓ If the nuclide decays by release of an alpha particle, the mass number decreases by 4 and the atomic number decreases by 2. This is expressed as;

$${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\mathrm{He}$$

(Parent Nuclide) (daughter nuclide) (alpha particle)

Uranium, for example, decays by emitting an alpha to become thorium. The decay is expressed as;

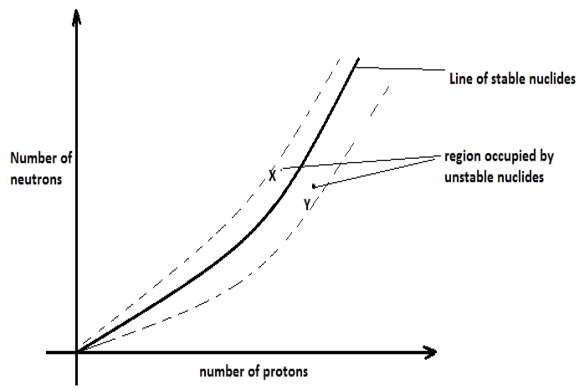
$${}^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$$

Nuclide

A group of atoms that have the same atomic numbers and the same mass numbers.

Nuclear Stability

- ✓ Stable nuclides have a proton to neutron ratio of about 1:1. However, as atoms get heavier, there is a marked deviation from this ratio, with the number of neutrons far superseding that of protons. In such circumstances, the nucleus is likely to be unstable. When this happens, the nucleus is likely to disintegrate in an attempt to achieve stability.



Similarly, polonium undergoes alpha decay to become lead.

$^{210}_{84}Po \rightarrow ^{206}_{82}Pb \quad + \quad ^{4}_{2}He$

Beta Decay-represented by $^{0}_{-1}e$ and denoted by β

- ✓ If the nuclide decays by release of a (β-particle, the mass number remains the same but the atomic number increases by 1. This is expressed as;

$^{A}_{Z}X \rightarrow {}_{Z+1}^{A}Y \quad + \quad ^{0}_{-1}e$

(Parent nuclide) (daughter nuclide) (beta particle)

- ✓ Radioactive sodium, for example undergoes beta decay to become magnesium. This is written as;

$^{24}_{11}Na \rightarrow ^{24}_{12}Mg \quad + \quad ^{0}_{-1}e$

Gamma Radiation-is denoted by γ

- ✓ Some nuclides might be in an excited state and to achieve stability, they may emit energy in form of gamma radiation, without producing new isotopes. For example:

(i) Cobalt-60;

$^{60}_{27}Co \rightarrow ^{60}_{27}Co \quad + \quad \gamma$

(ii) Thorium-230;

$^{230}_{90}Th \rightarrow ^{230}_{90}Th \quad + \quad \gamma$

Example 1

Thorium- 230 [$^{230}_{90}Th$] undergoes decay to become Radon-222 $^{222}_{86}Rn$ Find the number of alpha particles emitted.

Solution

Let the number of alpha particles emitted be x. The expression for the decay is;

$^{230}_{90}Th \rightarrow ^{222}_{86}Rn \quad + X\,(^{4}_{2}He)$

Thus;

4x + 222 = 230 2x + 86 = 90

Example 3

Uranium – 238($^{238}_{92}U$) undergoes decay to become lead-206 ($^{206}_{82}Pb$). Find the number of $\propto$ and β -particles emitted in the process.

Solution

Let the number of $\propto$ and β-particles emitted be x and y respectively.

$^{238}_{92}U \rightarrow ^{206}_{82}Pb \quad + \quad X\,(^{4}_{2}He) + y\,(^{0}_{-1}e)$

238 = 206 + 4x

4x = 32

x = 8

Also;

92 = 82 + 2x - y

92 = 82+ 1 6 -y

92 = 98 - y

y = 6

Eight $\propto$ -particles and six β-particles are emitted.

Example 4

4x = 8 *or* 2x = 4 x=2 x=2 Two alpha particles are emitted. ***Example 2*** Lead-214 ($^{214}_{82}Pb$) decays to polonium-214 ($^{214}_{84}Po$) by emitting **β** -particles. Calculate the number of **β** -particles emitted. ***Solution*** Let x be the number of **β**-particles emitted. $^{214}_{82}Pb \rightarrow ^{214}_{84}Po + x(^{0}_{-1}e)$ 82 = 8 4 - x x =2 Two **β**-particles are emitted.	Uranium 234 ($^{234}_{92}U$) decays to polonium ($^{218}_{84}Po$) by emitting alpha particles. Write down the nuclear equation representing the decay. ***Solution*** Let the number of alpha particles (helium) be x. $^{234}_{92}U \rightarrow ^{218}_{84}Po + x(^{4}_{2}He)$ 234 = 218 + 4x 16 = 4x x = 4 The decay equation is, therefore; $^{234}_{92}U \rightarrow ^{218}_{84}Po + 4(^{4}_{2}He)$

Properties of emitted radiations

Alpha particles

(i) Are positively charged hence deflected by electric and magnetic fields. (See diagram).

(ii) They have low penetrating power but high ionizing effect because they are heavy and slow.

(iii) They lose energy rapidly and so have very short range.

(iv) Can be stopped by a thin sheet of paper.

(v) They affect photographic plates

Beta particles

(i) Have no mass and are represented by ${}^{0}_{-1}e$.

(ii) Are negatively charged hence deflected by both electric and magnetic fields. (see diagram).

(iii) Have more penetrating power than alpha particles but lower ionizing effect.

(iv) Penetrate a sheet of paper but stopped by aluminium foil.

Gamma rays

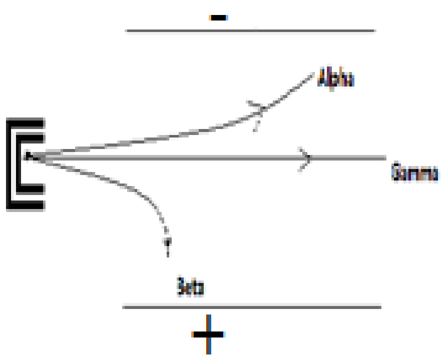
(i) High energetic electromagnetic radiation.

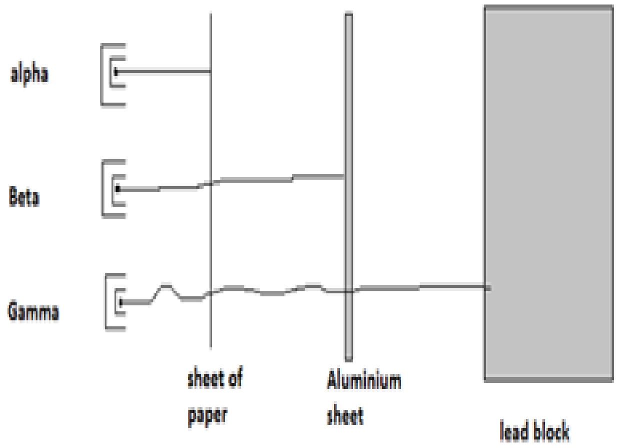
(ii) Have no mass and no charge hence cannot be deflected by electric and magnetic fields.

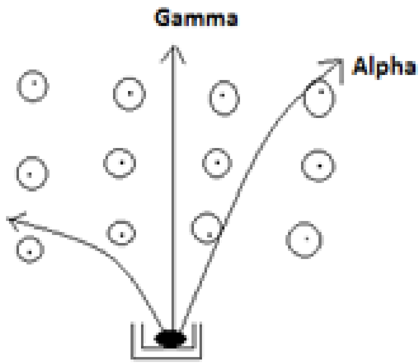
(iii) Have very high penetrating power and very low ionizing power.

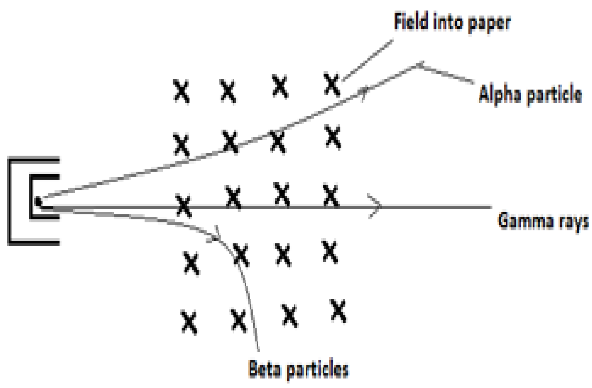
(iv) Can penetrate through a sheet of paper and aluminium sheets but stopped by a thick block of lead.

Summary









Note: The main difference between X-rays and gamma rays is that gamma rays originate from energy changes in the nucleus of atoms while X-rays originate from energy changes associated with electron structure of atoms.

Radiation Detectors

Methods Of Detecting Nuclear Radiations

The methods of detection rely on the ionizing property.

1. Photographic Emulsions

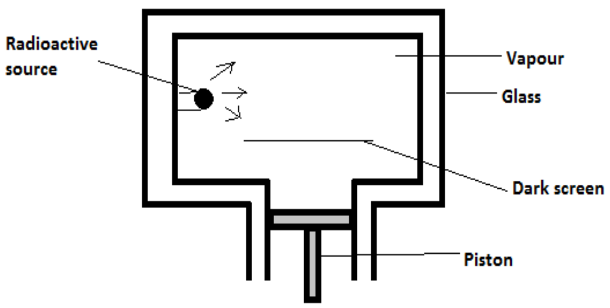
All the three radiations affect photographic emulsion or plate. Photographic films are very useful to workers who handle radioactive materials. These workers are given special badges which contain a small piece of unexposed photographic film. If, during the time it had been worn, the worker was exposed to radiations, it should darken on development, implying that further safety precautions should be taken.

2. Cloud Chamber

When air is cooled until the vapour it contains reaches saturation, it is possible to cool it further without condensation occurring. Under these conditions, the vapour is said to be supersaturated. This can only occur if the air is free of any dust, which normally acts as nuclei on which the vapour can condense to form droplets. Gaseous ions can also act as nuclei for condensation. The ionization of air molecules by radiations is investigated by a cloud chamber,

The common types of cloud chambers are **expansion cloud chamber** and **diffusion cloud chamber**. In both types, saturated vapour (water or alcohol) is made to condense on air ions caused by radiations. Whitish lines of tiny liquid drops show up as tracks when illuminated.

Expansion Cloud Chamber

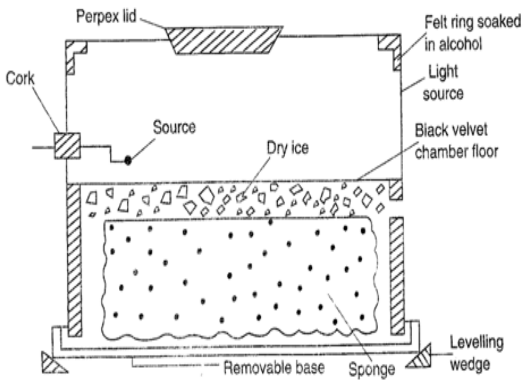


When a radioactive element emits radiations into the chamber, the air inside is ionized.

If the piston is now moved down suddenly, air in the chamber will expand and cooling occurs.

When this happens, the ions formed act as nuclei on which the saturated alcohol or water vapour

Diffusion Cloud Chamber



Functions of the components of diffusion chamber

Dry ice: cools the blackened surface making the air at the lower surface of the chamber cool.

Sponge: it ensures that the dry ice is in contact with the blackened surface

Wedges: it keeps the chamber in a horizontal position.

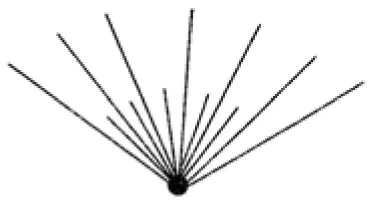
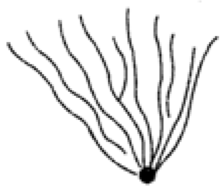
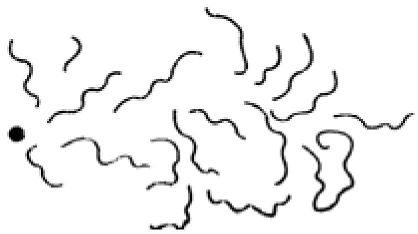
Light source: illuminates the tracks making them clearly visible.

Blackened surface: provides better visibility of the tracks formed.

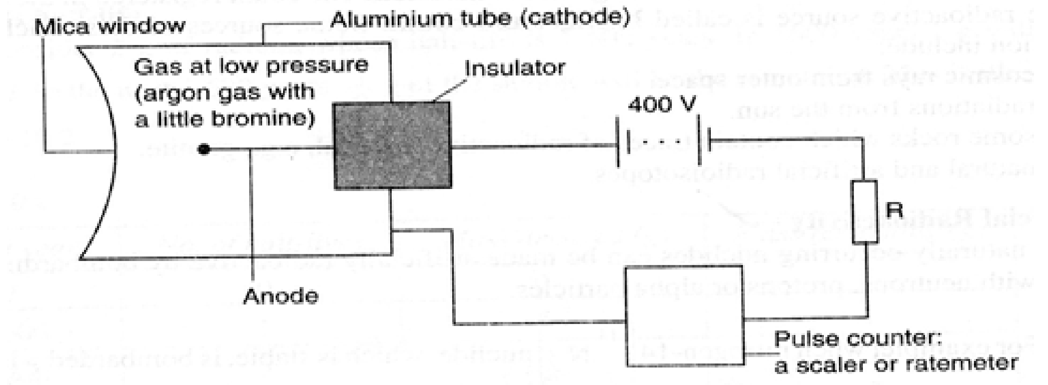
Principle of operation

The alcohol from the felt ring vaporizes and diffuses towards the black surface. The radioactive substance emits radiations which ionizes the air. The vaporized alcohol condenses on the ions forming tracks. The tracks are well defined if an electric field is created by frequently rubbing the Perspex lid of the chamber with a piece of cloth. The tracks obtained in the above cloud chambers vary according to the type of radiation. **Alcohol is preferred because it is highly volatile and hence evaporates easly.**

condenses, forming tracks. The shape and appearance of the track will which type of the particles have been emitted.	

The tracks due to alpha particles are short, straight and thick. This is because: (i) Alpha particles cause heavy ionization, rapidly losing energy, hence their short range. (ii) They are massive and their path cannot therefore be changed by air molecules. (iii) Alpha particles cause more ions on their paths as they knock off more electrons, see	
The tracks formed by beta particles are generally thin and irregular in direction. This is because beta particles, being lighter and faster, cause less ionization of air molecules. In addition, the particles are repelled by electrons of atoms within their path.	
Gamma rays produce scanty disjointed tracks,	

Geiger-Muller Tube The Geiger-Muller (G-M) tube is a type of ionization chamber.



The thin mica window allows passage of radiations these radiations ionizes the argon gas inside the tube. The electrons are attracted to the anode as the positive ions moves towards the cathode. More ions are produced as collisions continue. Small currents are produced which are amplified and passed to the scaler connected to the tube. The presence of small amount of halogen in the tube is to help absorbing the kinetic energy of the positive ions to reduce further ionisation and enhance quick return to normal. This is called quenching the tube i.e. **Bromine gas acts as a quenching agent.**

The gold leaf electroscope

A charged electroscope loses its charge in the presence of a radioactive source. The radioactive source ionizes the air around the electroscope. Ions on the opposite charge to that of the electroscope are attracted to the cap and eventually neutralize the charge of the electroscope. As a detector a charged electroscope is not suitable for detecting beta and gamma radiations because their ionizing effect in air is not sufficiently intense so the leaf may not fall noticeably.

Background Radiation

- ✓ Radiations that are registered or observed in the absence of a radioactive source.The count registered in the absence of the radioactive source is called **background count.**
- ✓ **sources of these backgrounds radiation include:**

(i) Cosmic rays from outer space.

(ii) Radiations from the sun.

(iii) Some rocks which contain traces of radioactive material, e.g., granite,

(iv) Natural and artificial radioisotopes.

In experiments, the average background count rate should be recorded before and after the experiment such that:

correct count rate = count rate - background radiations registered

Artificial Radioactivity

Some naturally occurring nuclides can be made artificially radioactive by bombarding them with neutrons, protons or alpha particles.

For example, when nitrogen--14(${}^{14}_{7}U$) nuclide, which is stable, is bombarded with fast moving alpha particles, radioactive oxygen is formed. This is represented by;

$${}^{4}_{2}He + {}^{14}_{7}U \rightarrow {}^{17}_{8}O + {}^{1}_{1}H$$

Other artificially radioactive nuclides are silicon-27 (${}^{27}_{14}Si$), sulphur-35 (${}^{35}_{16}S$) and chlorine-36(${}^{36}_{17}Cl$)

Decay Law

States that the rate of disintegration at a given time is directly proportional to the number of nuclides present at

Half-life

- ✓ The time taken for half the numbers of nuclides initially present in a radioactive sample to decay.
- ✓ Half-life of a radioactive substance can be determined using the following methods:

Decay series

Decay formula

$$N = N_0\left(\frac{1}{2}\right)^{\frac{T}{t}}$$

where,

N = original count rate

that time. This can be expressed as;

$\frac{dN}{dt} \propto -N$, where N is the number of nuclides present at a given time. It follows that;

$\frac{dN}{dt} = -\lambda N$, where λ is a constant known as the decay constant.

The negative sign shows that the number N decreases as time increases.

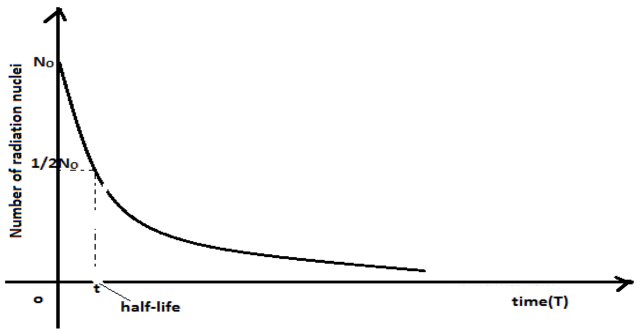
$\frac{dN}{dt}$ is referred to as the activity of the sample.

N_o = Remaining count rate

T = total time of decay

t = half - life

From a graph



Applications of Radioactivity

(i) Carbon Dating

Living organisms take in small quantities of radioactive carbon-14, in addition to the ordinary Carbon-12. The ratio of carbon-12 to carbon-14 in the organisms remains fairly constant. The count-rate can give this value.

When the organisms die, there is no more intakes of carbon and therefore the ratio changes due to the decay of carbon-14. The count-rate of carbon-14 therefore declines with time. The new ratio of carbon-12 to carbon-14 is then used to determine the age for the fossil.

(ii) Medicine

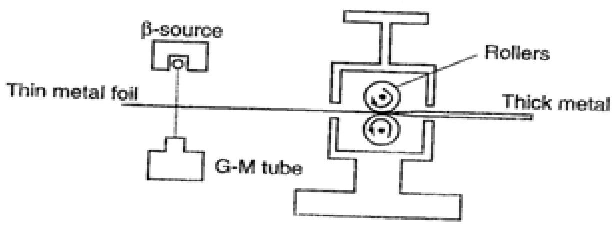
Gamma rays, like X-rays, are used in the control of

(iii) Detecting Pipe Bursts

Underground pipes carrying water or oil many suffer bursts or leakages. If the water or oil is mixed with radioactive substances from the source, the mixture will seep out where there is an opening. If a detector is passed on the ground near the area, the radiations will be detected.

(iv) Determining Thickness of Metal Foil

In industries which manufacture thin metal foils, paper and plastics, radioactive radiations can be used to determine and maintain the required thickness. If a beta source, for example, is placed on one side of the foil and G -M tube on the other, the count rate will be a measure of the thickness of the metal foil.



A thickness gauge can be adapted for automatic control of the manufacturing process.

(v) Trace Elements

The movement of traces of a weak radioisotope introduced into an organism can be monitored using a radiation detector. In agriculture, this method is applied to study the plant uptake of fertilizers and other chemicals.

(vi) Detection of Flaws

Cracks and airspaces in welded joints can be cancerous body growths. The radiation kills cancer cells when the tumour is subjected to it. Gamma rays are also used in the sterilization of medical equipment, and for killing pests or making them sterile.

detected using gamma radiation from cobalt-60. The cobalt-60 is placed on one side of the joint and a photographic film on the other. The film, when developed, will show any weakness in the joint.

Hazards of Radiation

When the human body is exposed to radiation, the effect of the radiation depends on its nature, the dose received and the part irradiated. Gamma rays present the main radiation hazard. This is because they penetrate deeply into the body, causing damage to body cells and tissues. This may lead to skin burns and blisters, sores and delayed effects such as cancer, leukaemia and hereditary defects. Extremely heavy doses of radiation may lead to death.

Precautions

(i) Radioactive elements should never be held with bare hands.

(ii) Forceps or well protected tongs should be used when handling them.

(iii) For the safety of the users, radioactive materials should be kept in thick lead boxes.

(iv) In hospitals and research laboratories, radiation absorbers are used.

Nuclear Fusion

Experiments show that a lot of energy is released when the nuclei of light elements fuse together to form a heavier nucleus. The fusing together of nuclei to form a heavier nucleus is called **nuclear fusion.** An example of nuclear fusion is the formation of alpha particles when lithium fuses with hydrogen;

Nuclear Fission

It was discovered that if a nucleus of uranium is bombarded with a neutron, the uranium nucleus splits into two almost equal nuclei. When a nucleus is bombarded and it splits, it is said to have undergone nuclear fission as shown below.

$$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow ^{138}_{56}\mathrm{Ba} + ^{95}_{36}\mathrm{Kr} + 3\left(^{1}_{0}\mathrm{n}\right) + \text{energy}$$

Protons and neutrons (nucleons) are kept together in the small volume of the nucleus by what called binding energy. To split the nucleus, this binding energy has to be released. The energy released during the splitting is called **nuclear energy.**

The emitted neutrons may encounter other uranium nuclides, resulting in more splitting with further release of energy. The produced neutrons are called **fission neutrons.**

Chapter Eleven ELECTRONICS

By the end of this topic, the learner should be able

a) *State the difference between conductor and insulators*
b) *Define intrinsic and extrinsic conductors*
c) *Explain doping in semi- conductor*
d) *Explain the working of a pin junction diode*
e) *Sketch current voltage characteristics for a diode*
f) *Explain the application of diode rectification*

Content

- ✓ *Conductors, semiconductors insulators*
- ✓ *Intrinsic and extrinsic semi-conductor*
- ✓ *Doping*
- ✓ *P-n junction diode*
- ✓ *Application of diodes: half wave rectification and full wave rectification*

Introduction

Definition – study of motion of free electrons in electrical circuits.

Applications – pocket calculators, clocks, musical instruments, radios, TVs, computers, robots etc.

Classes of Material

- ✓ Conductors – has free electrons – not tightly bound to the nucleus of the atom copper, aluminium.
- ✓ Insulators-have immobile (fixed) electrons
- ✓ Semi-conductors – with conducting properties between conductors and insulators silicon, germanium.

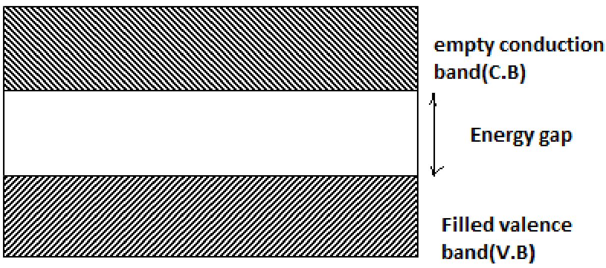
The Energy Band Theory.

- ✓ When two or more atoms are brought closer to each other, the energy levels split into smaller energy levels called bands. This is due to the interaction of both electric and magnetic fields of electrons

Types of bands

- ✓ Conduction band – free electrons.
- ✓ Valence band – unfilled, few electrons.
- ✓ Forbidden band/energy gap – no forbidden band, conduction and valence band overlap.
- ✓ Resistance increases with rise in temperature. A rise in temperature increases the vibrations of the atoms and this interferes with the electron flow. Hence the resistance of a conductor increases with temperature.

Insulators:-

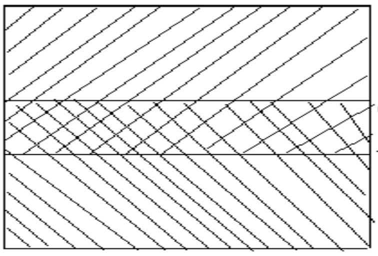


- ✓ Conduction band – has no electrons, empty.
- ✓ Valence band –filled with electrons.

- ✓ Conduction band – electrons are free to move under the influence of an electric current.
- ✓ Valence band – here electrons are not free to move.
- ✓ Forbidden band/energy band – represents the energy level that cannot be represented by electrons. The width of the band determines the conductivity of the material.

Conductors, insulators and semi-conductors in terms of energy band theory

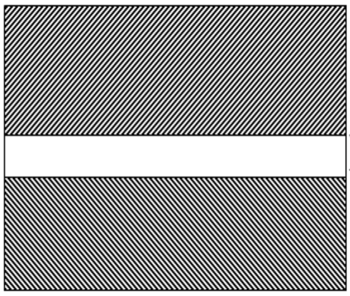
Conductors:-



✓

- ✓ Forbidden band – has very wide gap
- ✓ Temperature increase has no effect on their conductivity.

Semi – conductors:-



- ✓ Conduction band – empty at O.K. Partially filled at room temperature.
- ✓ Valence band –filled at O.K; full of electrons at very low temperatures
- ✓ Forbidden band – have very narrow gap.
- ✓ Resistance reduces with rise in temperature.

- ✓ Increase in temperature increases the chance of electrons moving from the valence band to conduction band. Electrical resistance therefore reduces because the total current flow is due to the flow of electrons and holes. **Have negative temperature coefficient of resistance.**

Note: semi – conductors

- ✓ **At room temperature**: - Has holes in the valence band & free electrons in the conduction band. **At OK** it behaves like an insulator.
- ✓ **HOLES**: Holes are created when an electron moves from valence band to conduction band.
- ✓ Holes are very important for conduction of electric current in semi-conductors.

Types of Semi-Conductors

Intrinsic semi-conductors

- They are pure semi-conductors, electrical properties of a pure substance.
- Has equal number of electrons and holes.
- Conductivity is very low, insulator at low temperatures.
- Usually not used in a pure state e.g. silicon,

Extrinsic Semi-Conductors

Made by adding a controlled amount of different element to an intrinsic semi-conductor.

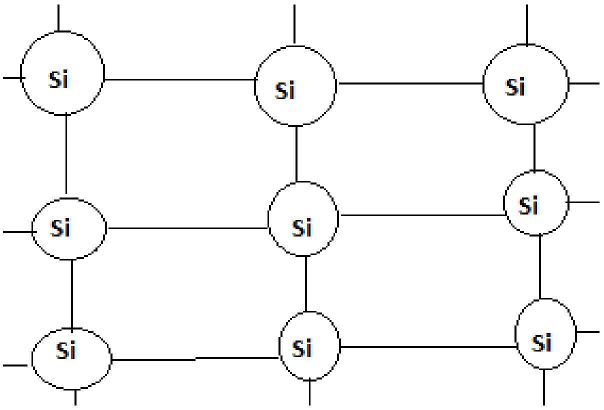
Two types of extrinsic semi-conductors:-

- N – Type semi-conductor – formed by doping a group 4 element with a Group 5 element.
- P – Type semi-conductor – formed by doping a group 4 element with a group 3 element.
- Group 4 elements – Tetravalent – Silicon, germanium, etc
- Group 5 elements – Pentavalent – doping element, donor impurity – phosphorous, antimony.
- Group 3 elements – Trivalent – boron, aluminium and indium

N-Type Semi –Conductor

- Formed by adding a Pentavalent atom (Phosphorus) to a group 4 semi-conductor (Silicon) and an extra electron is left unpaired and is available for conduction.
- Majority charge carriers are **electrons**; minority charge carriers are positive holes.
- Phosphorous is called a DONOR ATOM. Silicon

Germanium



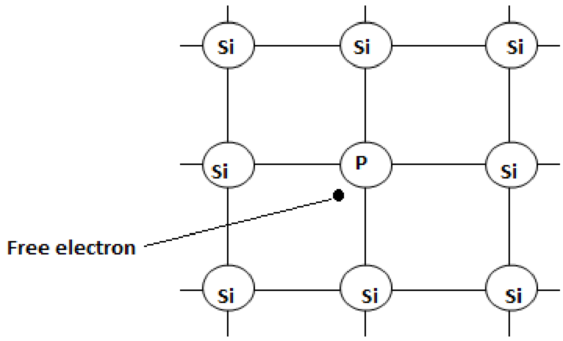
Extrinsic semi- conductors

- With added impurities to improve its electrical properties .
- All semi-conductors in practical use has added impurities

Doping: - A process of adding a very small quantity of impurities to a pure semi-conductor to obtain a desired property.

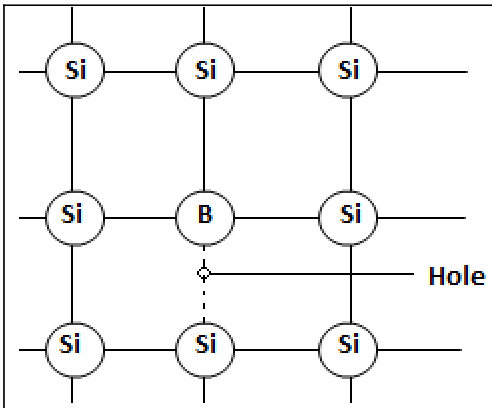
- Process of introducing an impurity atom into the lattice of a pure semi-conductor.

has now more electrons



P-Type Semi –Conductor

- Formed by adding a trivalent atom (Boron) to a group 4 atom (Silicon), a fourth electron will be unpaired and a gap will be left called a positive hole.
- Pure semi-conductor is doped with impurity of group 3 element; combination creates a positive hole which accepts an electron.
- The doping material creates a positive hole, which can accept an electron – called an Acceptor.



P-N Junction Diodes (Junction Diodes)

Definition

- An electronic device with two electrodes, which allows current to flow in one direction only.
- It is an electrical one way valve. It is a solid device.

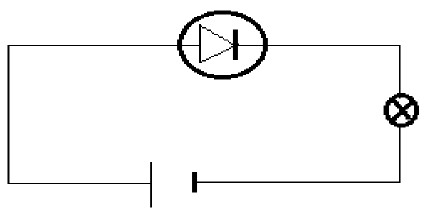
Formation of P-N Junction Diode

- It consists of such a p-n junction with the **p-side** connected to the **Anode** and the **n-side** to the **cathode**.
- Formed by doping a crystal of pure silicon so that a

Biasing

i) Forward Bias

- A diode is forward biased when the cathode is connected to n-side and anode to the p-side in a circuit.
- In forward bias, the depletion layer is narrowed and resistance is reduced.
- It allows holes to flow to n-side and electrons to p-side.
- The majority charge carriers cross the junction. It conducts current and the bulb lights

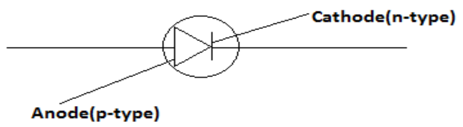


Reverse Bias

- A diode is reverse biased when the cathode is connected to p-side and anode to the n-side in a circuit.

junction is formed between the p-type and n-type regions.

Circuit symbol



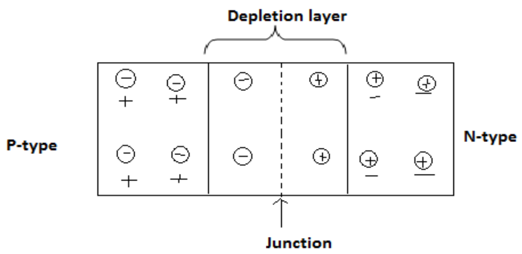
Depletion Layer

- The region between the p-type and n-type semi-conductor which conducts very poorly.
- At the junction electrons diffuse from both sides and neutralize each other.

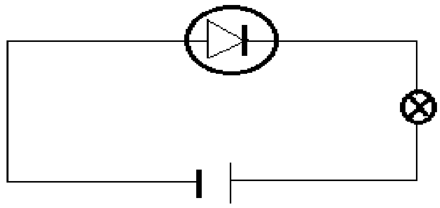
Junction

- The place (boundary) between two different types of semi-conductors.
- A narrow depletion layer if formed on either side of the junction free from charge carriers & high resistance.

Diagram of unbiased Junction Diode



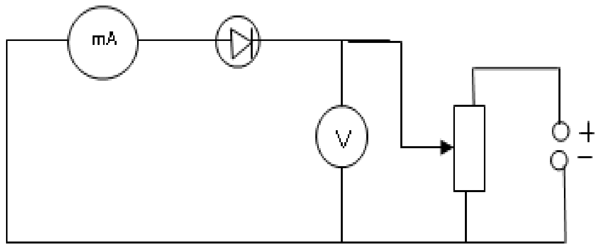
- The current through the diode is virtually zero. It hardly conducts, the bulb does not light. Electrons and holes are pulled away from the depletion layer, making it wider.
- The electrons and holes are attracted to opposite ends of the diode away from the junction. The wider the depletion layer, the higher the resistance of the junction.



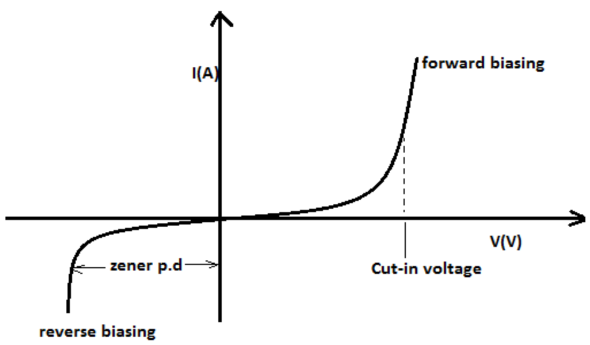
Characteristic Curves for P-N Junction Diodes

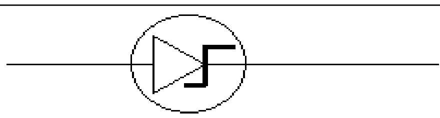
Forward biasing

The circuit below shows how the connections are made.



The characteristic graph of current, I against reverse bias voltage is obtained as shown below. The curve is non-ohmic.it is non-linear. The current increases exponentially with voltage up to a point where a sharp increase in current is noticed. This voltage is called threshold/cut-in/breakpoint voltage. At this voltage potential the barrier is overcome by bias and charges easily flow across the junction.





Symbol of Zener diode

Application of zener Diodes

- Used in industry as voltage regulators or stabilizers, by providing a constant voltage to a load.
- Voltage remains constant as current increases.

Application of P-N Junction Diodes

a) To protect equipment, circuits or devices by a reverse power supply.

b) To rectify ac to dc

c) Enable the Audio Frequency energy carrier by

Reverse Biasing

In reverse biasing, resistance is very high, however, the flow of leakage current results from flow of minority charge carriers. At breakdown voltage or Zener break down covalent bonds rapture liberating electrons. Those electrons collide with some atoms causing ionisation this is called avalanche breakdown. The two processes produce excess electrons for heavy conduction. Beyond breakdown voltage a diode is damaged.

The Zener Diode

Definition

- A zener Diode is a silicon p-n semi-conductor, which is designed to work in reverse biased connection.

Principle of operation

- When the reverse-bias of the diode is increased, a large sudden increase in current is obtained at one particular reverse voltage.
- At the reverse voltage, the p-n junction diode breaks down into a conductor, by breaking down the barrier layer.
- The breakdown of the p-n junction diode is known as zener breakdown or zener effect.
- The characteristic is almost a vertical line, i.e. the zener current, which occur as a result of the zener voltage.

modulated radio waves to be detected.

Rectification and Smoothing

A) Definition

- Rectification is the process of converting a.c current to d.c current.
- A Rectifier is a device that changes a.c to d.c.

b) Reasons for rectification

- The conversion of a.c. to d.c. is often necessary for all electric equipment, such as radios, T.V. sets, computers, musical instruments, e.t.c, use steady d.c.

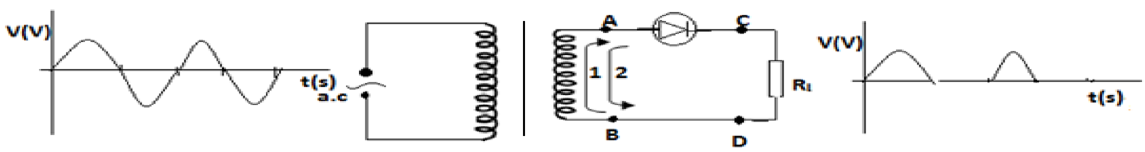
Types of rectification

There are two types of rectification, namely:-

- Half-wave rectification
- Full-wave rectification.

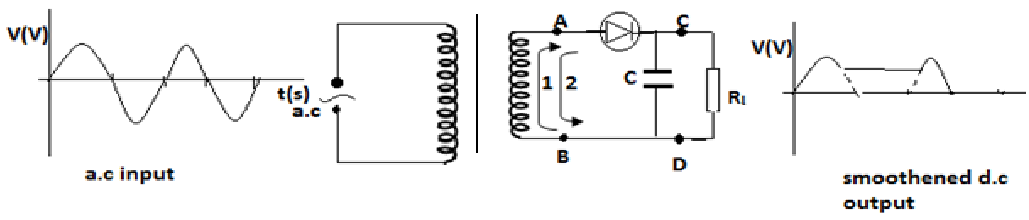
Half-wave rectification and smoothing

- One diode is used which removes the negative half-wave cycle of the applied a.c.
- It gives a varying but one-way direct current across the load R. R is a piece of electronic equipment requiring a d.c. supply.



- If the Y-input terminals of a CRO are connected first across the input, the waveform on the left will be displayed on the screen.

- When a CRO is connected across R, the output waveform is seen to be positive half-wave of the a.c.
- Smoothing is done using a capacitor connected across R, to give a much steadier varying d.c. supply.
- The smoothing capacitor provides extra charge so that current flows continuously even as the phase current changes and the current go to zero.



- The larger the capacitor, the better the smoothing.
- On the positive half-cycle of the a.c. input the diode conducts, current passes through R and also into the capacitor C to charge it up.
- On the negative half-cycle, the diode is reversing biased and cannot conduct, but C partly discharges through R.
- The charge-storing action of the capacitor, C thus maintains current in R and a steadier p.d across it when the diode is not conducting.

NOTE: - A single diode only allow half of the a.c. to flow through the load R, so far half of the power supply is cut off.

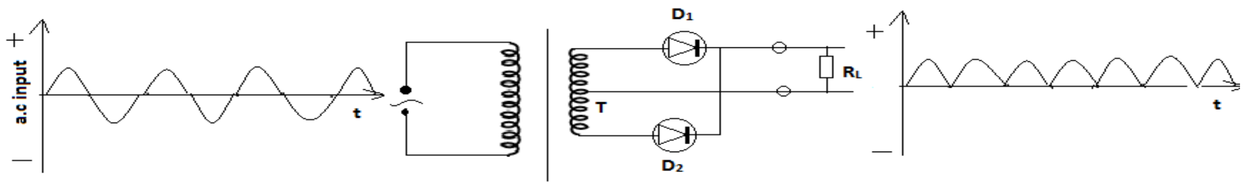
Full- wave Rectification and smoothing

There are two methods for obtaining a full-wave rectification namely:-

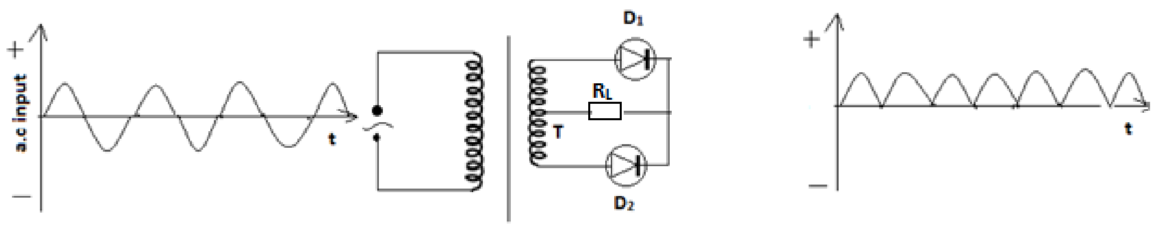
- Using two diodes – Full-wave centre-tap transformer.
- Using four diodes – Full-wave bridge rectifier

Using Centre-Tap Transformer

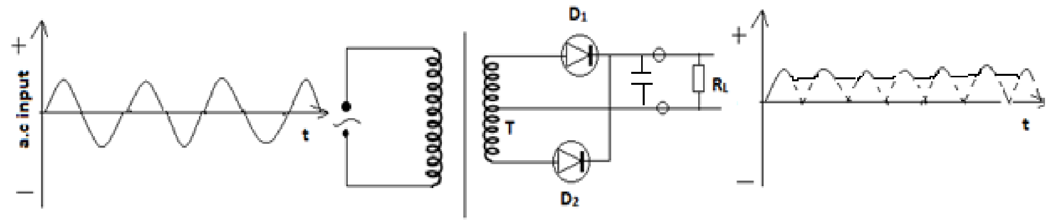
- In a full-wave rectifier, both halves of the a.c. cycles are transmitted but in the direction, i.e. same side.



OR

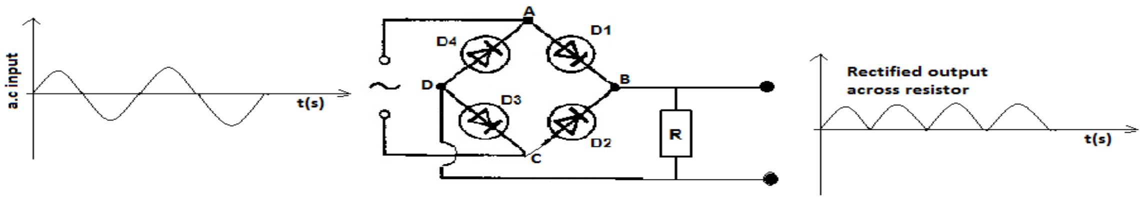


- During the first half-cycle, when A is positive, D_1 conducts through the load R at the same time B is negative with respect to T, so no current flows in the diode D_2.
- In the next half-cycle when B is positive, D_2 conducts through the load R in the same direction as before. A is positive with respect to T so no current flows in D_1.



Using the bridge Rectifier – four diodes

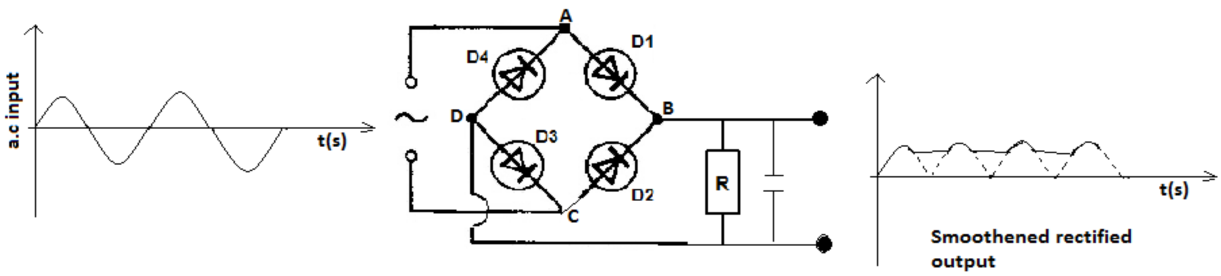
- In the 1st half-cycle, diode D_2 and D_4 conducts.
- In the 2nd half-cycle, diode D_3 and D_1 conducts.
- During both cycles, current passes through R in the same direction, giving a p.d. that varies as shown by the CRO.
- When a large capacitor is connected across R, the output d.c. is smoothed as shown.



- During the first half cycle, point A is positive with respect to C, diode D_1 and D_3 are forward biased while diode D_2 and D_4 are reverse biased. Current therefore flows through ABDCA. During the second half-cycle, point A becomes negative with respect to point C. diodes D_2 and D_4 become forward biased while D_1 and D_3 are reverse biased. Conventional current therefore flows through CBDAC.
- If a capacitor is connected across the resistor, the rectified output is smoothened.

Advantages of bridge rectifier

- ✓ A smaller transformer can be used because there is no need for centre –tapping.
- ✓ It is used for high voltage regulation.



QUESTIONS

1. Draw the structure of a crystal lattice to show the arrangement of electrons in following:
    - ✓ Pure silicon.
    - ✓ P-type semiconductors
    - ✓ N-type semiconductors
2. Explain how temperatures rise affects the electrical conductivity or pure semiconductors.

    (a)Draw the symbol of a p-n diagram junction diode.

    (b)Use a circuit diagram to distinguish between forward and reserve bias of p-n junction diode.
3. (a)Use a labelled diagram to explain how a full valve rectification may be achieved by using a resistor and :(i) Two diodes. (ii) Four diodes.
4. With the aid of a diagram explain how a capacity can be used to smoothen a full wave which has been rectified. Show using a sketch how the smoothened wave will appear on the screen of C.R.O.
5. What is meant by the following terms: semiconductor, intrinsic conduction, extrinsic conduction, doping, donor atoms, acceptor atoms, n-type semiconductor, p-type, semiconductor, depletion layer, forward bias, hole, reverse bias and Zener effect?
6. Explain how doping produces a p-type and an n-type semiconductor.
7. Distinguish between electronics and electricity.
8. a) What is rectification?

(b) With diagrams, describe how half-wave and full-wave rectification can be achieved.

9. **Explain** why a diode conducts easily on forward bias and not in reverse bias.

END OF SECONDARY SCHOOL SYLLABUS. WISH YOU ALL THE BEST.