THE ONLY SOURCE OF KNOWLEDGE IS EXPERIENCE.

ALBERT EINSTEIN
अभारोवि / ACKNOWLEDGEMENT

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Module of Physics for XII

Rationale of Module

Physics is a branch of science based upon the reasons & logic. One cannot learn Physics only by memorizing the contents and knowledge of the material but can learn by the practical involvement and application of content & knowledge.

The course of the Physics for Class XII is based upon various chapters and concepts out of which there are some areas & chapters that are considered to be difficult for the students as well as for the teachers.

In this module an attempt is made not only to identify the difficult & hard areas of the course but also an attempt is made to solve & explain those hard areas in a very simple and practical language, so that they become very simple, easy, meaningful and stimulating for the students as well as for the teachers.

In this module, not only the contents of the course are explained but also the special attention is given to the methodology of the content, objectives of the content, required material to teach the content, and procedure to achieve the objectives of the content. The self-assessment questions are also included at the end of each content methodology, which helps the students as well as the teachers for effective learning.

For the explanation of content very simple and daily useable examples are given and related numerical problems are solved for the guidance of students.

The good point of this module is that an increasing knowledge about all the contents has been added for the help of teachers.
**MODULE : 1**

**CONCEPT: CAPACITOR**

**LEARNING OBJECTIVES:** The objectives of the concept are to know about

1) Capacitance of a conductor
2) Capacitor
3) Parallel plate capacitor
4) Capacitance of parallel plate capacitor
5) Energy of parallel plate capacitor
6) Combination of capacitors- Series and parallel combination

**Material Required:-**

- PowerPoint presentation, Different types of capacitors

**Content:-**

Capacitance of a conductor is the charge holding ability. On supply of charge to a conductor, its electric potential increases. The charge given to a conductor is directly proportional to the electric potential.

\[ Q \propto V \]
\[ Q = CV \] where ‘C’ is capacitance

Capacitance of a conductor is the quantity of charge required to increase its potential by unity.

SI Unit of capacitance is farad (F)

- Microfarad (μF) \(1\mu F = 10^{-6} \) F
- Nanofarad (nF) \(1nF = 10^{-9} \) F
- Picofarad (pF) \(1pF = 10^{-12} \) F

**Capacitor -**

A Capacitor consists of two or more parallel conductive (metal) plates which are not connected or touching each other, but are electrically separated either by air or by some form of a good insulating material such as waxed paper, mica, ceramic, plastic or some form of a liquid gel as used in electrolytic capacitors. The insulating layer between capacitors plates is commonly called the Dielectric.
Due to this insulating layer, DC current cannot flow through the capacitor as it blocks it allowing instead a voltage to be present across the plates in the form of an electrical charge.

The conductive metal plates of a capacitor can be either square, circular or rectangular, or they can be of a cylindrical or spherical shape with the general shape, size and construction of a parallel plate capacitor depending on its application and voltage rating.

**Capacitance of a Parallel Plate Capacitor:**

The capacitance of a parallel plate capacitor is proportional to the area, $A$ in metres$^2$ of the smallest of the two plates and inversely proportional to the distance or separation, $d$ (i.e. the dielectric thickness) given in metres between these two conductive plates.

The generalised equation for the capacitance of a parallel plate capacitor is given as: $C = \varepsilon (A/d)$ where $\varepsilon$ represents the absolute permittivity of the dielectric material being used. The permittivity of a vacuum, $\varepsilon_0$ also known as the "permittivity of free space" has the value of the constant $8.84 \times 10^{-12}$ Farads per metre.

To make the maths a little easier, this dielectric constant of free space, $\varepsilon_0$, which can be written as $1/(4\pi \times 9 \times 10^9)$, may also have the units of picofarads (pF) per metre as the constant giving: $8.84$ for the value of free space. Note though that the resulting capacitance value will be in picofarads and not in farads.

Generally, the conductive plates of a capacitor are separated by some kind of insulating material or gel rather than a perfect vacuum. When calculating the capacitance of a capacitor, we can consider the permittivity of air, and especially of dry air, as being the same value as a vacuum as they are very close.
The Dielectric of a Capacitor:

The actual permittivity or “complex permittivity” of the dielectric material between the plates is then the product of the permittivity of free space ($\varepsilon_0$) and the relative permittivity ($\varepsilon_r$) of the material being used as the dielectric and is given as:

$$\text{Capacitance, } C = \frac{\varepsilon_0 \varepsilon_r A}{d} \text{ Farads}$$

Multi-plate Capacitor:

Now we have five plates connected to one lead (A) and four plates to the other lead (B). Then BOTH sides of the four plates connected to lead B are in contact with the dielectric, whereas only one side of each of the outer plates connected to ‘A’ is in contact with the dielectric. Then as above, the useful surface area of each set of plates is only eight and its capacitance is therefore given as:

$$C = \frac{\varepsilon_0 \varepsilon_r (n-1)A}{d} = \frac{\varepsilon_0 \varepsilon_r (9-1)A}{d} = \frac{\varepsilon_0 \varepsilon_r 8A}{d}$$

Energy Stored by Capacitors:

Let us consider charging an initially uncharged parallel plate capacitor by transferring a charge $Q$ from one plate to the other, leaving the former plate with charge -$Q$ and the latter with charge +Q. Suppose that the capacitor plates carry a charge ‘q’ and that the potential difference between the plates is $V$. The work we do in transferring an infinitesimal amount of charge ‘$dq$’ from the negative to the positive plate is simply

$$dW = V \ dq.$$
In order to evaluate the total work done ‘W’ in transferring the total charge ‘q’ from one plate to the other, we can divide this charge into many small increments ‘dq’, find the incremental work \(dW\) done in transferring this incremental charge, using the above formula, and then sum all of these works. The only complication is that the potential difference \(V\) between the plates is a function of the total transferred charge. In fact, so
\[
dW = \frac{dq}{C}.
\]
Integration yields
\[
W(Q) = \int_0^Q \frac{dq}{C} = \frac{Q^2}{2C}.
\]
Note, again, that the work \(W\) done in charging the capacitor is the same as the energy stored in the capacitor. Since \(C = Q/V\), we can write this stored energy in one of three equivalent forms:
\[
W = \frac{Q^2}{2C} = \frac{CV^2}{2} = \frac{QV}{2}.
\]
Where is the energy in a parallel plate capacitor actually stored? Well, if we think about it, the only place it could be stored is in the electric field generated between the plates. This insight allows us to calculate the energy (or, rather, the energy density) of an electric field.
Consider a vacuum-filled parallel plate capacitor whose plates are of cross sectional area \(A\), and are spaced a distance \(d\) apart. The electric field \(E\) between the plates is approximately uniform, and of magnitude \(\sigma/\varepsilon_0\),
\[
\sigma = \frac{Q}{A}, \quad \sigma = \frac{Q}{A},
\]
where \(Q\) is the charge stored on the plates. The electric field elsewhere is approximately zero. The potential difference between the plates is \(V = Ed\). Thus, the energy stored in the capacitor can be written
\[
W = \frac{CV^2}{2} = \frac{\varepsilon_0 A E^2 d^2}{2} = \frac{\varepsilon_0 E^2 Ad}{2},
\]
Now, \(Ad\) is the volume of the field-filled region between the plates, so if the energy is stored in the electric field then the energy per unit volume, or energy density, of the field must be
\[ w = \frac{\varepsilon_0 E^2}{2}. \]

It is easily demonstrated that the energy density in a dielectric medium is

\[ w = \frac{\varepsilon E^2}{2}, \]

**Combination of Capacitors:-**

**a) Capacitors in Parallel:-**

When capacitors are placed in parallel with one another the total capacitance is simply the **sum of all capacitances**. This is analogous to the way resistors add when in series.

\[
C_{Tot} = C_1 + C_2 + \ldots + C_{N-1} + C_N
\]

So, for example, if you had three capacitors of values 10µF, 1µF, and 0.1µF in parallel, the total capacitance would be 11.1µF (10+1+0.1).

**b) Capacitors in Series:-**

Much like resistors are a pain to add in parallel, capacitors get funky when placed in series. The total capacitance of \( N \) capacitors in series is the inverse of the sum of all inverse capacitances.

\[
\frac{1}{C_{Tot}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots + \frac{1}{C_{N-1}} + \frac{1}{C_N}
\]

If you only have two capacitors in series, you can use the “product-over-sum” method to calculate the total capacitance:

\[
C_{Tot} = \frac{C_1 C_2}{C_1 + C_2}
\]

Taking that equation even further, if you have two equal-valued capacitors in series, the total capacitance is half of their value. For example two 10F super capacitors in
series will produce a total capacitance of 5F (it’ll also have the benefit of doubling the voltage rating of the total capacitor, from 2.5V to 5V).

**Methodology:-**

1) **Use of videos and animations**
   
   [https://www.youtube.com/watch?v=pnBRFXgaTMo](https://www.youtube.com/watch?v=pnBRFXgaTMo)

2) **Use of PowerPoint presentation**

**Action of teacher in the class:-**

1) Teacher will ask questions on charge, electric potential and charge storing ability
2) Teacher will give concept of capacitance and capacitor with the help of animations
3) Teacher will show the videos
4) Teacher will prepare assessment sheets

**Assessment:-**

1) What is capacitance? Write its SI unit.
2) Derive an expression for capacitance of parallel plate capacitor.
3) Draw charge-potential graph for two capacitors C1 and C2, given that C1>C2.
4) Find the expression for energy stored in a parallel plate capacitor.
5) There are two capacitor of capacitances 40 µF and 20 µF. Find the equivalent capacitance of their (i) series combination and (ii) parallel combination.

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CONCEPT: KIRCHHOFF’S LAWS AND WHEATSTONE BRIDGE

Learning Objectives:- The objectives of the concept are to know about

1) Understand Kirchhoff’s laws and Wheatstone Bridge Principle.
2) Develop the skill among the students so that they can solve the numerical problems based on these concepts.
3) Apply these rules to give reasons of the higher order problems.
4) Explore the applications of Kirchhoff’s Laws and Wheatstone bridge principle in electric circuits.

Material Required:-

Chalk, duster, PowerPoint presentation, Galvanometer, Battery, connecting wires etc.

Content:-

Kirchhoff’s Laws:-

i) Kirchhoff’s Junction Rule
The algebraic sum of the currents at a junction in a closed circuit is zero.

\[ I_1 + I_4 = I_2 + I_3 + I_5 \]

Therefore, \( I_1 + I_4 = I_2 + I_3 + I_5 \)

Hence, \( I_1 + I_4 - I_2 - I_3 - I_5 = 0 \)

or \( SI = 0 \)

(Sum of currents entering a junction = Sum of currents leaving the junction)

This rule is based on the fact that charge cannot be accumulated at any point in a conductor in a steady situation.
ii) **Kirchhoff’s Loop Rule**

The algebraic sum of the potential differences in any loop including those associated with emfs and those of resistive elements must be equal to zero.

\[ \sum V = 0 \text{ (Valid for any closed loop)} \]

This rule is based on energy conservation, i.e., the net change in the energy of a charge after completing the closed path is zero. Otherwise, one can continuously gain energy by circulating charge in a particular direction.

**Steps to solve circuits by Kirchhoff’s laws:**

- Assume unknown currents in a given circuit and show their directions by arrows.
- Choose any closed loop and find the algebraic sum of voltage drops plus the algebraic sum of the emfs in that closed loop and equate it to zero.
- Write equations for as many closed loops as the number of unknown quantities. Solve the equations to find the unknown quantities.
- If the value of assumed current is negative, it means that the actual direction of the current is opposite to that of the assumed direction.

**Wheatstone Bridge:**

\( R_x \) is the unknown resistance to be measured; \( R_1, R_2 \) and \( R_3 \) are resistors of known resistance and the resistance of \( R_2 \) is adjustable. If the ratio of the two resistances in the known leg \( (R_2/R_1) \) is equal to the ratio of the two in the unknown leg \( (R_x/R_3) \), then the voltage between the two midpoints \( (B \text{ and } D) \) will be zero and no current will flow through the galvanometer \( V_g \). If the bridge is unbalanced, the direction of the current indicates whether \( R_2 \) is too high or too low. \( R_2 \) is varied until there is no current through the galvanometer, which then reads zero.

At the point of balance, the ratio of

\[
\frac{R_2}{R_1} = \frac{R_x}{R_3}
\]

\[ \Rightarrow R_x = \frac{R_2}{R_1} \cdot R_3 \]

Alternatively, if \( R_1, R_2, \) and \( R_3 \) are known, but \( R_2 \) is not adjustable, the voltage difference across or current flow through the meter can be used to calculate the value of \( R_x \), using Kirchhoff’s circuit laws (also known as Kirchhoff’s rules). This setup is frequently used in strain gauge and resistance thermometer measurements, as it is
usually faster to read a voltage level off a meter than to adjust a resistance to zero the voltage.

**Derivation**

Directions of currents arbitrarily assigned

First, Kirchhoff's first rule is used to find the currents in junctions B and D:

\[ I_3 - I_x + I_G = 0 \]
\[ I_1 - I_2 = I_G = 0 \]

Then, Kirchhoff's second rule is used for finding the voltage in the loops ABD and BCD:

\[ (I_3 \cdot R_3) - (I_G \cdot R_G) - (I_1 \cdot R_1) = 0 \]
\[ (I_x \cdot R_x) - (I_2 \cdot R_2) + (I_G \cdot R_G) = 0 \]

When the bridge is balanced, then \( I_G = 0 \), so the second set of equations can be rewritten as:

\[ I_3 \cdot R_3 = I_1 \cdot R_1 \]
\[ I_x \cdot R_x = I_2 \cdot R_2 \]

Then, the equations are divided and rearranged, giving:

\[ R_x = \frac{R_2 \cdot I_2 \cdot I_3 \cdot R_3}{R_1 \cdot I_1 \cdot I_x} \]

From the first rule, \( I_3 = I_x \) and \( I_1 = I_2 \). The desired value of \( R_x \) is now known to be given as:

\[ R_x = \frac{R_3 \cdot R_2}{R_1} \]
Methodology:-

1) Use of meter bridge to explain the Wheatstone bridge
   https://www.youtube.com/watch?v=nQNxN9EzV7s
   https://www.youtube.com/watch?v=qebl2kNsDzo

2) Use of PowerPoint presentation on Kirchhoff’s laws and Wheatstone bridge

Action of teacher in the class:-

1) Teacher will ask questions on Ohm’s law and combination of resistances.
2) Demonstration of meter bridge to explain Wheatstone bridge
3) Teacher has to explain the concept with PowerPoint presentation.
4) Teachers will summaries the concept and prepare the assessment test.
5) Assessment of class test

SUMMARY:-
Kirchhoff’s laws: These laws are used to solve problems in electrical network.

   Junction Rule: The algebraic sum of currents at a junction is zero
   Loop Rule: The algebraic sum of changes in potential in a closed loop is zero.

It is an arrangement four resistors in the form of a quadrilateral in which a galvanometer and a cell are connected across the junctions. When the bridge is balanced, the ratio of resistances is equal.

Meter bridge works on the balanced condition of Wheatstone bridge. It is used to measure the resistance and hence resistivity of a given material.

Assessment:-

1) Find the value of the unknown resistance X and the current drawn by the circuit from the battery if no current flows through the galvanometer. Assume the resistance per unit length of the wire is 0.01Ωcm⁻¹.
2) Figure shows two circuits each having a galvanometer and a battery of 3V. When the galvanometer in each arrangement do not show any deflection, obtain the ratio \( \frac{R_1}{R_2} \).

3) A 10V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 38 Ω as shown in fig. Find the value of current.

4) Find the value of unknown resistance X in the given circuit, if no current flows through the section AD. Also calculate the current drawn by the circuit from the battery of emf 6.0 V and negligible internal resistance.

5) In the circuit diagram, find the potential difference across the plates of capacitor C.

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CONCEPT: AMPERE’S CIRCUITAL LAW

Learning Objectives:- The objectives of the concept are to know about

1) Magnetic field due to current carrying wire
2) Right hand thumb rule
3) Ampere circuital law

Material Required:-

Power Point Presentation, Copper wires, cell, Model, Charts etc.

Content:

**Magnetic field due to current carrying wire**:- When current was allowed to flow through a wire placed parallel to the axis of a magnetic needle kept directly below the wire, the needle was found to deflect from its normal position.

**Right Hand Thumb Rule or Curl Rule:**-
If a current carrying conductor is imagined to be held in the right hand such that the thumb points in the direction of the current, then the tips of the fingers encircling the conductor will give the direction of the magnetic lines of force.
Ampere’s circuital law:

Ampere's circuital law in magnetism is analogous to gauss's law in electrostatics. This law is also used to calculate the magnetic field due to any given current distribution. This law states that "The line integral of resultant magnetic field along a closed plane curve is equal to \( \mu_0 \) time the total current crossing the area bounded by the closed curve provided the electric field inside the loop remains constant." Thus

\[
\oint_C \mathbf{B} \cdot d\mathbf{r} = \mu_0 I.
\]

Proof:

Let us form the dot product of this element with the local magnetic field \( \mathbf{B} \). Thus,

\[
d\omega = \mathbf{B} \cdot d\mathbf{r} = B \, dr \, \cos \theta,
\]

where \( \theta \) is the angle subtended between the direction of the line element and the direction of the local magnetic field. We can calculate a \( d\omega \) for
every line element which makes up the loop \( C \). If we sum all of the \( dw \) values thus obtained, and take the limit as the number of elements goes to infinity, we obtain the \textit{line integral}

\[
\mathbf{w} = \oint_C \mathbf{B} \cdot d\mathbf{r}.
\]

Suppose that \( C \) is a circle of radius \( r \) centred on the wire. In this case, the magnetic field-strength is the same at all points on the loop. In fact,

\[
\mathbf{B} = \frac{\mu_0 I}{2\pi r}.
\]

Moreover, the field is everywhere parallel to the line elements which make up the loop. Thus,

\[
\oint_C \mathbf{B} \cdot d\mathbf{r} = \mu_0 I.
\]

**Methodology:-**

1) Use of charts and models to explain the Ampere’s circuital law

   [https://www.youtube.com/watch?v=4XjHcXxwuc](https://www.youtube.com/watch?v=4XjHcXxwuc)

2) Use of PowerPoint presentation on the concept

**Action of teacher in the class:-**

- Teacher will ask questions on the magnetic effect of electric current.
- Teacher will explain the Ampere’s circuital law and its applications.
- Teacher has to explain the concept with PowerPoint presentation.
- Teacher will summaries the concept and prepare the assessment test.
- Assessment of class test
Assessment:-

1) What is magnetic effect of current?
2) State right hand thumb rule to find the direction of magnetic field due to current carrying wire.
3) State and prove Ampere’s circuital law.
4) How Gauss’s theorem and Ampere’s circuital law are related to each other?
5) How can you find the magnetic field due to toroid by using Ampere’s circuital law?

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MODULE :-4

CONCEPT: FORCE BETWEEN TWO PARALLEL CURRENT CARRYING CONDUCTORS

Learning Objectives:- The objectives of the concept are to know about

3) Force on a moving charge in a magnetic field
4) Force on a current carrying in a magnetic field
5) Right hand rule no.1
6) Fleming’s left hand rule
7) Force between two parallel current carrying conductors
8) Definition of Ampere

Material Required:-

Power Point Presentation, Two insulated copper wires, two cells, Model, Charts etc.

Content:-

**Force on a moving charge in a magnetic field:** The force on a charge particle in a magnetic field depends on (i) magnitude of charge \( q \), (ii) component of velocity along the direction perpendicular to the direction of magnetic field \( v \sin \theta \) and (iii) magnitude of magnetic field strength \( B \).

\[ F = q(v \sin \theta) B \]
\[ F = qvB \sin \theta \]

**Force on a current carrying in a magnetic field:** When an electrical wire is exposed to a magnet, the current in that wire will be affected by a magnetic field. The effect comes in the form of a force. The expression for magnetic force on current can be found by summing the magnetic force on each of the many individual charges that comprise the current. Since they all run in the same direction, the forces can be added.

The force \( F \) a magnetic field \( B \) exerts on an individual charge \( q \) traveling at drift velocity \( v_d \) is:

\[ F=qv_dB\sin\theta \]
In this instance, $\theta$ represents the angle between the magnetic field and the wire (magnetic force is typically calculated as a cross product). If $B$ is constant throughout a wire, and is 0 elsewhere, then for a wire with $N$ charge carriers in its total length $l$, the total magnetic force on the wire is:

$$F = Nqv_0B \sin \theta$$

Given that $N=nV$, where $n$ is the number of charge carriers per unit volume and $V$ is volume of the wire, and that this volume is calculated as the product of the circular cross-sectional area $A$ and length ($V=Al$), yields the equation:

$$F = (nqAv)B \sin \theta$$

The terms in parentheses are equal to current ($I$), and thus the equation can be rewritten as:

$$F = IlB \sin \theta$$

The direction of the magnetic force can be determined using the right hand rule no.1.

**Right hand rule no.1**: The thumb is pointing in the direction of the current, with the four other fingers parallel to the magnetic field. Curling the fingers reveals the direction of magnetic force.
**Fleming’s left hand rule**: If the central finger, fore finger and thumb of left hand are stretched mutually perpendicular to each other and the central finger points to current, fore finger points to magnetic field, then thumb points in the direction of motion (force) on the current carrying conductor.

![Fleming's left hand rule](image)

**Force between two parallel current carrying conductors**: It is experimentally established fact that two current carrying conductors attract each other when the current is in same direction and repel each other when the currents are in opposite direction.

Figure below shows two long parallel wires separated by distance $d$ and carrying currents $I_1$ and $I_2$. 

Consider fig 5(a) wire A will produce a field $B_1$ at all near by points. The magnitude of $B_1$ due to current $I_1$ at a distance $d$ i.e. on wire b is

$$B_1 = \mu_0 I_1 / (2\pi d) \quad \text{(8)}$$

According to the right hand rule the direction of $B_1$ is in downward as shown in figure (5a).

Consider length l of wire B and the force experienced by it will be $(I_2 l \times B)$ whose magnitude is

$$F_2 = I_2 l B = \frac{\mu_0 l I_1 I_2}{2\pi d} \quad \text{(9)}$$

Direction of $F_2$ can be determined using vector rule. $F_2$ lies in the plane of the wires and points to the left.

From figure (5) we see that direction of force is towards A if $I_2$ is in same direction as $I_1$ fig(5a) and is away from A if $I_2$ is flowing opposite to $I_1$ (fig 5b).

Force per unit length of wire B is

$$\frac{F_2}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

Similarly force per unit length of A due to current in B is

$$\frac{F_1}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

and is directed opposite to the force on B due to A. Thus the force on either conductor is proportional to the product of the current.

We can now make a conclusion that the conductors attract each other if the currents are in the same direction and repel each other if currents are in opposite direction.
Definition of Ampere:-

\[
\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}
\]

When \( I_1 = I_2 = 1 \) Ampere and \( r = 1 \) m, then \( F = 2 \times 10^{-7} \) N/m.

One ampere is that current which, if passed in each of two parallel conductors of infinite length and placed 1 m apart in vacuum causes each conductor to experience a force of \( 2 \times 10^{-7} \) Newton per meter of length of the conductor.

Methodology:-

1) Use of charts and models to explain the force between two current carrying conductors
   https://www.youtube.com/watch?v=nfSJ62mzKyY&ebc=ANyPxKp5Vv6W9m185NkY7cKC0PwwUC9EljVPx8le9gzwzjlahX19QBOrcfr95XbqlWhM-qQZ_G4hGsPshPSnFHtOF0zjUMafj9w

2) Use of PowerPoint presentation on the concept

Action of teacher in the class:-

- Teacher will ask questions on the magnetic field due to current carrying conductor.
- Teacher will explain the force on current carrying wire in magnetic field and force between two current carrying wires.
- Teacher has to explain the concept with PowerPoint presentation.
- Teacher will summarise the concept and prepare the assessment test.
- Assessment of class test
Assessment:-

6) What is magnetic effect of current?
7) Find the expression for force experienced by current wire in magnetic field.
8) How can one find the direction of force experienced by current wire in magnetic field?
9) Explain the right hand rule no.1.
10) Find the expression for force per unit length between two parallel current carrying wires.

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CONCEPT: CYCLOTRON

**Learning Objectives:** The objectives of the concept are to know about

- Charge particle in an electric field
- Charge particle in magnetic field
- Cyclotron
- Importance of Cyclotron
- Limitations of Cyclotron

**Material Required:-**

PowerPoint presentation, Video, Animation

**Content:**

**Charge particle in electric field:**

When a particle of charge $q$ and mass $m$ is placed in an electric field $E$, the electric force exerted on the charge is $qE$. If this is the only force exerted on the particle, it must be the net force and so must cause the particle to accelerate. In this case, Newton’s second law applied to the particle gives

$$F = qE = ma$$

The acceleration of the particle is therefore

$$a = \frac{qE}{m}$$

If ‘$E$’ is uniform (that is, constant in magnitude and direction), then the acceleration is constant. If the particle has a positive charge, then its acceleration is in the direction of the electric field. If the particle has a negative charge, then its acceleration is in the direction opposite the electric field.

**Charge particle in magnetic field:**

Charge particle accelerated by the voltage and enter in a perpendicular magnetic field, it perform uniform circular motion. The magnetic force experience by charge particle in magnetic field provides centripetal force to the particle. The centripetal force $F_C$ required to keep them in their curved path is

$$F_C = \frac{mv^2}{r}$$
where ‘m’ is the particle’s mass, ‘v’ its velocity, and ‘r’ is the radius of the path. This force is provided by the Lorentz force $F_B$ of the magnetic field $B$

$$F_B = qvB$$

where ‘q’ is the particle’s charge.

$$Bqv = \frac{mv^2}{r}$$

$$r = \frac{mv}{Bq}$$

**Cyclotron:-** It accelerates the charge particles, to perform nuclear reactions.

**Principle:-**

A positively charged particle can be accelerated to high energy with the help of an oscillating electric field, by making it cross the same electric field time and again with the use of a strong magnetic field.

**Construction:-**

It consists of two dees or D-shaped metal chambers $D_1$ and $D_2$. The dees are separated by a small distance. The two dees are perpendicular to their plane. $P$ is the position where the ion source is placed.

The dees are maintained to a potential difference whose polarity alternates with the same frequency as the circular motion of the particles. The dees are closed in a steel box placed between the poles of a strong electromagnet. The magnetic field is perpendicular to the plane of the dees.
**Theory and Working:-**

The positive ion P to be accelerated is placed in between the two dees. If at any instant, D₁ is at negative potential and D₂ is at positive potential, then the ion gets accelerated towards D₁ but since its perpendicular to B, it describes a circular path of radius \( r \) and Lorentz force provides the centripetal force.

\[
\text{Now, } Bq \nu = \frac{mv^2}{r} \\
\therefore r = \frac{mv}{Bq}
\]

Time taken to describe a semicircle is

\[
t = \frac{\pi r}{\nu} = \frac{\pi m}{Bq} = \frac{\pi}{B \left( \frac{q}{m} \right)} = \text{constant}
\]

If this time is equal to the time during which D₁ and D₂ change their polarity, the ion gets accelerated when it arrives in between the gaps. The electric field accelerates the ion further. Once the ion is inside the dee D₂, it now describes a greater semicircle due to the magnetic field. This process repels and the ion goes on describing a circular path of greater radius and finally acquires a high energy. The ion is further removed from a window W. The maximum energy acquired by the ion source is

\[
\frac{mv_0^2}{r_0} = Bq \nu_0 \\
\nu_0 = \frac{Bq r_0}{m}
\]

\[
k.E_{\text{max}} = \frac{1}{2} m \nu_0^2 = \frac{1}{2} m \left( \frac{Bq r_0}{m} \right)^2
\]

\[
k.E_{\text{max}} = \frac{B^2 q^2 r_0^2}{2m}
\]

The frequency of cyclotron is given by

\[
f_c = \frac{qB}{2 \pi m}
\]
So, does the magnetic force cause circular motion? Magnetic force is always perpendicular to velocity, so that it does no work on the charged particle. The particle's kinetic energy and speed thus remain constant. The direction of motion is affected, but not the speed. This is typical of uniform circular motion. The simplest case occurs when a charged particle moves perpendicular to a uniform B-field, such as shown in . (If this takes place in a vacuum, the magnetic field is the dominant factor determining the motion.) Here, the magnetic force (Lorentz force) supplies the centripetal force.

**Limitations of Cyclotron:-**

i) Only when the speed of the circulating ion is less than 'c' the speed of light, we find the frequency of revolution to be independent of its speed.

ii) At higher speeds, the mass of the ion will increase and this changes the time period of the ion revolution. This results in the ion lagging behind the electric field and it eventually loses by collisions against the walls of the dees.

iii) The cyclotron is suitable for accelerating heavy charged particles but not electrons.

iv) Cyclotrons cannot accelerate in uncharged particles.

v) It is not suited for very high kinetic energy.

**Methodology:-**

- Use of videos and animations
  [https://www.youtube.com/watch?v=cNnNM2Zqlsc](https://www.youtube.com/watch?v=cNnNM2Zqlsc)

- Use of PowerPoint presentation

**Action of teacher in the class:-**

- Teacher will ask questions on magnetic force experienced by charge particle in magnetic field.
- Teacher will show the videos
- Teacher will prepare assessment sheets
Assessment:-

1) A charge particle moving along + X axis and magnetic field is along –Y axis. Find the direction of force experienced by the charge particle.

2) Calculate the formula for radius of the circular path describe by the charge particle in a perpendicular magnetic field.

3) An alpha particle and a proton moving in a magnetic field with same speed. Calculate the ratio of radii of their path describe by these particles in the magnetic field.

4) Explain the working principle of Cyclotron with the help of suitable diagram.

5) What are the limitations of Cyclotron?

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MODULE :- 6

CONCEPT: MOVING COIL GALVANOMETER

Learning Objectives:- The objectives of the concept are to know about

- Torque produced in a current carrying loop in magnetic field
- Moving coil galvanometer
- Conversion of galvanometer into ammeter
- Conversion of galvanometer into voltmeter

Material Required:-

PowerPoint presentation, Video, Moving coil galvanometer, Chart

Content:-

**Torque Experienced by a Current Loop in a Magnetic Field**

Consider a rectangular loop $PQRS$ of length $l$, breadth suspended in a uniform magnetic field $\vec{B}$. The length of loop $= PQ = RS = l$ and breadth $= QR = SP = b$. Let at any instant the normal to the plane of loop make an angle $\theta$ with the direction of magnetic field $\vec{B}$ and $I$ be the current in the loop. We know that a force acts on a current carrying wire placed in a magnetic field. Therefore each side of loop will experience a force. The net force and torque acting on the loop will be determined by the forces acting on all sides of loop. Suppose that
the forces on sides $PQ$, $QR$, $RS$ and $SP$ are $\vec{F}_1$, $\vec{F}_2$, $\vec{F}_3$ and $\vec{F}_4$ respectively. The sides $QR$ and $SP$ make angle $(90^\circ - \theta)$ with the direction of magnetic field. Therefore each of the forces $\vec{F}_2$ and $\vec{F}_4$ acting on these sides has same magnitude

\[ F' = Blbsin(90^\circ - \theta) = Blb \cos \theta. \]

According to Fleming’s left hand rule the forces $\vec{F}_2$ and $\vec{F}_4$ are equal and opposite but their line of action is same. Therefore these forces cancel each other, i.e., the resultant of $\vec{F}_2$ and $\vec{F}_4$ is zero.

The sides $PQ$ and $RS$ of current loop are perpendicular to the magnetic field, therefore the magnitude of each of forces $\vec{F}_1$ and $\vec{F}_3$ is

\[ F = IlB \sin 90^\circ = IlB. \]

According to Fleming’s left hand rule the forces $\vec{F}_1$ and $\vec{F}_3$ acting on sides $PQ$ and $RS$ are equal and opposite, but their lines of action are different; therefore the resultant force of $\vec{F}_1$ and $\vec{F}_3$ is zero, but they form a couple called the deflecting couple. When the normal to plane of loop makes an angle $\theta$ with the direction of magnetic field $B$, the perpendicular distance between $F_1$ and $F_3$ is $bsin \theta$.

\[ \therefore \text{ Moment of couple or Torque, } \quad \tau = (\text{Magnitude of one force } F) \times \text{ perpendicular distance} \]

\[ \tau = (Blb) \times (bsin \theta) = llb \times B \sin \theta \]

But $Ilb = \text{area of coil} = A \ (\text{say})$

\[ \therefore \text{ Torque, } \tau = L1B \sin \theta \quad \ldots(1) \]

If coil contains $N$-turns, then torque

\[ \tau = NILB \sin \theta \quad \ldots(2) \]

In vector form $\tau = NIL \times B = m \times B$

where $m = NIL$ is the magnetic moment of the current loop.
**Moving Coil Galvanometer**:--

It is the instruments to measure the small currents.

**Principle**:--

The torque on a current loop in a uniform magnetic field is used to measure electrical magnetic field is used to measure electrical currents.

**Construction**:--

![Diagram of a moving coil galvanometer]

**Working**:--

The galvanometer consists of a coil of wire often rectangular, carrying the current to be measured. There are generally many turns in the coil to increase its sensitivity. The coil is placed in a magnetic field such that the lines of $B$ remain nearly parallel to the plane of wire as it turns. This is achieved by having a soft iron cylinder placed at the center of the coil. Magnetic field lines tend to pass through the iron cylinder, producing the field configuration. The moving coil is hung from a spring which winds up as the coil rotates; this winding up produces a restoring torque proportional to the winding up (or twisting) of the spring, i.e. to the angular deflection of the coil. The coil comes to equilibrium when this restoring torque $k$ balances the torque due to the magnetic field balances the torque due to the magnetic field. Since by design field lines are radial,

we have $\sin \theta \sim 1$, so that for equilibrium

$$k \phi = INBA$$

$$\phi = \frac{NBA I}{k}$$
CONVERSION OF GALVANOMETER INTO AMMETER:-
Since Galvanometer is a very sensitive instrument therefore it can’t measure heavy currents. In order to convert a Galvanometer into an Ammeter, a very low resistance known as "shunt" resistance is connected in parallel to Galvanometer. Value of shunt is so adjusted that most of the current passes through the shunt. In this way a Galvanometer is converted into Ammeter and can measure heavy currents without fully deflected.

Let resistance of galvanometer = $R_g$ and it gives full-scale deflection when current $I_g$ is passed through it. Then,

$$V_g = I_g R_g \quad \text{(i)}$$

Let a shunt of resistance ($R_s$) is connected in parallel to galvanometer. If total current through the circuit is $I$.

Then current through shunt:

$$I_s = (I - I_g)$$

potential difference across the shunt:

$$V_s = I_s R_s$$

or

$$V_s = (I - I_g) R_s \quad \text{(ii)}$$

But

$$V_s = V_g$$

$$(I - I_g) R_s = I_g R_g$$

$$R_s = \frac{I_g}{I - I_g} R_g$$

CONVERSION OF GALVANOMETER INTO VOLTMETER:-
Since Galvanometer is a very sensitive instrument, therefore it cannot measure high potential difference. In order to convert a Galvanometer into voltmeter, a very high resistance known as "series resistance" is connected in series with the galvanometer.
Let resistance of galvanometer = $R_g$ and resistance $R_x$ (high) is connected in series to it. Then combined resistance = $(R_g + R_x)$.

![Diagram](image.png)

If potential between the points to be measured = $V$ and if galvanometer gives full-scale deflection, when current "$I_g" passes through it. Then,

$$V = I_g (R_g + R_x)$$

$$V = I_g R_g + I_g R_x$$

$$V - I_g R_g = I_g R_x$$

$$R_x = \frac{(V - I_g R_g)}{I_g}$$

Thus $R_x$ can be found.

**Methodology:-**

- Use of Moving coil galvanometer and videos
  [https://www.youtube.com/watch?v=9-l04iP5zwU](https://www.youtube.com/watch?v=9-l04iP5zwU)

- Use of PowerPoint presentation

**Action of teacher in the class:-**

- Teacher will ask questions on force experienced by current carrying conductor in magnetic field.
- Teacher will show the videos
- Teacher will prepare assessment sheets
**Assessment:**

- Derive the expression for torque experienced by a current carrying loop in a uniform magnetic field.
- Explain the working of moving coil galvanometer with the help of suitable diagram.
- How can we convert a galvanometer into an ammeter?
- How can we convert a galvanometer into voltmeter?
- Which has more resistance milli-ammeter or ammeter?

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CONCEPT: A.C.GENERATOR

Learning Objectives: The objectives of the concept are to know about

- Explore the principle of Faraday’s law of Electromagnetic induction
- Study of Lenz’s law and Fleming’s right hand rule
- We find an expression for instantaneous e. m. f. and current

Material Required:

Clalk, duster, Power point presentation, Electric model of A.C.GENERATOR

Content –

An 'AC generator' or 'dynamo' is a machine which produces AC from mechanical energy. Actually, it is an alternator which converts one form of energy into another.

Principle - It is based on the principle of the electromagnetic induction.

According to the Faraday's law of electromagnetic induction, whenever a conductor moves in a magnetic field EMF gets induced across the conductor. If the close path is provided to the conductor, induced emf causes current to flow in the circuit.

OR

When a coil is rotated about an axis perpendicular to the direction of uniform magnetic field, an induced e.m.f. is produced across it.

Construction –

The a.c. generator consists of the following parts-

1. Armature – A rectangular coil consisting of a large number of turns of copper wire wound over a soft iron core is called the armature. The soft iron core is used to increase the magnetic flux.
2. Field magnet – It is a strong permanent magnet having concave poles. The armature is rotated between the two poles of magnet, so that axis of armature is perpendicular to magnetic field lines.
3. Slip rings- The leads from the arms of the armature are connected to two rings R₁ and R₂ separately. These rings help to provide movable contact and for this reason, they are called slip rings. As the armature and hence the leads rotate, the rings R₁ and R₂ also rotate about the central axis.
4. Brushes – The flexible metallic pieces $B_1$ and $B_2$, called brushes, are used to pass on the current from armature to the slip rings across which the external load resistance $R$ is connected. As the slip rings rotate, the brushes provide movable contact by keeping themselves pressed against the rings.

Armature is a soft iron core on which a coil having a large number of turns of insulated copper wire is wound. Magnetic poles are concave and cylindrical. The concave poles produce a radial magnetic field.

The ends of the armature are connected to two slip rings. They rotate along with the coil. The slip rings are made of metal and are insulated from each other.

There are two brushes $B_1$ and $B_2$ made of carbon. One end of each brush is in contact with the rotating slip rings and the other end is connected to an external circuit. Here the brushes are connected to a galvanometer and brushes do not rotate with the coil.

The axle is rotated mechanically from outside by a diesel engine, flowing water, steam or high-speed wind.
To start with, suppose the plane of the coil is perpendicular to the plane of the paper in which the magnetic field is applied, with AB at the front and CD at the back, the flux linked with the coil is maximum in this position. As the coil rotates clockwise, AB moves inwards and CD moves outwards. According to Fleming’s right hand rule, the current induced in AB is from A to B, and in CD, from C to D. In the external circuit, current flows from B₂ to B₁. After half of the rotation of the coil, AB is at the back and CD is at the front. Therefore, AB starts moving outwards and CD inwards. The current induced in AB is from B to A, and in CD, from D to C. The current flows from B₁ to B₂ through the external circuit. We therefore see that the induced current in the external circuit changes direction after every half rotation of the coil, and hence is alternating in nature.

- As the armature rotates about an axis perpendicular to the magnetic field, it keeps on changing its relative orientation with respect to the field
- Thus the flux keeps on changing continuously with time
- This change in magnetic flux induces an emf
- If the outer terminals of the armature are connected to an external circuit, an electric current flows through it
- The deflection of the galvanometer needle indicates that an emf is induced
- The direction of the induced emf is reversed after every half rotation of the coil
- Thus in one rotation of the coil, the current changes its direction twice
Such a current which changes its direction after equal intervals of time is called alternating current (AC).

To get a direct current (DC) generator a split-ring type commutator must be used. In this arrangement, one brush is at all times in contact with the arm moving up in the field while the other is in contact with the arm moving down. Thus a unidirectional current is produced in such a generator.

The AC current produced in India has a frequency of 50 hertz (Hz). The coil is rotated at the rate of 50 revolutions in 1 second. So in 50 revolutions the current changes its direction 100 times in one second.

Expression for instantaneous e. m. f. --

As the armature coil rotates, the angle θ changes continuously. Therefore, the flux linked with the coil changes.
Now,

\[ \phi = N \left( \vec{B} \cdot \vec{A} \right) \]

\[ = NBA \cos \theta \]

\[ = NBA \cos wt \]

where \( N \) is the number of turns in the coil, \( A \) is the area enclosed by each three of the coil and \( B \) is the strength of the magnetic field.

\[ E = -\frac{d\phi}{dt} = - \frac{d\left( NBA \cos \omega t \right)}{dt} \quad \text{(from Faraday's law of EMF)} \]

\[ = - NBA (-\sin wt )w \]

\[ E = + NBA \omega \sin wt \]

e = e_o \sin wt. This is the EMF Supplied by the A.C. generator

\[ i = \frac{e}{R} = \frac{e_o}{R} \sin \omega t - i_l \sin \omega t \]

**Methodology:-**

1. Use of video of A.C. generator
   [https://www.youtube.com/watch?v=gQyamjPrw-U](https://www.youtube.com/watch?v=gQyamjPrw-U)

2. Use of PowerPoint presentation on A.C. generator

**Action of teacher in the class:-**

- Teacher will ask questions on Faraday’s law, Lenz’s law and Fleming right hand rule
- Teacher has to explain the concept with PowerPoint presentation.
- Teacher will summarise the concept and prepare the assessment test.
- Assessment of class test

**SUMMARY:-**

1. An 'AC generator' or 'dynamo' is a machine which produces AC from mechanical energy. Actually, it is an alternator which converts one form of energy into another.
2. It is based on the principle of the electromagnetic induction.
3. As the armature coil rotates, the angle $\theta$ changes continuously. Therefore, the flux linked with the coil changes.

Now,

$$\phi = N \left( \vec{B} \cdot \vec{A} \right)$$

$$= NBA \cos \theta$$

$$= NBA \cos wt$$

4. $e = e_0 \sin wt$. This is the EMF Supplied by the A.C. generator

$$i \approx \frac{e}{R} - \frac{e_0}{R} \sin \omega t - i_0 \sin \omega t$$

**Assessment:**

Q.1 State Faraday’s law of electromagnetic induction?

Q.2 State Lenz’s law and how it is related to conservation of energy?

Q.3 State Fleming Right Hand Rule?

Q.4 You are given a fixed length of wire to design a generator. For a given magnetic field strength and given frequency of rotation, will you use one turn or two turn square coil to generate maximum e.m.f?

Q.5 A 100 turn coil of area 0.1 m$^2$ rotates at half a revolution per second. It is placed in a uniform magnetic field of 0.01T perpendicular to the axis of rotation of the coil. Calculate the maximum voltage generated in the coil?

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CONCEPT: TRANSFORMER

Learning Objectives: The objectives of the concept are to know about

- Mutual Induction
- Avoiding eddy currents in bulk matter
- Step up and step down transformer
- Energy losses in transformer
- Use of transformer in long distance transmission

Material Required:-

PowerPoint presentation, transformer, insulated copper wire of different thickness

Content:

Mutual Induction:- It is the phenomenon in which a change of current in one coil causes an induced emf in another coil placed near to the first coil. The coil in which current is changed is called primary coil and the coil in which emf is induced is called secondary coil.

Transformer:-

For simplification or approximation purposes, it is very common to analyze the transformer as an ideal transformer model as presented in the two images. An ideal transformer is a theoretical, linear transformer that is lossless and perfectly coupled; that is, there are no energy losses and flux is completely confined within.
the magnetic core. Perfect coupling implies infinitely high core magnetic permeability and winding inductances and zero net magneto motive.

Ideal transformer connected with source $V_P$ on primary and load impedance $Z_L$ on secondary, where $0 < Z_L < \infty$.

A varying current in the transformer's primary winding creates a varying magnetic flux in the core and a varying magnetic field impinging on the secondary winding. This varying magnetic field at the secondary induces a varying electromotive force (EMF) or voltage in the secondary winding. The primary and secondary windings are wrapped around a core of infinitely high magnetic permeability so that all of the magnetic flux passes through both the primary and secondary windings. With a voltage source connected to the primary winding and load impedance connected to the secondary winding, the transformer currents flow in the indicated directions. (See also Polarity.)

Ideal transformer and induction law:-

According to Faraday's law of induction, since the same magnetic flux passes through both the primary and secondary windings in an ideal transformer, a voltage is induced in each winding, according to eq. (1) in the secondary winding case, according to eq. (2) in the primary winding case. The primary EMF is sometimes termed counter EMF. This is in accordance with Lenz's law, which states that induction of EMF always opposes development of any such change in magnetic field.

The transformer winding voltage ratio is thus shown to be directly proportional to the winding turns ratio according to eq. (3).
According to the law of Conservation of Energy, any load impedance connected to the ideal transformer's secondary winding results in conservation of apparent, real and reactive power.

Energy losses do occur in them due to four main causes:-

**A) Resistance of windings** – the low resistance copper wire used for the windings still has resistance and thereby contribute to heat loss.

**B) Flux leakage** – the flux produced by the primary coil may not be all linked to the secondary coil if the design of the core is bad.

**C) Eddy currents** – the changing magnetic field not only induces currents in the secondary coil but also currents in the iron core itself. These currents flow in little circles in the iron core and are called eddy currents. The eddy currents cause heat loss. The heat loss, however, can be reduced by having the core laminated (thin sheets of soft iron insulated from one another). (See image below)

**D) Hysteresis** – The magnetization of the core is repeatedly reversed by the alternating magnetic field. The repeating core magnetization process expends energy and this energy appears as heat. The heat generated can be kept to a minimum by using a magnetic material which has a low hysteresis loss. Hence, soft iron is often chosen for the core material because the magnetic domains within it changes rapidly with low energy loss.

**Lamination of iron core:**

As stated above, eddy currents generate resistive losses in the form of heat (Joule heating). This effect reduces the efficiency of iron-core transformers. (or any other devices which uses changing magnetic fields) Lamination (using
thin sheets of magnetic material) is a way to counter the effect. In the image above, eddy current can circulate on wide arcs within a non-laminated iron core. This will generate a lot of resistive losses and is not ideal.

**Use of transformer in long distance transmission**

A transformer is used to step up the primary voltage to a very high secondary voltage, about 400 to 500 kv. When the output voltage is stepped up, the output current is stepped down by the same ratio. Because the power cables are a very low resistance, and because the current is very small, there is very little loss of energy in the cables. The power losses = \(I^2R\), which is the energy loss that appears as heat in the cables, are therefore kept to a minimum, and this enables the voltage to be efficiently sent over very long distances.

**Methodology**:-

- Use of videos and animations
  - https://www.youtube.com/watch?v=ZjwzpoCf8A
  - https://www.youtube.com/watch?v=VucsoEhB0NA

- Use of PowerPoint presentation

**Action of teacher in the class**:-

- Teacher will ask questions on electromagnetic induction
- Teacher will ask questions on use of transformer
- Teacher will show the videos
- Teacher will prepare assessment sheets
Assessment:-

- What is mutual induction?
- What are the demerits of eddy currents? How can we minimise eddy currents in metallic objects?
- Draw the diagram of step up transformer.
- What are losses of energy in transformer?
- How can we use transformer in long distance transmission of electricity?

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CONCEPT: COMPOUND MICROSCOPE

Learning Objectives: The objectives of the concept are to know about

- Real and virtual image formed by lenses.
- Image formation by convex lens
- Magnification of lens
- Combination of lenses
- Simple microscope
- Working of Compound Microscope

Material Required:-

PowerPoint presentation, Convex lenses, Candles, Compound microscope

Content:-

1) A real image is produced on a screen (or some other detector) when all of the rays from a single point on an object strike a single point on the screen.

A virtual image is produced when rays of light reach our eyes that appear to come from a real object, but there is in fact no object at the apparent source of the light. We cannot actually place a screen at the point where the image appears to be.

2) Image formation by a convex lens:-

https://www.youtube.com/watch?v=FVpPU4NIJh0&ebc=ANyPxKrB2siLru9SCtRahpfVh0LNedW4hd-g1tDfid3RPGwWWuyD-e9z2qlP7gqkc072PDMCi2g3ObYnymcnj4g4et7zzsR8iw
3) Magnification of the lens:-

The **linear magnification** or transverse **magnification** is the ratio of the image size to the object size. If the image and object are in the same medium it is just the image distance divided by the object distance.

https://www.youtube.com/watch?v=HGVUVFyc6o

4) Combination of lenses:-

Consider two convex lenses in contact such that their separation is very small as compared to their focal length.

Let a point object "O" is placed at a distance "p₁" from the lenses L₁ whose real image I₁ is formed at a distance q₁.
Using thin lens formula

\[ \frac{1}{f_1} = \frac{1}{p_1} + \frac{1}{q_1} \] 

... (1)

Image serves as a virtual object for the second lens. If we neglect small distance between the lenses, the distance of this virtual object from lens \( L_2 \) will be the same as its distance from \( L_1 \). If \( L_2 \) forms an image \( I_2 \) of this virtual object at a distance \( q_2 \) then \( p_2 \).

For latest information, free computer courses and high impact notes visit: www.citycollegiate.com

\[ \frac{1}{f_2} = \frac{1}{p_2} + \frac{1}{q_2} \]

\[ \frac{1}{f_2} = \frac{1}{-q_1} + \frac{1}{q_2} \]

\[ \frac{1}{f_2} = \frac{1}{q_1} + \frac{1}{q_2} \] 

... (2)

Adding equation (1) and equation (2)

\[ \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{p_1} + \frac{1}{q_1} - \frac{1}{q_1} + \frac{1}{q_2} \]

\[ \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{p_1} + \frac{1}{q_2} \] 

\[ \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{p_1} + \frac{1}{q_2} \] 

... (3)

now if we replace the two lenses of focal lengths \( f_1 \) and \( f_2 \) by a single lens of focal length \( f \) such that it forms an image at a distance \( q_2 \) of an object placed at a distance \( p_1 \) from it as shown such lens is called equivalent lens and
Its focal length is known as equivalent focal length. For the above lens

\[ \frac{1}{f} = \frac{1}{p_1} + \frac{1}{q_2} \quad (4) \]

comparing equation (3) and equation (4), we get

\[ \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} \]

If \( f_1 > f_2 \) the combined lens behaves as a concave lens.
If \( f_2 > f_1 \) the combined lens behaved as a convex lens.

5) **Simple Microscope**

https://www.youtube.com/watch?v=R-uMcngNsSk&ebc=ANyPxKoyiP-ZVvyaMbKIYRo1SA-qS-K61VVozhnTxHGLpJYOWRGmB91q4F5jX3ldzOVY05Teh05vsTBocCh9wq3PwJ_RYF1Q

The magnifying power or angular magnification of a microscope may be defined as the ratio of the angle subtended at the eye by the image formed at the distance of the distinct vision to the angle subtended by the object when placed at the distance of the distinct vision.

The ray diagram shows that the image of the object AB is formed at \( A'B' \). \( A'B' \) is formed at the least distance of distinct vision.

The figure shows that the angle \( A'OB' \) subtended at the eye by the object in the position \( A'B' \) is greater than the angle AOB subtended by it in the position AB. From this it is clear that the eye estimates the angle subtended by an object on it and not the linear size of the object.
Magnifying power - angle subtended at the eye by the image formed at the distance of distinct vision
angle subtended at the eye by the object placed at the distance of distinct vision

\[ \frac{\angle A'OB'}{\angle A''OB'} \]

\[ = \frac{\angle AOB}{\angle A''OB'} \]

\[ = \frac{\tan \angle AOB}{\tan \angle A''OB'} \] (When \( \theta \) is small and in radian measure
\[ \theta = \tan \theta \])

\[ \frac{AB}{OB} \cdot \frac{OE'}{AB} \]

\[ = \frac{OB'}{OB} \] (\( \therefore AB = A''B' \))

Magnifying power \((m)\) = \( \frac{OB'}{OB} \)

But \( OB' = \) Least distance of distinct vision from the lens or eye = \( D \)

\( OB = u = \) distance between the lens and the object

\[ m = \frac{D}{u} \]

The distance between the image and the lens is negative as the image is virtual.

\[ \therefore D = -v \]

The lens formula for a convex lens is

\[ \frac{1}{f} = \frac{1}{v} - \frac{1}{u} \] \( \cdots \cdots \) \((1)\)

Where \( f \) is the focal length of the lens
Multiplying both sides of the equation (1) by \( v \) we get

\[
\frac{v}{f} = \frac{v}{v} - \frac{v}{u}
\]

\[
\frac{v}{f} = 1 - \frac{v}{u}
\]

But \( m = \frac{v}{u} \)

\[
\frac{v}{f} = 1 - m
\]

\[
m = 1 - \frac{v}{f}
\]

In the case of a simple microscope \( v = -D \)

\[
\therefore m = 1 + \frac{D}{f}
\]

6) **COMPOUND MICROSCOPE:-**

https://www.youtube.com/watch?v=iNnX_mJHKl0

**Compound microscope**

36.41 (a) Diagram of a compound microscope, which consists of an objective lens and an eyepiece lens. (b) A compound microscope. The three-objective turret allows the user to choose from several powers of magnification. Combinations of eyepieces with different focal lengths and different objectives can produce a wide range of magnifications.

A simple magnifier provides only limited assistance in inspecting minute details of an object. Greater magnification can be achieved by combining two lenses in a device called
compound microscope, a schematic diagram of which is shown in Figure 36.41a. It consists of one lens, the objective, that has a very short focal length $f_0 < 1 \text{ cm}$ and a second lens, the eyepiece, that has a focal length $f_e$ of a few centimeters. The two lenses are separated by a distance $L$ that is much greater than either $f_0$ or $f_e$. The object, which is placed just outside the focal point of the objective, forms a real, inverted image at $I_1$, and this image is located at or close to the focal point of the eyepiece. The eyepiece, which serves as a simple magnifier, produces at $I_2$ a virtual, inverted image of $I_1$. The lateral magnification $M_1$ of the first image is $-\frac{q_1}{p_1}$. Note from Figure 36.41a that $q_1$ is approximately equal to $L$ and that the object is very close to the focal point of the objective: $p_1 \approx f_0$. Thus, the lateral magnification by the objective is

$$M_1 \approx -\frac{L}{f_0}$$

Methodology:-

- Use of videos and animations
  
  https://www.youtube.com/watch?v=iNnX_mJHK10
  
  https://www.youtube.com/watch?v=R-uMcngNsSk&ebc=ANyPxKoyiP-ZVvyMblYRo1SA-qS-K61VVozhnTxHGLpJYOwRGmB91q4F5JX3IdzOVY0StTeh05vsTBocCh9wq3PwJ_RYF1Q

- Use of PowerPoint presentation

Action of teacher in the class:-

- Teacher will ask questions on mirrors and lenses
- Teacher will ask questions on use of mirrors and lenses
- Teacher will show the videos
Assessment:

- Distinguish real and virtual images in optics.
- What is the total focal length of a convex lens of focal length 30 cm in contact with a concave lens of focal length 20 cm? Is the system a converging or a diverging lens? Ignore thickness of the lenses.
- Where an object should be placed from a converging lens of focal length 20 cm, so as to obtain a real image of magnification 2?
- How does the focal length of a convex lens change if monochromatic red light is used instead of monochromatic blue light?

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CONCEPT: Young’s Double slit Experiment

Learning Objectives:- The objectives of the concept are to know about

- Interference of light.
- Concept of coherent source.
- Young’s double slit experiment.
- Condition for constructive and destructive interference.
- Concept of fringe width and its mathematical expression.

Material Required:-

Smart board, Powerpoint presentation, double slit, Laser light, and pin ole box to demonstrate the experiment.

Content:-

Interference of light: - The phenomenon of redistribution of light energy due to the superposition of light from two coherent sources is known as interference of light.

Wave 1 + Wave 2 = Constructive Interference

Wave 1 + Wave 2 = Destructive Interference

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Examples of interference Effect in our daily life

Coherent Sources

- Coherent sources are those sources of light which emit continuous light waves of same wavelength, same frequently and are in same phase or have a constant phase difference.
- For observing interference phenomenon, coherence of waves is a must. For light waves emitted by two sources of light to remain coherent, the initial phase difference between waves should remain constant in time. If the phase difference changes continuously or randomly with time then the sources are incoherent.
- Two independent sources of light are not coherent and hence cannot produce interference because light beam is emitted by millions of atoms radiating independently so that phase difference between waves from such fluctuates randomly many times per second.
- Two coherent sources can be obtained either by the source and obtaining its virtual image or by obtaining two virtual images of the same source. This is because any change in phase in real source will cause a simultaneous and equal change in its image.

Young’s double slit Experiment

The phenomenon of interference in light was demonstrated by Thomas Young in 1801. It provides solid evidence that light is a wave. Interference fringes consisting of alternately bright and dark fringes (or bands) which are equally spaced are observed. These fringes are actually images of the slit. The following diagram shows how the pattern is
For an interference pattern to be observable
1. The waves are coherent, i.e. the waves from each source maintain a constant phase difference.
2. Two sources are said to be coherent if waves from the sources have a constant phase difference between them.

Experimental Set up
(i) The single slit S is a narrow slit which ensures that only a small portion of the monochromatic light source is used. S can be considered to be approximately a point source. Waves from this point source are further splitted into 2 coherent point sources at double slits S₁ and S₂.
(ii) Waves emerging from S₁ and S₂ interfere in space, producing interference fringes which are captured on a screen.
(iii) The distance D (from the double slits to the screen) is very much greater than d.
(iv) The light source should be monochromatic, i.e. producing light of a single wavelength, so as to ensure that fringes are of one colour

Derivation of the Fringe Separation
In young's double slit experiment, light wave produce interference pattern of alternate bright and dark fringes or interference band. To find the position of fringes, their spacing and intensity at any point P on screen XY. Consider the figure given below
Here S1 or S2 two pin holes of YDS interference experiment and position of maxima and minima can be determined on line XOX parallel to Y-axis and lying on the plane parallel to S1, S2 or S2
Consider a point P on XY plane such that CP = x. The nature of interference between two waves reaching point P depends on the path difference S2P-S1P from figure

\[ S_1P^2 = D^2 + \left(x - \frac{d}{2}\right)^2 = D^2 \left[1 + \left(\frac{x - \frac{d}{2}}{D}\right)^2\right] \]

\[ S_2P^2 = D^2 \left[1 + \left(\frac{x + \frac{d}{2}}{D}\right)^2\right] \]

\[ S_2P^2 - S_1P^2 = \left(x + \frac{d}{2}\right)^2 - \left(x - \frac{d}{2}\right)^2 = 2xd \]

\[ (S_2P - S_1P)(S_2P + S_1P) = 2xd \]

\[ S_2P - S_1P = \frac{2xd}{S_2P + S_1P} \]

for x, d<<D, S1P+S2P=2D
with negligible error included, path difference would be

\[ S_2P - S_1P = \frac{2xd}{2D} = \frac{xd}{D} \]

And corresponding phase difference between wave is

\[ \phi = \text{path difference} \times \frac{2\pi}{\lambda} \]

\[ \text{phase difference} = \frac{2\pi}{\lambda} \times \frac{xd}{D} \]

Condition of bright fringes (constructive interference)
If the path difference (S2P-S1P) is even multiple of \( \lambda/2 \), the point P is bright

\[ \frac{xd}{D} = \frac{2n\lambda}{2} \]

or, \( x = \frac{n\lambda D}{d} \)

Equation (21) gives the condition for bright fringes or constructive interference

ii) Condition for dark fringes (destructive interference)
If the path difference is an odd multiple of $\lambda/2$, the Point P is dark. So,

$$\frac{x d}{D} = \frac{(2n - 1) \lambda}{d}$$

or,

$$x = \frac{(2n - 1) \lambda D}{d}$$

Equation (22) gives the condition for dark fringes or destructive interference. From equations (21) and (22), we can get position of alternate bright and dark fringes respectively. Distance between two consecutive right fringes is given by

$$x_{n-1} - x_n = \frac{D}{2d} (n - 1) \lambda - \frac{D}{2d} n \lambda = \frac{D}{d} \lambda$$

And for dark fringes

$$x_{n-1} - x_n = \frac{D}{2d} (2n + 1) \lambda - \frac{D}{2d} (2n - 1) \lambda = \frac{D}{d} \lambda$$

Thus the distance between two successive dark and bright fringes is same. This distance is known as fringe width and is denoted by $\beta$. Thus

Thus, Fringe width $\beta = \lambda \frac{D}{a}$

Clearly $\beta$ is a constant if $\lambda$, $D$ and $a$ are kept constant. If all factors are kept constant, the fringes are evenly spaced near the central axis.

Factors affecting fringe width.

(i) The fringe separation is increased if distance to the screen $D$ is increased.
(ii) The fringe separation is decreased if slit separation ‘$a$’ is increased.

In the flash animation below, try to drag one circle away from the other and observe what happen to the fringe separation.

(iii) The fringe separation is increased as wavelength of light $\lambda$ is increased.

Methodology:-

- Video clips from internets on this experiment.
  https://www.youtube.com/watch?v=MDX3qb_BMs4

- Use of PowerPoint presentation.

Action of teacher in the class:-

- Teacher will ask questions on number system (specially on decimal and binary number system)
- Demonstration of electric models and explains the input and output relations.
- Teacher has to explain the concept with PowerPoint presentation.
- Teacher will summarise the concept and prepare the assessment test.
- Assessment of class test
SUMMARY:-

- Interference results due to superposition of light waves coming from two coherent sources.
- Bright and dark fringes in the interference pattern are called fringe.
- Bright fringe is also called constructive interference or maxima.
- Dark fringe is also called destructive interference or minima.
- The wave nature of light was confirmed by Young’s double-slit.

Assessment:-

1) What is interference phenomenon?
2) Give two examples from the surrounding where interference pattern is observed?
3) Draw the experimental set up for Young’s double slit Experiment and label it?
4) What is fringe width? Derive the expression for it?
5) Write down the factors on which fringe width depends?
6) In YDSE , the fringe width obtain is 3.0mm in air . If the apparatus is immersed in water (refractive index 4/3), what will be the new fringe width?

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CONCEPT: H-ATOM SPECTRUM

Learning Objectives:- The objectives of the concept are to know about

- Alpha particle scattering experiment
- Rutherford atom model
- Bohr’s atom model
- Hydrogen atom spectrum
- Limitation of Bohr’s theory

Material Required:-

Power Point Presentation, Video and Animation, Charts etc.

Content:-

1) Geiger–Marsden experiment:

The Geiger–Marsden experiment(s) (also called the Rutherford gold foil experiment) were a landmark series of experiments by which scientists discovered that every atom contains a nucleus where its positive charge and most of its mass are concentrated. They deduced this by measuring how an alpha particle beam is scattered when it strikes a thin metal foil. The experiments were performed between 1908 and 1913 by Hans Geiger and Ernest Marsden under the direction of Ernest Rutherford at the Physical Laboratories of the University of Manchester.

An alpha particle is a sub-microscopic, positively charged particle of matter. According to Thomson's model, if an alpha particle were to collide with an atom, it would just fly straight through, its path being deflected by at most a fraction of a degree. At the atomic scale, the concept of "solid matter" is meaningless, so the alpha particle would not bounce off the atom like a marble; it would be affected only by the atom's electric fields, and Thomson's model predicted that the electric fields in an atom are just too weak to affect a passing alpha particle much (alpha particles tend to move very fast). Both the negative and positive charges within the Thomson atom are spread out over the atom's entire volume. According to Coulomb's Law, the less concentrated a sphere of electric charge is, the weaker its electric field at its surface will be.
As a worked example, consider an alpha particle passing tangentially to a Thomson gold atom, where it will experience the electric field at its strongest and thus experience the maximum deflection $\theta$. Since the electrons are very light compared to the alpha particle, their influence can be neglected and the atom can be seen as a heavy sphere of positive charge.

\[
Q_n = \text{positive charge of gold atom} = 79 \ e = 1.266 \times 10^{-17} \ C
\]

\[
Q_\alpha = \text{charge of alpha particle} = 2 \ e = 3.204 \times 10^{-19} \ C
\]

\[
r = \text{radius of a gold atom} = 1.44 \times 10^{-10} \ m
\]

\[
\nu_\alpha = \text{velocity of alpha particle} = 1.53 \times 10^7 \ m/s
\]

\[
m_\alpha = \text{mass of alpha particle} = 6.645 \times 10^{-27} \ kg
\]

\[
k = \text{Coulomb's constant} = 8.998 \times 10^9 \ N \cdot m^2/C^2
\]

Using classical physics, the alpha particle's lateral change in momentum $\Delta p$ can be approximated using the impulse of force relationship and the Coulomb force expression:

\[
\Delta p = F \Delta t = k \cdot \frac{Q_\alpha Q_n}{r^2} \cdot \frac{2r}{\nu_\alpha}
\]

\[
\theta \approx \frac{\Delta p}{p} < k \cdot \frac{2Q_\alpha Q_n}{m_\alpha r^2} = 8.998 \times 10^9 \times \frac{2 \times 3.204 \times 10^{-19} \times 1.266 \times 10^{-17}}{6.645 \times 10^{-27} \times 1.44 \times 10^{-10} \times (1.53 \times 10^7)^2}
\]

\[
\theta < 0.000326 \ rad \ (or \ 0.0186^\circ)
\]

The above calculation is but an approximation of what happens when an alpha particle comes near a Thomson atom, but it is clear that the deflection at most will be in the order of a small fraction of a degree. If the alpha particle were to pass through a gold foil some 400 atoms thick and experience maximal deflection in the same direction (unlikely), it would still be a small deflection.

**The outcome of the experiments**

At Rutherford's behest, Geiger and Marsden performed a series of experiments where they pointed a beam of alpha particles at a thin foil of metal and measured the scattering pattern by using a fluorescent screen. They spotted alpha particles bouncing off the metal foil in all directions, some right back at the source. This
should have been impossible according to Thomson's model; the alpha particles should have all gone straight through. Obviously, those particles had encountered an electrostatic force far greater than Thomson's model suggested they would, which in turn implied that the atom's positive charge was concentrated in a much tinier volume than Thomson imagined.

When Geiger and Marsden shot alpha particles at their metal foils, they noticed only a tiny fraction of the alpha particles were deflected by more than 90°. Most just flew straight through the foil. This suggested that those tiny spheres of intense positive charge were separated by vast gulfs of empty space. Imagine you are standing on the edge of a copse of trees with a large bag full of tennis balls. If you were to blindly throw tennis balls at the trees, you would notice that most of the balls would fly through hitting nothing, while a few would strike tree trunks and bounce off in all directions. This analogy illustrates what Rutherford saw in the scattering pattern of the alpha particles. Most particles went straight through the metal foil because its matter was mostly empty space, but a few had "struck" some small but strong obstacle: the nuclei of the atoms.

Rutherford thus rejected Thomson's model of the atom, and instead proposed a model where the atom consisted of mostly empty space, with all its positive charge concentrated in its center in a very tiny volume, surrounded by a cloud of electrons.

2) **Rutherford determines the nucleus is positively charged**

In his 1911 Rutherford assumed that the central charge of the atom was positively charged, but he acknowledged he couldn't say for sure, since either a negative or a positive charge would have fitted his scattering model. The results of other experiments confirmed his hypothesis. In a 1913 paper, Rutherford declared that the "nucleus" (as he now called it) was positively charged, based on the result of experiments exploring the scattering of alpha particles in various gases.

In 1917, Rutherford and his assistant William Kay began exploring the passage of alpha particles through gases such as hydrogen and nitrogen. In an experiment where they shot a beam of alpha particles through hydrogen, the alpha particles knocked the hydrogen nuclei forwards in the direction of the beam, not backwards. In an experiment where they shot alpha particles through nitrogen, he discovered that the alpha particles knocked hydrogen nuclei (i.e. protons) out of the nitrogen nuclei.

3) **Rutherford atom model:**

Atom is electrically neutral. The atom consisted of mostly empty space, with all its positive charge concentrated in its centre in a very tiny volume, surrounded by a cloud of electrons. The force of attraction between nucleus and electron gives centripetal force to the electron.
4) **The Bohr Model of the Atom:**

Niels Bohr proposed a model for the hydrogen atom that explained the spectrum of the hydrogen atom. The **Bohr model** was based on the following assumptions.

- The electron in a hydrogen atom travels around the nucleus in a circular orbit.
- The energy of the electron in an orbit is proportional to its distance from the nucleus. The further the electron is from the nucleus, the more energy it has.
- Only a limited number of orbits with certain energies are allowed. In other words, the orbits are quantized.
- The only orbits that are allowed are those for which the angular momentum of the electron is an integral multiple of Planck’s constant divided by 2p.
- Light is absorbed when an electron jumps to a higher energy orbit and emitted when an electron falls into a lower energy orbit.
- The energy of the light emitted or absorbed is exactly equal to the difference between the energies of the orbits.

Some of the key elements of this hypothesis are illustrated in the figure below.

Three points deserve particular attention. First, Bohr recognized that his first assumption violates the principles of classical mechanics. But he knew that it was impossible to explain the spectrum of the hydrogen atom within the limits of classical physics. He was therefore willing to assume that one or more of the principles from classical physics might not be valid on the atomic scale.

Second, he assumed there are only a limited number of orbits in which the electron can reside. He based this assumption on the fact that there are only a limited number of lines in the spectrum of the hydrogen atom and his belief that these lines were the result of light being emitted or absorbed as an electron moved from one orbit to another in the atom.

Finally, Bohr restricted the number of orbits on the hydrogen atom by limiting the allowed values of the angular momentum of the electron. Any object moving along a straight line has a *momentum* equal to the product of its mass \((m)\) times the velocity \((v)\) with which it moves. An object moving in a circular orbit has an *angular momentum* equal to its mass \((m)\) times the velocity \((v)\) times the radius of the orbit \((r)\). Bohr assumed that the angular momentum of the electron can take on only certain values, equal to an integer times Planck’s constant divided by 2p.

\[
\frac{mv{r}}{2\pi} = n\left[\frac{h}{2\pi}\right] \text{ (where } n = 1, 2, 3, 4, \ldots)\]
5) **Hydrogen atom spectrum:**

6) **Origin of Continuum, Emission, and Absorption Spectra**

The origins of these three types of spectra are illustrated in the following figure.

![Sources of continuous, emission, and absorption spectra](image)

Thus, *emission spectra* are produced by thin gases in which the atoms do not experience many collisions (because of the low density). The emission lines correspond to photons of discrete energies that are emitted when excited atomic states in the gas make transitions back to lower-lying levels.

A *continuum spectrum* results when the gas pressures are higher. Generally, solids, liquids, or dense gases emit light at all wavelengths when heated.

An *absorption spectrum* occurs when light passes through a cold, dilute gas and atoms in the gas absorb at characteristic frequencies; since the re-emitted light is unlikely to be emitted in the same direction as the absorbed photon, this gives rise to dark lines (absence of light) in the spectrum.

Substituting the relationship between the frequency, wavelength, and the speed of light into this equation suggests that the energy of a photon is inversely proportional to its wavelength. The inverse of the wavelength of electromagnetic radiation is therefore directly proportional to the energy of this radiation.

By properly defining the units of the constant, $R_H$, Bohr was able to show that the wavelengths of the light given off or absorbed by a hydrogen atom should be given by the following equation.

$$\frac{1}{\lambda} = R_H \left( \frac{1}{\nu_1^2} - \frac{1}{\nu_2^2} \right)$$
Thus, once he introduced his basic assumptions, Bohr was able to derive an equation that matched the relationship obtained from the analysis of the spectrum of the hydrogen atom.

7) Limitations of the Bohr Model

The Bohr Model was an important step in the development of atomic theory. However, it has several limitations.

- It is in violation of the Heisenberg Uncertainty Principle. The Bohr Model considers electrons to have both a known radius and orbit, which is impossible according to Heisenberg.
- The Bohr Model is very limited in terms of size. Poor spectral predictions are obtained when larger atoms are in question.
- It cannot predict the relative intensities of spectral lines. It does not explain the Zeeman Effect, when the spectral line is split into several components in the presence of a magnetic field.

Methodology:

- Use of charts and models to explain the atom model
  [https://www.youtube.com/watch?v=FfY4R5mkMY8](https://www.youtube.com/watch?v=FfY4R5mkMY8)

- Use of PowerPoint presentation on hydrogen spectrum
Action of teacher in the class:-

- Teacher will ask questions on atom models
- Teacher will explain the atom models with the help of charts
- Teacher has to explain the concept with PowerPoint presentation.
- Teacher will summarise the concept and prepare the assessment test.
- Assessment of class test

Assessment:-

1) Explain the observations and outcome of alpha particles scattering experiments.
2) Explain the drawbacks of Rutherford atom model.
3) What are the postulates of Bohr’s atom model?
4) Draw the absorption spectrum of H-atom.
5) What are the limitations of Bohr’s atom model?

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CONCEPT: TRANSISTOR AS AN AMPLIFIER

Learning Objectives:- The objectives of the concept are to know about

- NPN and PNP Transistor
- Modulation
- Amplitude Modulation
- Modulation Index
- Propagation of EM Wave
- LOS Communication

Material Required:-

Power Point Presentation, Different types of transistor, Amplifier, Charts etc.

Content:-

1) NPN and PNP transistor:-

The fusion of these two diodes produces a three layer, two junction, three terminal device forming the basis of a Bipolar Junction Transistor, or BJT for short.

Transistors are three terminal active devices made from different semiconductor materials that can act as either an insulator or a conductor by the application of a small signal voltage. The transistor’s ability to change between these two states enables it to have two basic functions: “switching” (digital electronics) or “amplification” (analogue electronics). Then Bipolar Transistors have the ability to operate within three different regions:

- Active Region – the transistor operates as an amplifier and $I_c = \beta I_b$
- Saturation – the transistor is “Fully-ON” operating as a switch and $I_c = I_{(saturation)}$
- Cut-off – the transistor is “Fully-OFF” operating as a switch and $I_c = 0$
The Bipolar Transistor basic construction consists of two PN-junctions producing three connecting terminals with each terminal being given a name to identify it from the other two. These three terminals are known and labelled as the Emitter (E), the Base (B) and the Collector (C) respectively.

Bipolar Transistors are current regulating devices that control the amount of current flowing through them in proportion to the amount of biasing voltage applied to their base terminal acting like a current-controlled switch. The principle of operation of the two transistor types PNP and NPN, is exactly the same the only difference being in their biasing and the polarity of the power supply for each type.

2) **Transistor Construction:-**

   ![PNP Transistor](image1)
   ![NPN Transistor](image2)

   **a) Physical Construction**

   ![Two-diode Analogy](image3)

   **b) Two-diode Analogy**

   ![Circuit Symbols](image4)

   **c) Circuit Symbols**

3) **Transistor Configurations:-**

   As the Bipolar Transistor is a three terminal device, there are basically three possible ways to connect it within an electronic circuit with one terminal being common to both the input and output. Each method of connection responding differently to its
input signal within a circuit as the static characteristics of the transistor vary with each circuit arrangement.

- Common Base Configuration – has Voltage Gain but no Current Gain.
- Common Emitter Configuration – has both Current and Voltage Gain.
- Common Collector Configuration – has Current Gain but no Voltage Gain.

4) The Common Base (CB) Configuration as an amplifier:

As its name suggests, in the Common Base or grounded base configuration, the BASE connection is common to both the input signal AND the output signal with the input signal being applied between the base and the emitter terminals. The corresponding output signal is taken from between the base and the collector terminals as shown with the base terminal grounded or connected to a fixed reference voltage point.

The input current flowing into the emitter is quite large as its the sum of both the base current and collector current respectively, therefore, the collector current output is less than the emitter current input resulting in a current gain for this type of circuit of “1” (unity) or less, in other words the common base configuration “attenuates” the input signal.

This type of amplifier configuration is a non-inverting voltage amplifier circuit, in that the signal voltages Vin and Vout are “in-phase”. This type of transistor arrangement is not very common due to its unusually high voltage gain characteristics. Its input characteristics represent that of a forward biased diode while the output characteristics represent that of an illuminated photo-diode.

Also this type of bipolar transistor configuration has a high ratio of output to input resistance or more importantly “load” resistance ( RL ) to “input” resistance ( Rin ) giving it a value of “Resistance Gain”. Then the voltage gain ( Av ) for a common base configuration is therefore given as:
Common Base Voltage Gain

\[ A_v = \frac{V_{out}}{V_{in}} = \frac{I_C \times R_L}{I_E \times R_{IN}} \]

Where: IC/IE is the current gain, alpha (α) and RL/Rin is the resistance gain.

The common base circuit is generally only used in single stage amplifier circuits such as microphone pre-amplifier or radio frequency (RF) amplifiers due to its very good high frequency response.

5) The Common Emitter (CE) Configuration as an amplifier

In the Common Emitter or grounded emitter configuration, the input signal is applied between the base and the emitter, while the output is taken from between the collector and the emitter as shown. This type of configuration is the most commonly used circuit for transistor based amplifiers and which represents the “normal” method of bipolar transistor connection.

The common emitter amplifier configuration produces the highest current and power gain of all the three bipolar transistor configurations. This is mainly because the input impedance is LOW as it is connected to a forward biased PN-junction, while the output impedance is HIGH as it is taken from a reverse biased PN-junction.
In this type of configuration, the current flowing out of the transistor must be equal to the currents flowing into the transistor as the emitter current is given as \( I_e = I_c + I_b \).

As the load resistance (RL) is connected in series with the collector, the current gain of the common emitter transistor configuration is quite large as it is the ratio of \( I_c/I_b \). A transistor’s current gain is given the Greek symbol of Beta, (\( \beta \)).

As the emitter current for a common emitter configuration is defined as \( I_e = I_c + I_b \), the ratio of \( I_c/I_e \) is called Alpha, given the Greek symbol of \( \alpha \). Note: that the value of Alpha will always be less than unity.

Since the electrical relationship between these three currents, \( I_b, I_c \), and \( I_e \) is determined by the physical construction of the transistor itself, any small change in the base current (\( I_b \)), will result in a much larger change in the collector current (\( I_c \)).

Then, small changes in current flowing in the base will thus control the current in the emitter-collector circuit. Typically, Beta has a value between 20 and 200 for most general purpose transistors. So if a transistor has a Beta value of say 100, then one electron will flow from the base terminal for every 100 electrons flowing between the emitter-collector terminal.

By combining the expressions for both Alpha, \( \alpha \) and Beta, \( \beta \) the mathematical relationship between these parameters and therefore the current gain of the transistor can be given as:
Where: “Ic” is the current flowing into the collector terminal, “Ib” is the current flowing into the base terminal and “Ie” is the current flowing out of the emitter terminal.

Then to summaries a little. This type of bipolar transistor configuration has a greater input impedance, current and power gain than that of the common base configuration but its voltage gain is much lower. The common emitter configuration is an inverting amplifier circuit. This means that the resulting output signal is 180° “out-of-phase” with the input voltage signal.

**Methodology:-**

- Use of charts and working models to explain the transistor
- Use of PowerPoint presentation on the concept
**Action of teacher in the class:-**

- Teacher will ask questions on the PN diode and its working.
- Teacher will explain the PNP and NPN transistors and their components.
- Teacher has to explain the concept with PowerPoint presentation.
- Teacher will summaries the concept and prepares the assessment test.
- Assessment of class test

**Assessment:-**

- Draw the symbols of NPN and PNP transistors?
- Why the base of transistor is thin as compared to emitter and collector?
- What are necessary conditions for action of transistor?
- Explain the working of CE NPN transistor as an amplifier with the help of suitable circuit diagram.
- Establish the relation between current gain in CB configuration and CE configuration of transistor as an amplifier?

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CONCEPT: PN JUNCTION DIODE AND RECTIFIER

Learning Objectives:- The objectives of the concept are to know about

- Study of intrinsic and extrinsic semiconductors and formation of PN Junction
- Explore the application of semiconductor devices as a rectifier.
- Conversion of AC into DC.
- Ripple factor
- We will study DC output obtained from the half wave and full wave rectifier.

Material Required:-
Chalk, duster, Power Point Presentation, Electric models of rectifier

Content:-

PN Junction Diode

When a P-type semiconductor is joined to a N-type semiconductor such that the crystal structure remains continuous at the boundary, the resulting arrangement is called a PN junction diode or a semiconductor diode or a crystal diode.

a) In forward bias due to relatively large no. of charge carriers diode offers low resistance, conversely in reverse bias due to smaller no. of charge carriers it offers high resistance and the current of very small magnitude flows through it.

b) Forward current is called diffusion current and the reverse current is called drift current.

c) Near the junction due to recombination of electrons and holes a layer is formed that is devoid of free charge carriers but contains fixed ions and is called depletion layer.

d) Size of depletion layer decreases in forward bias and increases in reverse biased position.

e) During flow of current the electrons and holes recombine at the junction and equal no. of electrons are supplied by the –ve terminal of the battery, whereas equal no. of holes are generated through the breaking of bonds near the +ve voltage region of the diode. The electrons so generated move to the +ve of the battery. Inside the diode current carriers are electrons on N-side and holes on P-side.

f) The property of the diode to offer low resistance in forward bias and very high resistance in reverse bias is used for rectifying i.e. changing A.C. to D.C.
PN Junction Diode as a Half Wave Rectifier:

The process of converting alternating current into direct current is called ‘rectification’.

The device used for rectification is called ‘rectifier’.

The PN junction diode offers low resistance in forward bias and high resistance in reverse bias.

A simple Half Wave Rectifier is nothing more than a single pn junction diode connected in series to the load resistor. If you look at the above diagram, we are giving an alternating current as input. Input voltage is given to a step down transformer and the resulting reduced output of transformer is given to the diode ‘D’ and load resistor RL. The output voltage is measured across load resistor RL.

The ac voltage across the secondary winding changes polarities after every half cycle of input wave. During the positive half-cycles of the input ac voltage i.e. when upper end of the secondary winding is positive w.r.t. its lower end, the diode is forward biased and therefore conducts current. If the forward resistance of the diode is assumed to be zero (in practice, however, a small resistance exists) the input voltage during the positive half-cycles is directly applied to the load resistance $R_L$, making its upper end positive w.r.t. its lower end. The waveforms of the output current and output voltage are of the same shape as that of the input ac voltage.

During the negative half cycles of the input ac voltage i.e. when the lower end of the secondary winding is positive w.r.t. its upper end, the diode is reverse biased and so does not conduct. Thus during the negative half cycles of the input ac voltage, the current through and voltage across the load remains zero. The reverse current, being very small in magnitude, is neglected. Thus for the negative half cycles no power is delivered to the load. Thus the output voltage (VL) developed across load resistance $R_L$ is a series of positive half cycles of alternating voltage, with intervening very small constant negative voltage levels, It is obvious from the figure that the output is not a steady dc, but only a pulsating dc wave. To make the output wave smooth and useful in a DC power supply, we have to use a filter across the load. Since only half-cycles of the input wave are used, it is called a half wave rectifier.
Ripple Factor
Ripple factor is in fact a measure of the remaining alternating components in a filtered rectifier output. It is the ratio of the effective value of the ac components of voltage (or current) present in the output from the rectifier to the dc component in output voltage (or current).

Disadvantages of Half wave rectifier
1. The output current in the load contains, in addition to dc component, ac components of basic frequency equal to that of the input voltage frequency. Ripple factor is high and an elaborate filtering is, therefore, required to give steady dc output.
2. The power output and, therefore, rectification efficiency is quite low. This is due to the fact that power is delivered only during one half cycle of the input alternating voltage.
3. Transformer utilization factor is low.
4. DC saturation of transformer core resulting in magnetizing current and hysteresis losses and generation of harmonics.

The DC output available from a half-wave rectifier is not satisfactory to make a general power supply. However it can be used for some applications like battery charging.

PN Junction Diode as a Full Wave Rectifier:

Full Wave Rectifier Circuit

The full wave rectifier circuit consists of two power diodes connected to a single load resistance \( (R_L) \) with each diode taking it in turn to supply current to the load. When point A of the transformer is positive with respect to point C, diode \( D_1 \) conducts in the forward direction as indicated by the arrows. When point B is positive (in the negative half
of the cycle) with respect to point C, diode $D_2$ conducts in the forward direction and the current flowing through resistor $R$ is in the same direction for both half-cycles. As the output voltage across the resistor $R$ is the phase or sum of the two waveforms combined, this type of full wave rectifier circuit is also known as a "bi-phase" circuit.

As the spaces between each half-wave developed by each diode is now being filled in by the other diode the average DC output voltage across the load resistor is now double that of the single half-wave rectifier circuit and is about $0.637V_{\text{max}}$ of the peak voltage, assuming no losses.

**The advantage of center-tap full wave rectifier:-**

1. The rectification efficiency of full-wave rectifier is double of that of a half-wave rectifier.
2. The ripple voltage is low and of higher frequency in case of full-wave rectifier so simple filtering circuit is required.
3. Higher output voltage, higher output power and higher Transformer Utilization Factor (TUF) in case of a full-wave rectifier.
4. In a full-wave rectifier, there is no problem due to dc saturation of the core because the dc current in the two halves of the two halves of the transformer secondary flow in opposite directions.

**Methodology:-**

- Use of electrical model of full wave rectifier & Vedio
  [https://www.youtube.com/watch?v=m1VC77kHmqI](https://www.youtube.com/watch?v=m1VC77kHmqI)

- Use of PowerPoint presentation on PN diode and its applications.

**Action of teacher in the class:-**

- Teacher will ask questions on semiconductors (specially on intrinsic, extrinsic semiconductor)
- Demonstration of formation of PN junction and Rectifier
- Teacher has to explain the concept with PowerPoint presentation.
- Teacher will summarise the concept and prepare the assessment test.
- Assessment of class test
**SUMMARY:-**

# When a P-type semiconductor is joined to a N-type semiconductor such that the crystal structure remains continuous at the boundary, the resulting arrangement is called a PN junction diode or a semiconductor diode or a crystal diode.
# Forward current is called diffusion current and the reverse current is called drift current.
# Near the junction due to recombination of electrons and holes a layer is formed that is devoid of free charge carriers but contains fixed ions and is called depletion layer.
# The process of converting alternating current into direct current is called 'rectification'.
# pn junction diode conducts current only when it is forward biased and does not when it is reverse biased.

**Assessment:-**

1. What do you mean by doping?
2. What is the direction of diffusion current in a diode?
3. How does the width of depletion layer of p-n junction diode change with decrease in reverse bias?
4. Name the type of biasing of a p – n junction diode so that the junction offers very high resistance.
5. Can we take one slab of p-type semiconductor and physically join it to another n-type semiconductor to get p-n junction?
6. In half-wave rectification, what is the output frequency if the input frequency is 50 Hz. What is the output frequency of a full-wave rectifier for the same input frequency.

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CONCEPT: LOGIC GATES

Learning Objectives: The objectives of the concept are to know about

- Explore the application of Boolean algebra in the design of electronic circuits. The basic elements of circuits are Gates. Each type of gate implements a Boolean operation.
- Binary quantities and variables.
- Study of logic gates
- We will study Combinational Circuits - the circuits whose output depends only on the input and not on the current state of the circuit.

Material Required:
Chalk, duster, Power Point Presentation, Electric models of logic gates

Content:

An Analog signal is any continuous signal for which the time varying feature (variable) of the signal is a representation of some other time varying quantity.

A digital signal uses discrete (discontinuous) values. By contrast, non-digital (or analog) systems use a continuous range of values to represent information.

Boolean algebra is the technique to draw the truth table for the given logic gate. The Boolean expressions represent the logic gates with number of inputs. The function of each gate can be represented by a truth table or using Boolean notation. Boolean algebra is the branch of algebra in which the values of the variables are the truth values true and false, usually denoted 1 and 0 respectively. Instead of elementary algebra where the values of the variables are numbers, and the main operations are
addition and multiplication, the main operations of Boolean algebra are
the conjunction \textit{AND}, denoted \textit{\&}, the disjunction \textit{OR}, denoted +, and the negation \textit{NOT},
denoted -.

\textbf{@ Boolean Constants}

1) Boolean algebra allows only two values; 0 and 1.
2) Logic 0 can be: false, off, low, no, open switch.
3) Logic 1 can be: true, on, high, yes, closed switch.
4) Three basic logic operations: OR, AND, and NOT.

\textbf{Boolean Variables}

- variables that can only take the values ‘0’ or ‘1’

\textbf{LOGIC GATES:–}

\begin{itemize}
  \item The OR gate
  \begin{itemize}
    \item S1
    \item S2
    \item L
  \end{itemize}
  \begin{tabular}{|c|c|c|}
    \hline
    S1 & S2 & L \\
    \hline
    0 & 0 & 0 \\
    0 & 1 & 1 \\
    1 & 0 & 1 \\
    1 & 1 & 1 \\
    \hline
  \end{tabular}

  \begin{itemize}
    \item (a) Circuit
    \item (b) Truth table
  \end{itemize}

  \begin{itemize}
    \item \textit{A} \text{ AND } \text{B} \rightarrow \text{C}
    \begin{itemize}
      \item \text{A} = \{0, 1\}
      \item \text{B} = \{0, 1\}
      \item \text{C} = \{0, 1\}
      \item \text{C} = \text{A \& B}
    \end{itemize}

    \begin{itemize}
      \item (a) Circuit symbol
      \item (b) Truth table
      \item (c) Boolean expression
    \end{itemize}
  \end{itemize}
\end{itemize}
- The NOT gate
COMBINATION OF GATES:

- **The NAND gate**

  ![NAND gate diagram]

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  (a) Circuit symbol  (b) Truth table  (c) Boolean expression $C = \overline{A \cdot B}$

- **The NOR gate:**

  ![NOR gate diagram]

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  (a) Circuit symbol  (b) Truth table  (c) Boolean expression $C = \overline{A + B}$

**Methodology:**

- Use of electrical model of logic gates to verify the truth table [https://www.youtube.com/watch?v=Xi18hI1LqAA](https://www.youtube.com/watch?v=Xi18hI1LqAA)
- Use of PowerPoint presentation on logic gates

**Action of teacher in the class:**

- Teacher will ask questions on number system (specially on decimal and binary number system)
- Demonstration of electric models and explains the input and output relations.
- Teacher has to explain the concept with PowerPoint presentation.
- Teacher will summarise the concept and prepare the assessment test.
- Assessment of class test
SUMMARY:-

- It is common to represent the two states of a binary variable by ‘0’ and ‘1’
- Logic circuits are usually implemented using logic gates
- Circuits in which the output is determined solely by the current inputs are termed combinational logic circuits
- Logic functions can be described by truth tables or using Boolean algebraic notation
- Binary digits may be combined to form digital words
- Digital words can be processed using binary arithmetic
- Several codes can be used to represent different forms of information

Assessment:-

- What are Boolean variables?
- What is the difference between analog signal and digital signal
- Give the truth tables and symbols of AND.
- Give the logic symbol, truth table and Boolean Expression for OR Gate
- How can we construct NAND GATE?
- Write down the Boolean expression and truth table for the following gate:

![Logic Gate Diagram]

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CONCEPT: AMPLITUDE MODULATION

Learning Objectives:- The objectives of the concept are to know about

- Need of modulation
- Modulation
- Amplitude Modulation
- Modulation Index
- Propagation of EM Wave
- LOS Communication

Material Required:-

Power Point Presentation, Charts etc.

Content:-

Need of modulation:-

i) To reduce the height of antenna:- The antenna used in communication may be half antenna or quarter antenna. The length of antenna is one-fourth of wavelength of signal. In modulation, frequency increases which decreases the wavelength and hence height of antenna.

ii) To increase of power of radiation of signal:- The power of antenna depends on length of antenna and wavelength of signal. Hence to increase the power modulation is required.

Power of antenna \( \propto \left(\frac{L}{\lambda}\right)^2 \).

iii) To avoid the mixing of signals from different transmitters.

Modulation:- Modulation is the process of variation of some characteristic of a high frequency wave (carrier wave) in accordance with the instantaneous value of a modulating signal.

Amplitude modulation (AM) is a modulation technique used in electronic communication, most commonly for transmitting information via a radio carrier wave. In amplitude modulation, the amplitude (signal strength) of the carrier wave is varied in proportion to the waveform being transmitted. That waveform may, for instance, correspond to the sounds to be reproduced by a loudspeaker, or the light intensity of television pixels. This technique contrasts with frequency modulation, in which the frequency of the carrier signal is varied, and phase modulation, in which its phase is varied.

AM was the earliest modulation method used to transmit voice by radio. "AM" is often used to refer to mediumwave AM radio broadcasting.
\[ e_m = E_m \sin \omega_mt \]  
(Modulating Signal)

\[ e_c = E_c \sin \omega_ct \]  
(Carrier Wave)

\[ e = (E_c + E_m \sin \omega_m t) \sin \omega_ct \]  
(Modulated Wave)

\[ e = E_c \sin \omega_c t + (m E /2) \cos (\omega_c - \omega_m)t - (m E /2) \cos (\omega_c + \omega_m)t \]

**Modulation Index:**

The AM modulation index is a measure based on the ratio of the modulation excursions of the RF signal to the level of the unmodulated carrier. It is thus defined as:

\[ h = \frac{\text{peak value of } m(t)}{A} = \frac{M}{A} \]

where \( M \) and \( A \) are the modulation amplitude and carrier amplitude, respectively; the modulation amplitude is the peak (positive or negative) change in the RF amplitude from its unmodulated value. Modulation index is normally expressed as a percentage, and may be displayed on a meter connected to an AM transmitter.

In practice, the propagation characteristics of these radio waves vary substantially depending on the exact frequency and the strength of the transmitted signal (a function of both the transmitter and the antenna characteristics). Broadcast FM radio, at comparatively low frequencies of around 100 MHz, are less affected by the presence of buildings and forests.
Propagation of Electromagnetic Wave:-

Electromagnetic transmission includes light emissions traveling in a straight line. The rays or waves may be diffracted, refracted, reflected, or absorbed by atmosphere and obstructions with material and generally cannot travel over the horizon or behind obstacles.

Ground Wave Propagation:- At low frequency (below approximately 3 MHz) radio signals travel as ground waves, which follow the Earth’s curvature due to diffraction with the layers of the atmosphere. This enables AM radio signals in low-noise environments to be received well after the transmitting antenna has dropped below the horizon.
(ii) **Sky Wave Propagation**:- Frequencies between approximately 1 and 30 MHz can be reflected by the F1/F2 Layer, thus giving radio transmissions in this range a potentially global reach (see shortwave radio), again along multiple deflected straight lines. The effects of multiple diffraction or reflection lead to macroscopically "quasi-curved paths".

(iii) **Space Wave Propagation**:- However, at higher frequencies and in lower levels of the atmosphere, neither of these effects are significant. Thus any obstruction between the transmitting antenna (transmitter) and the receiving antenna (receiver) will block the signal, just like the light that the eye may sense. Therefore, since the ability to visually see a transmitting antenna (disregarding the limitations of the eye's resolution) roughly corresponds to the ability to receive a radio signal from it, the propagation characteristic of VHF and higher radio frequency (>30 MHz) paths is called "line-of-sight". The farthest possible point of propagation is referred to as the "radio horizon".

The *radio horizon* is the locus of points at which direct rays from an antenna are tangential to the surface of the Earth. If the Earth were a perfect sphere and there were no atmosphere, the radio horizon would be a circle.

![Diagram of radio horizon](image)

R is the radius of the Earth, h is the height of the transmitter (exaggerated), d is the line of sight distance

The radio horizon of the transmitting and receiving antennas can be added together to increase the effective communication range. Antenna heights above 1,000,000 feet (189 miles; 305 kilometres) will cover the entire hemisphere and not increase the radio horizon.

*Radio wave propagation* is affected by atmospheric conditions, *ionospheric absorption*, and the presence of obstructions, for example mountains or trees. Simple formulas that include the effect of the atmosphere give the range as:

\[
\text{horizon}_{\text{miles}} \approx \sqrt{2 \times \text{height}_{\text{feet}}} \cdot \\
\text{horizon}_{\text{km}} \approx 3.57 \cdot \sqrt{\text{height}_{\text{metres}}}
\]
Geometric distance to horizon

Assuming a perfect sphere with no terrain irregularity, the distance to horizon from a high altitude transmitter (i.e., line of sight) can readily be calculated.

Let \( R \) be the radius of Earth and \( h \) be the altitude of a telecommunication station. Line of sight distance \( d \) of this station is given by the Pythagorean theorem:

\[
d^2 = (R + h)^2 - R^2 = 2 \cdot R \cdot h + h^2
\]

Since the altitude of the station is much less than the radius of the Earth,

\[
d \approx \sqrt{2 \cdot R \cdot h}
\]

If the height is given in metres, and distance in kilometres,[2]

\[
d \approx 3.57 \cdot \sqrt{h}
\]

**Line of Sight (LoS)**

Line of sight (LoS) is a type of propagation that can transmit and receive data only where transmit and receive stations are in view of each other without any sort of an obstacle between them. FM radio, microwave and satellite transmission are examples of line-of-sight communication. Travel time only then represents the distance between transmitter and receiver, when line of sight propagation is the basis for the measurement.

**Methodology:-**

- Use of charts and models to explain the modulation and propagation of electromagnetic wave
- **Use of PowerPoint presentation on the concept**

**Action of teacher in the class:-**

- Teacher will ask questions on the basic communication system
- Teacher will explain the modulation with the help of charts
- Teacher has to explain the concept with PowerPoint presentation.
- Teacher will summarise the concept and prepare the assessment test.
- Assessment of class test
Assessment:-

- What is the need of modulation?
- What is modulation? Explain amplitude modulation graphically.
- Distinguish ground wave, sky wave and space wave propagation.
- What is modulation index?
- What is line of sight communication? Which propagation used in LoS?

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