12th STD.

# PUBLIC EXAMINATION - MARCH - 2023

Reg. No.

PART - III

## PHYSICS

(With Answers)

Time Allowed : 3.00 Hours ] [ Maximum Marks : 70

**Instructions :** (1) Check the question paper for fairness of printing. If there is any lack of fairness, inform the Hall Supervisor immediately.
(2) Use **Blue** or **Black** ink to write and underline and pencil to draw diagrams.

### PART - I

**Note :** (i) Answer **all** the questions. **(15 × 1 = 15)**
(ii) Choose the most appropriate answer from the given **four** alternatives and write the option code and the corresponding answer.

1. The wavelength $\lambda_e$ of an electron and $\lambda_p$ of a photon of same energy E are related by :

   (a) $\lambda_p \propto \frac{1}{\sqrt{\lambda_e}}$ (b) $\lambda_p \propto \lambda_e$
   (c) $\lambda_p \propto \lambda_e^2$ (d) $\lambda_p \propto \sqrt{\lambda_e}$

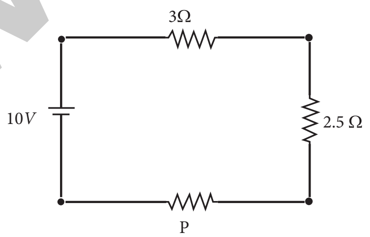
2. Two polaroids are kept with their transmission axes inclined at 30°. Unpolarised light of intensity I falls on the first polariod. Intensity of light emerging from the second polaroid.

   (a) $\frac{1}{8}I$ (b) $\frac{1}{4}I$ (c) $\frac{3}{8}I$ (d) $\frac{3}{4}I$

3. If the magnitude of the magnetic field is $3 \times 10^{-6}$T, then the magnitude of the electric field for a electromagnetic wave is :

   (a) 600 $Vm^{-1}$ (b) 100 $Vm^{-1}$
   (c) 900 $Vm^{-1}$ (d) 300 $Vm^{-1}$

4. There is a current of 1.0 A in the circuit shown below. What is the resistance of P ?




   (a) 3.5 Ω (b) 1.5 Ω
   (c) 4.5 Ω (d) 2.5 Ω

5. A carbon resistor of (47 ± 4.7 ) k Ω is to be marked with rings of different colours for its identification. The colour code sequence will be :

   (a) Violet – Yellow – Orange – Silver
   (b) Yellow – Green – Violet – Gold
   (c) Green – Orange – Violet - Gold
   (d) Yellow – Violet – Orange – Silver

6. In an hydrogen atom, the electron revolving in the second orbit, has angular momentum :

   (a) $\frac{4h}{\pi}$ (b) h (c) $\frac{2h}{\pi}$ (d) $\frac{h}{\pi}$

7. In Young's double-slit experiment, the slit separation is doubled. To maintain the same fringe spacing on the screen, the screen-to-slit distance D must be changed to :

   (a) $\sqrt{2D}$ (b) 2D (c) $\frac{D}{\sqrt{2}}$ (d) $\frac{D}{2}$

8. A parallel plate capacitor stores a charge Q at a voltage V. Suppose the area of the parallel plate capacitor and distance between the plates are each doubled them which is the quantity that will change?

   (a) Voltage (b) Capacitance
   (c) Energy density (d) Charge

9. An electromagnetic wave is propagating in a medium with velocity $\vec{\upsilon} = \upsilon\hat{i}$. The instantaneous oscillating electric field of this electromagnetic wave is along $+Y$ axis, then the direction of oscillating magnetic field of the electromagnetic wave will be along:

   (a) $+Z$ direction (b) $-Y$ direction

   (c) $-Z$ direction (d) $-X$ direction

10. For light incident from air on a slab of refractive index 2, the maximum possible angle of refraction is :

    (a) 60° (b) 30° (c) 90° (d) 45°

11. The Zener diode is primarily used as :

    (a) Oscillator (b) Rectifier

    (c) Voltage regulator (d) Amplifier

12. The flux linked with a coil at any instant t is given by $\Phi_B = 15t^2 - 50t + 250$. The induced emf at t = 3s is :

    (a) –40 V (b) – 190 V

    (c) 40 V (d) – 10 V

13. An example of Diamagnetic material is ________.

    (a) Nickel (b) Water

    (c) Aluminium (d) Iron

14. What is value of Forbidden Energy gap for silicon at room temperature?

    (a) 0.3eV (b) 0.7eV

    (c) 0.9eV (d) 1.1 eV

15. The alloys used for muscle wires in Robots are :

    (a) Gold silver alloys

    (b) Shape memory alloys

    (c) Two dimensional alloys

    (d) Gold copper alloys

## PART - II

**Note :** Answer **any six** questions. Question number **24** is **Compulsory.** **(6 × 2 = 12)**

16. Define 'electric field'.

17. How will you define Q-factor?

18. State Ampere's Circuital Law.

19. Explain the reason for the glittering of diamond.

20. The ratio of intensities of two waves in an interference pattern is 36 : 1. What is the ratio of the amplitudes of the two interfering waves?

21. Define work function of a metal. Give its unit.

22. What is meant by activity or decay rate? Give its unit.

23. Draw the circuit diagram of a full wave rectifier.

24. If the resistance of coil is 3 Ω at 20°C and α = 0.004/°C then, determine its resistance at 100°C

## PART - III

**Note :** Answer **any six** questions. Question number **33** is **Compulsory.** **(6 × 3 = 18)**

25. Derive an expression for electrostatic potential due to a point charge.

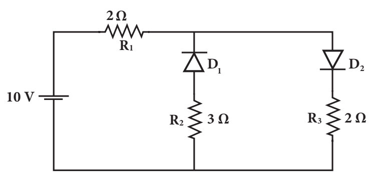
26. State Kirchhoff's First and Second Rules.

27. Explain the conversion of galvanometer into an ammeter.

28. How will you induce an emf by changing the area enclosed by the coil?

29. What are Fraunhofer lines? How are they useful in the identification of elements present in the Sun?

30. The given circuit has two ideal diodes connected as shown in figure below. Calculate the current flowing through the resistance $R_1$.



31. What is optical path? Write down the equation for optical path and mention what each term represents.

32. Write any three Laws of Photoelectric Effect.

33. Calculate the amount of energy released in joules when 1 kg of $^{235}_{92}U$ undergoes fission reaction.

## PART - IV

**Note:** Answer **all** the questions **(5 × 5 = 25)**

34. (a) (i) State Coulomb's Law in electrostatics.

(ii) State the differences between Coulomb force and Gravitational force.

**(OR)**

(b) Describe the Fizeau's method to determine the speed of light.

35. (a) Discuss the working of Cyclotron in detail.

**(OR)**

(b) Discuss the diffraction at single slit and obtain the condition for $n^{th}$ minimum.

36. (a) Derive an expression for phase angle between the applied voltage and current in a series RLC circuit.

**(OR)**

(b) Describe Davisson-Germer experiment which demonstrated the wave nature of the electrons.

37. (a) Describe the microscopic model of current and obtain microscopic form of Ohm's Law.

**(OR)**

(b) Derive an expression for Radius and Velocity of an electron in the $n^{th}$ orbit using Bohr atom model.

38. (a) (i) Write down the properties of electromagnetic waves.

(ii) The relative magnetic permeability of the medium is 2.5 and the relative electrical permittivity of the medium is 2.25. Compute the refractive index of the medium.

**(OR)**

(b) Describe the function of a transistor as an amplifier with the neat circuit diagram. Sketch the input and output waveforms.

# ANSWERS

## PART - I

1. (c) $\lambda_p \propto \lambda_e^2$
2. (c) $\frac{3}{8}I$
3. (c) 900 $Vm^{-1}$
4. (c) 4.5 Ω
5. (d) Yellow – Violet – Orange – Silver
6. (d) $\frac{h}{\pi}$
7. (b) 2D
8. (c) Energy density
9. (a) +Z direction
10. (b) 30°
11. (c) Voltage regulator
12. (a) –40V
13. (b) Water
14. (d) 1.1 eV
15. (b) Shape memory alloys

## PART - II

16. (i) The electric field at the point P at a distance $r$ from the point charge $q$ is the force experienced by a unit charge and is given by

$$\vec{E} = \frac{\vec{F}}{q_0} = \frac{kq}{r^2}\hat{r} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$

(ii) Here $\hat{r}$ is the unit vector pointing from $q$ to the point of interest P.

(iii) The electric field is a vector quantity.

(iv) SI unit is Newton per Coulomb ($NC^{-1}$).

17. It is defined as the ratio of voltage across L or C at resonance to the applied voltage.

$$\text{Q - factor} = \frac{\text{Voltage across L or C at resonance}}{\text{Applied voltage}}$$

18. **Ampère's law:** The line integral of magnetic field over a closed loop is $\mu_0$ times net current enclosed by the loop.

$$\oint_C \vec{B}.\vec{dl} = \mu_0 I_{enclosed}$$

19. (i) Diamond appears dazzling because of the total internal reflection of light that happens inside the diamond. The refractive index of diamond is about 2.417.

(ii) It is much greater than the refractive index of ordinary glass which is about only 1.5. The critical angle of diamond is about 24.4°.

(iii) It is much less than that of ordinary glass. A skilled diamond cutter makes use of this larger range of angle of incidence (24.4° to 90° inside the diamond), to ensure that light entering the diamond is total internally reflected from the many cut faces before getting out. This gives a sparkling effect for diamond.

20. **Given data :** Maximum and minimum intensities in interference = 36 : 1

**To find :** Ratio of amplitudes $a_1 : a_2$ = ?

$$I_{max} = (a_1 + a_2)^2 \quad ...(1)$$

$$I_{min} = (a_1 - a_2)^2 \quad ...(2)$$

$$\frac{36}{1} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2}$$

Taking square root

$$\frac{6}{1} = \frac{(a_1 + a_2)}{(a_1 - a_2)}$$

$$6(a_1 - a_2) = (a_1 + a_2)$$

$$6a_1 - 6a_2 = a_1 + a_2$$

$$6a_1 - a_1 = 6a_2 + a_2$$

$$5a_1 = 7a_2$$

$$\frac{a_1}{a_2} = \frac{7}{5}$$

Ratio of amplitudes $a_1 : a_2 = 7 : 5$

21. (i) The minimum energy needed for an electron to escape from the metal surface is called work function of that metal.

(ii) It is denoted by $\phi_0$ and is measured in electron volt (eV).

22. Activity (R) or decay rate which is the number of nuclei decayed per second and it is denoted as

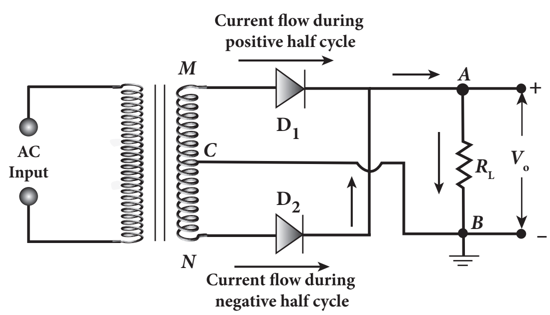
$$R = \left|\frac{dN}{dt}\right|$$

$$R = \left|\frac{dN}{dt}\right| = \lambda N_0 e^{-\lambda t}$$

$$R = R_0 e^{-\lambda t}.$$

The SI unit of activity R is Becquerel. There is also another standard unit for the activity called Curie(Ci).

23.



24. $R_0 = 3\Omega$, T = 100°C, $T_0$ = 20°C

$\alpha = 0.004/°C$, $R_T$ = ?

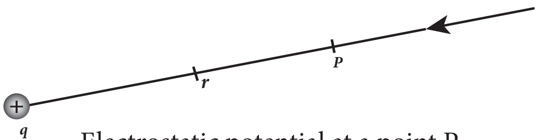
$R_r = R_0 (1 + \alpha (T - T_0))$

$R_{100} = 3 (1 + 0.004 \times 80)$

$R_{100} = 3.96\Omega$

## PART - III

25. (i) Consider a positive charge $q$ kept fixed at the origin. Let P be a point at distance $r$ from the charge $q$. This is shown in Figure.




Electrostatic potential at a point P

(ii) The electric potential at the point P is

$$V = \int_{\infty}^{r} \left(-\vec{E}\right) \cdot d\vec{r} = -\int_{\infty}^{r} \vec{E} \cdot d\vec{r} \qquad ...(1)$$

Electric field due to positive point charge q is

$$\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \hat{r}$$

$$V = \frac{-1}{4\pi\varepsilon_0} \int_{\infty}^{r} \frac{q}{r^2} \hat{r} . d\vec{r}$$

The infinitesimal displacement vector,

$d\vec{r} = dr\hat{r}$ and using $\hat{r} . \hat{r} = 1$, we have

$$V = -\frac{1}{4\pi\varepsilon_0} \int_{\infty}^{r} \frac{q}{r^2} \hat{r} . dr\hat{r} = -\frac{1}{4\pi\varepsilon_0} \int_{\infty}^{r} \frac{q}{r^2} dr$$

After the integration,

$$V = -\frac{1}{4\pi\varepsilon_0} q \left\{-\frac{1}{r}\right\}_{\infty}^{r} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r}$$

Hence the electric potential due to a point charge $q$ at a distance $r$ is

$$V = \frac{1}{4\pi\varepsilon_0} \frac{q}{r} \qquad ...(2)$$

**Important points :**

(i) If the source charge q is positive, V > 0. If $q$ is negative, then V is negative and equal to

$$V = \frac{1}{4\pi\varepsilon_0} \frac{q}{r}$$

(ii) It is clear that the potential due to positive charge decreases as the distance increases, but for a negative charge the potential increases as the distance is increased. At infinity, ($r = \infty$) electrostatic potential is zero (V = 0).

(iii) A positive charge moves from a point of higher electrostatic potential to a point of lower electrostatic potential and a negative charge moves from lower electrostatic potential to higher electrostatic potential.

(iv) The electric potential at a point P due to a collection of charges $q_1$, $q_2$, $q_3$....$q_n$ is equal to sum of the electric potentials due to individual charges.

26. **Kirchhoff's First Rules (Current rule) :**

(i) Kirchhoff's current rule states that the algebraic sum of the currents at any junction of a circuit is zero.

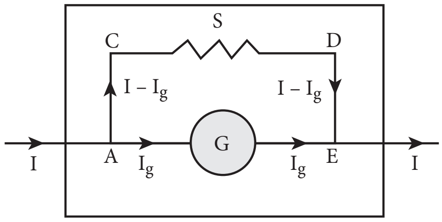
(ii) It is a statement of law of conservation of electric charge.

**Kirchhoff's Second Rules (Voltage rule):**

(i) It states that in a closed circuit the algebraic sum of the products of the current and resistance of each part of the circuit is equal to the total emf included the circuit.

(ii) This rule follows from the law of conservation of energy for an isolated system.

27. **Galvanometer into an ammeter :** A galvanometer is converted into an ammeter by connecting a low resistance in parallel with the galvanometer. This low resistance is called shunt resistance S.




**Ammeter**
**Shunt resistance connected in parallel**

I - Current passing through circuit

$I_g$ - Current passing through galvanometer

$R_g$ - galvanometer resistance

$(I - I_g)$ - current passing through shunt

S - shunt resistance

The potential difference across galvanometer is same as the potential difference across shunt resistance.

$$V_{galvanometer} = V_{shunt}$$

$$\Rightarrow \quad I_g R_g = (I - I_g)S$$

$$S = \frac{I_g}{(I - I_g)} R_g \text{ or}$$

$$I_g = \frac{S}{S + R_g} I$$

Since, the deflection in the galvanometer is proportional to the current passing through it.

$$\theta = \frac{1}{G} I_g \Rightarrow \theta \propto I_g \Rightarrow \theta \propto I$$

So, the deflection produced in the galvanometer is a measure of the current I passing through the circuit.

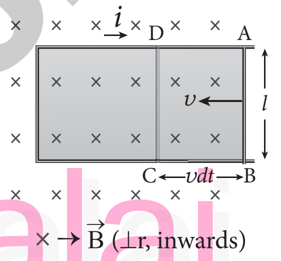
Shunt resistance is connected in parallel to galvanometer. Therefore, resistance of ammeter $(R_a)$ can be determined by computing the effective resistance, which is

$$\frac{1}{R_{eff}} = \frac{1}{R_g} + \frac{1}{S} \Rightarrow R_{eff} = \frac{R_g S}{R_g + S} = R_a$$

Since, the shunt resistance is a very low resistance and the ratio $\frac{S}{R_g}$ is also small. This means, $R_a$ is also small, i.e., the resistance offered by the ammeter is small.

28. (i) Consider a conducting rod of length $l$ moving with a velocity $v$ towards left on a rectangular fixed metallic framework as shown in Figure, and is placed in a uniform magnetic field $\vec{B}$ whose magnetic lines are perpendicularly directed into the plane of the paper.

(ii) As the rod moves from AB to DC in a time dt, the area enclosed by the loop changes and hence the magnetic flux through the loop decreases.




**Production of induced emf by changing the area enclosed by the loop**

(iii) The change in magnetic flux in time $dt$ is

$$d\Phi_B = B \times \text{change in area (dA)}$$

$$= B \times \text{Area ABCD}$$

Since area ABCD $= l\,(vdt)$

$$d\Phi_B = Blvdt \quad \text{(or)} \quad \frac{d\Phi_B}{dt} = Blv$$

(iv) As a result of change in flux, an emf is generated in the loop. The magnitude of the induced emf is

$$\varepsilon = \frac{d\Phi_B}{dt} \quad \varepsilon = Blv$$

**(v)** This emf is called motional emf. The direction of induced current is found to be clockwise from Fleming's right hand rule.

29. (i) When the spectrum obtained from the Sun is examined, it consists of large number of dark lines (line absorption spectrum). These dark lines in the solar spectrum are known as Fraunhofer lines.

(ii) The absorption spectra for various materials are compared with the Fraunhofer lines in the solar spectrum, which helps in identifying elements present in the Sun's atmosphere.

30. **Given Date :**

Applied voltage V = 10 V

$R_1 = 2\Omega$ ; $R_2 = 3\Omega$ ; $R_3 = 2\Omega$ ;

$D_1$ is reverse biased. So no current flows in the branch of diode $D_1$.(Block the current)

$D_2$ is forward biased and effects no resistance in the circuit. (pass the current)

Effective resistance $= R_1 + R_3$

$= 2 + 2 = 4\,\Omega$

$\therefore$ Current I $= \dfrac{V}{R} = \dfrac{10}{4}$

$\boxed{I = 2.5\text{ A}}$

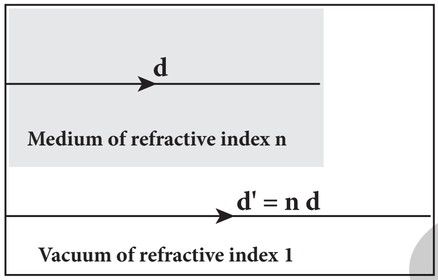
31. (i) Optical path of a medium is defined as the distance $d'$ light travels in vacuum in the same time it travels a distance $d$ in the medium.

(ii) Let us consider a medium of refractive index $n$ and thickness $d$. Light travels with a speed $v$ through the medium in a time $t$. The speed of light through the medium is written as,

$\upsilon = \dfrac{d}{t}$; rewritten for $t$ as, $t = \dfrac{d}{\upsilon}$;

In the same time $t$, light can cover a longer distance $d'$ in vacuum as it travels with greater speed $c$ in vacuum.

Now, we can write,




**Optical path**

$c = \dfrac{d'}{t}$; rewritten for $t$ as, $t = \dfrac{d'}{c}$

As the time taken in both the cases is the same, we can equate the time $t$,

$$\frac{d'}{c} = \frac{d}{\upsilon}$$

Rewritten for the optical path $d'$ as, $d' = \dfrac{c}{\upsilon} d$

As, $\dfrac{c}{\upsilon} = n$; the optical path $d'$ is,

$d' = nd$

The value of $n$ is always greater than 1, for a medium. Thus, the optical path $d'$ of a medium is always greater than $d$.

32. (i) For a given metallic surface, the emission of photoelectrons takes place only if the frequency of incident light is greater than a certain minimum frequency called the threshold frequency.

(ii) For a given frequency of incident light, the number of photoelectrons emitted is directly proportional to the intensity of the incident light. The saturation current is also directly proportional to the intensity of incident light.

(iii) Maximum kinetic energy of the photo electrons is independent of intensity of the incident light.

(iv) Maximum kinetic energy of the photo electrons from a given metal is directly proportional to the frequency of incident light.

(v) There is no time lag between incidence of light and ejection of photoelectrons.

33. **Solution :**

235 g of $^{235}_{92}U$ has $6.02 \times 10^{23}$ atoms. In one gram of $^{235}_{92}U$, the number of atoms is equal to

$$\frac{6.02 \times 10^{23}}{235} = 2.56 \times 10^{21}$$

So the number of atoms present in 1kg of

$^{235}_{92}U = 2.56 \times 10^{21} \times 1000 = 2.56 \times 10^{24}$

Each $^{235}_{92}U$ nucleus releases 200 MeV of energy during the fission. The total energy released by 1 kg of $^{235}_{92}U$ is

Q $= 2.56 \times 10^{24} \times 200$ MeV $= 5.12 \times 10^{26}$ Mev

In terms of joules,

$$Q = 5.12 \times 10^{26} \times 1.6 \times 10^{-13} J$$

$$= 8.192 \times 10^{13} J$$

## PART - IV

34.(a) (i) According to Coulomb, the force on the point charge $q_2$ exerted by another point charge $q_1$ is

$$\vec{F}_{21} = k\frac{q_1 q_2}{r^2}\hat{r}_{12}$$

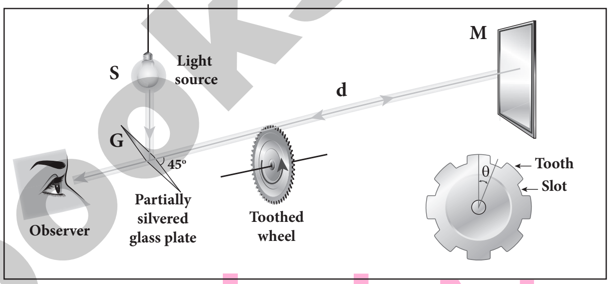
where $\hat{r}_{12}$ is the unit vector directed from charge $q_1$ to charge $q_2$ and k is the proportionality constant.

(ii)

| S. No | Coulomb | Gravitational |
|---|---|---|
| i) | It may be attractive or repulsive. | It is always attractive in nature. |
| ii) | It depends upon medium | It does not depend upon the medium |
| iii) | It is always greater in magnitude because of high value of $K = 9 \times 10^9\ Nm^2 C^{-2}$ | It is lesser than coulomb force because value of G is $6.67 \times 10^{-11}\ Nm^2 kg^{-2}$ |
| iv) | The force between the charges will not be same during motion or rest. | It is always same whether the two masses are rest or motion |

**(OR)**

(b) **Apparatus :** The apparatus used by Fizeau for determining speed of light in air medium is shown in Figure.




**Speed of light by Fizeau's method**

(i) The light from the source S was first allowed to fall on a partially silvered glass plate G kept at an angle of 45° to the incident light.

(ii) The light then was allowed to pass through a rotating toothed-wheel with N teeth and N cuts of equal widths whose speed of rotation could be varied through an external mechanism.

(iii) The light passing through one cut in the wheel will get reflected by a mirror M kept at a long distance d, about 8 km from the toothed wheel.

(iv) The toothed wheel was not rotating, the light reflected back from the mirror would again pass through the same cut and reach the eyes of the observer through the partially silvered glass plate.

**Working :**

(i) The angular speed of rotation of the toothed wheel was increased from zero to a value ω until light passing through one cut would completely be blocked by the adjacent tooth.

(ii) This is ensured by the disappearance of light while looking through the partially silvered glass plate.

**Expression for speed of light :** The speed ($v$) of light in air is equal to the ratio of the distance ($2d$) the light travelled from the toothed wheel to the mirror and to the time taken $t$.

$$v = \frac{2d}{t} \quad ...(1)$$

**(i)** The distance $d$ is a known value from the arrangement. The time taken $t$ for the light to travel the distance $2d$ is calculated from the angular speed ω of the toothed wheel.

**(ii)** The angular speed ω of the toothed wheel when the light disappeared for the first time is,

$$\omega = \frac{\theta}{t} \quad ...(2)$$

**(iii)** Here, θ is the angle between one tooth and the next slot which is turned within that time $t$.

$$\theta = \frac{\text{total angle of the circle in radian}}{\text{number of teeth + number of cuts}}$$

$$\theta = \frac{2\pi}{2N} = \frac{\pi}{N}$$

Substituting for θ in the equation (2),

$$\omega = \frac{\pi / N}{t} = \frac{\pi}{Nt}$$

Rewriting the above equation for $t$,

$$t = \frac{\pi}{N\omega} \quad ...(3)$$

Substituting $t$ from equation (3) in equation (1),

$$v = \frac{2d}{\pi / N\omega}$$

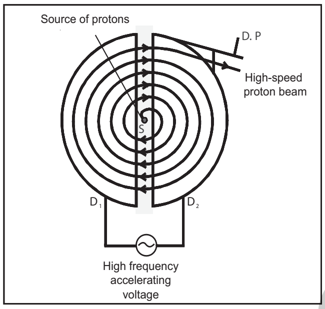
After rearranging $v = \dfrac{2dN\omega}{\pi}$

The speed of light in air was determined as,

$V = 2.99792 \times 10^8 \text{ ms}^{-1}$

35. (a) **Cyclotron :** Cyclotron is a device used to accelerate the charged particles to gain large kinetic energy. It is also called as high energy accelerator. It was invented by Lawrence and Livingston in 1934.

**Principle :** When a charged particle moves perpendicular to the magnetic field, it experiences magnetic Lorentz force.




Working of cyclotron

**Construction:**

(i) The particles are allowed to move in between two semi-circular metal containers called Dees (hollow D - shaped objects).

(ii) Dees are enclosed in an evacuated chamber and it is kept in a region with uniform magnetic field controlled by an electromagnet.

(iii) The direction of magnetic field is normal to the plane of the Dees. The two Dees are kept separated with a gap and the source S (which ejects the particle to be accelerated) is placed at the centre in the gap between the Dees. Dees are connected to high frequency alternating potential difference.

**Working:**

(i) Let us assume that the ion ejected from source S is positively charged. As soon as ion is ejected, it is accelerated towards a Dee (say, Dee – 1) which has negative potential at that time. Since the magnetic field is normal to the plane of the Dees, the ion moves in a circular path. After one semi-circular path inside Dee-1, the ion reaches the gap between Dees. At this time, the polarities of the Dees are reversed so that the ion is now accelerated towards Dee-2 with a greater velocity. For this circular motion, the centripetal force on the charged particle $q$ is provided by Lorentz force.

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

$$\Rightarrow r = \frac{m}{qB}v$$

$$\Rightarrow r \propto v \quad \text{---------(1)}$$

(ii) From the equation, (1) the increase in velocity increases the radius of circular path. This process continues and hence the particle moves in spiral path of increasing radius. Once it reaches near the edge, it is taken out with the help of deflector plate and allowed to hit the target T.

(iii) The important condition in cyclotron operation is that when the frequency f at which the positive ion circulates in the magnetic field must be equal to the constant frequency of the electrical oscillator $f_{osc}$. This is called resonance condition.

From equation, we have

$$f_{osc} = \frac{qB}{2\pi m}$$

The time period of oscillation is

$$T = \frac{2\pi m}{qB}$$

The kinetic energy of the charged particle is

$$KE = \frac{1}{2}mv^2 = \frac{q^2B^2r^2}{2m}$$

**Limitations:**

(i) the speed of the ion is limited

(ii) electron cannot be accelerated

(iii) uncharged particles cannot be accelerated

**(OR)**

(b) (i) Let a parallel beam of light fall normally on a single slit AB of width a. The diffracted beam falls on a screen kept at a distance D from the slit. The center of the slit is C.

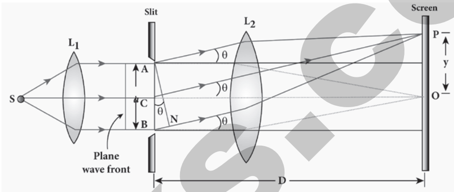
(ii) A straight line through C perpendicular to the plane of slit meets the center of the screen at O. Consider at any point P on the screen is to be found.

(iii) All the light reaching the point P from different points on the slit make an angle θ with the normal CO.

(iv) All the light waves start parallel to each other from different points of the slit and interfere at point P and other points to give the resultant intensities.

(v) The point P is in the geometrically shadowed region, up to which the central maximum is spread due to diffraction. Condition for the point P to be of various minima.

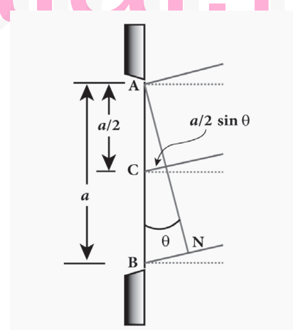
(vi) Divide the slit into much smaller even number of parts. Then, add their contributions at P with the proper path difference to show that destructive interference takes place at that point to make it minimum.




Diffraction at single slit

**Condition for P to be first minimum :**

(i) Let us divide the slit AB into two halves AC and CB. Now the width of each part is $\left(\frac{a}{2}\right)$. We have different points on the slit which are separated by the same width $\frac{a}{2}$ called corresponding points as shown in Figure.




**Corresponding points**

(ii) The path difference of light waves from different corresponding points meeting at point P and interfere destructively to make it first minimum. The path difference δ between waves from these corresponding points is, $\delta = \frac{a}{2}\sin\theta$

The condition for P to be first minimum,

$$\frac{a}{2}\sin\theta = \frac{\lambda}{2}$$

$$a \sin\theta = \lambda \text{ (first minimum)}$$

**Condition for P to be second minimum :**

(i) Let us divide the slit AB into four equal parts. Now, the width of each part is $\frac{a}{4}$. We have several corresponding points on the slit which are separated by the same width $\frac{a}{4}$. The path difference $\delta$ between the waves from these corresponding points is, $\delta = \frac{a}{4} \sin\theta$.

(ii) The condition for P to be second minimum,

$$\frac{a}{4} \sin\theta = \frac{\lambda}{2}$$

$$a \sin\theta = 2\lambda \text{ (second minimum)}$$

**Condition for P to be third minimum :**

The same way the slit is divided in to six equal parts to explain the condition for P to be third minimum is, $\frac{a}{6} \sin\theta = \frac{\lambda}{2}$

$$a \sin\theta = 3\lambda \text{ (third minimum)}$$

**Condition for P to be $n^{th}$ minimum :**

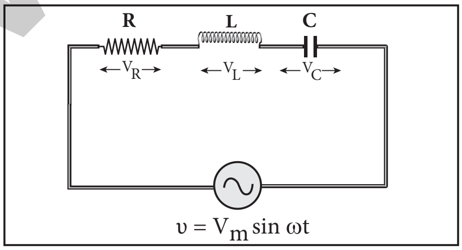
Dividing the slit into 2n number of (even number of) equal parts makes the light produced by one of the corresponding points to be cancelled by its counterpart. Thus, the condition for $n^{th}$ order minimum is,

$$\frac{a}{2n} \sin\theta = \frac{\lambda}{2}$$

$$a \sin\theta = n\lambda \text{ } (n^{th} \text{ minimum})$$

36. (a) (i) Consider a circuit containing a resistor of resistance R, an inductor of inductance L and a capacitor of capacitance C connected across an alternating voltage source (Figure ). The instantaneous value of the alternating voltage is given by

$$\upsilon = V_m \sin \omega t$$




**AC circuit containing R, L and C**

(ii) Let $i$ be the resulting current in the circuit at that instant. As a result, the voltage is developed across R, L and C.

(iii) We know that voltage across R ($V_R$) is in phase with $i$, voltage across L ($V_L$) leads $i$ by $\frac{\pi}{2}$ and voltage across C ($V_C$) lags behind $i$ by $\frac{\pi}{2}$

(iv) The phasor diagram is drawn with current as the reference phasor. The current is represented by the phasor $\vec{OI}$ $V_R$ by $\vec{OA}$ ; $V_L$ by $\vec{OB}$; $V_C$ by $\vec{OC}$ as shown in Figure.

(v) The length of these phasors are $OI = I_m$, $OA = I_m R$, $OB = I_m X_L$; $OC = I_m X_C$ The circuit is either effectively inductive or capacitive or resistive depending on the value of $V_L$ or $V_C$. Let us assume that $V_L > V_C$. Therefore, net voltage drop across L-C combination is $V_L - V_C$ which is represented by a phasor $\vec{OD}$

(vi) By parallelogram law, the diagonal $\vec{OE}$ gives the resultant voltage $\upsilon$ of $V_R$ and $(V_L - V_C)$ and its length OE is equal to $V_m$. Therefore,

$$V_m^2 = V_R^2 + (V_L - V_C)^2$$

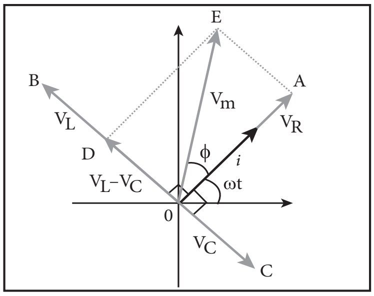
$$V_m = \sqrt{(I_m R)^2 + (I_m X_L - I_m X_C)^2}$$

$$= I_m \sqrt{R^2 + (X_L - X_C)^2} \quad \text{or}$$

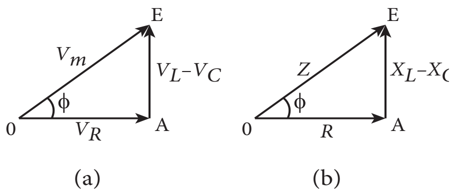
$$I_m = \frac{V_m}{\sqrt{R^2 + (X_L - X_C)^2}} \quad \text{or } I_m = \frac{V_m}{Z}$$

$$\text{where } Z = \sqrt{R^2 + (X_L - X_C)^2}$$

(vii) Z is called impedance of the circuit which refers to the effective opposition to the current by the series RLC circuit. The voltage triangle and impedance triangle are given in the Figure.




**Phasor diagram for a series RLC – circuit when $V_L > V_C$**




**Voltage and impedance triangle when $X_L > X_C$**

(viii) From phasor diagram, the phase angle between υ and $i$ is found out from the following relation

$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$$

**Special cases :**

(i) If $X_L > X_C$, $(X_L - X_C)$ is positive and phase angle Φ is also positive.

$\therefore i = I_m \sin \omega t;\ V = V_m \sin(\omega t + \Phi)$

(ii) If $X_L < X_C$, $(X_L - X_C)$ is negative and Φ is also negative.

$\therefore i = I_m \sin \omega t;\ V = V_m \sin(\omega t - \Phi)$

(iii) If $X_L = X_C$, Φ is zero. Therefore current and voltage are in the same phase and the circuit is resistive.

$\therefore \upsilon = V_m \sin \omega t;\ i = I_m \sin \omega t$

**(OR)**

(b) **Davisson – Germer experiment :**

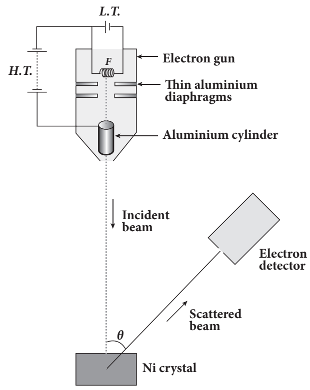
(i) Louis de Broglie hypothesis of matter waves was experimentally confirmed by Clinton Davisson and Lester Germer in 1927.

(ii) They demonstrated that electron beams are diffracted when they fall on crystalline solids.

(iii) Since crystal can act as a three-dimensional diffraction grating for matter waves, the electron waves incident on crystals are diffracted off in certain specific directions.

(iv) The filament F is heated by a low tension (L.T.) battery. Electrons are emitted from the hot filament by thermionic emission. They are then accelerated due to the potential difference between the filament and the anode aluminium cylinder by a high tension (H.T.) battery.

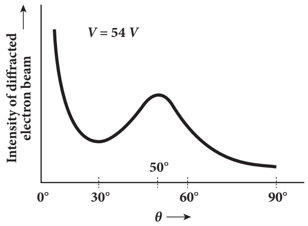
(v) Electron beam is collimated by using two thin aluminium diaphragms and is allowed to strike a single crystal of Nickel.




**Experimental set up of Davisson - Germer experiment**

(vi) The electrons scattered by Ni atoms in different directions are received by the electron detector which measures the intensity of scattered electron beam.

(vii) The detector is capable of rotation in the plane of the paper so that the angle θ between the incident beam and the scattered beam can be changed at our will. The intensity of the scattered electron beam is measured as a function of the angle θ.




Variation of intensity of diffracted electron beam with the angle θ

(viii) From the graph shows the variation of intensity of the scattered electrons with the angle θ for the accelerating voltage of 54V. For a given accelerating voltage V, the scattered wave shows a peak or maximum at an angle of 50° to the incident electron beam.

(ix) This peak in intensity is attributed to the constructive interference of electrons diffracted from various atomic layers of the target material.

(x) From the known value of interplanar spacing of Nickel, the wavelength of the electron wave was experimentally calculated as 1.65Å.

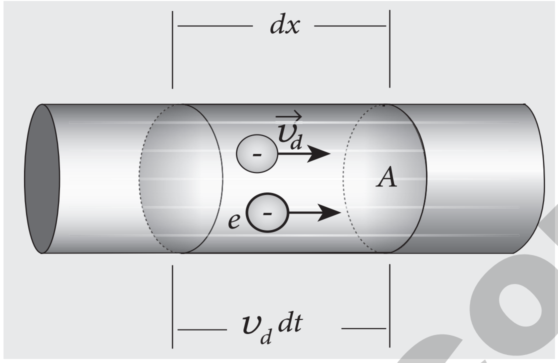
(xi) The wavelength can also be calculated from de Broglie relation for V = 54 V from equation.

$$\lambda = \frac{12.27}{\sqrt{V}} \text{Å} = \frac{12.27}{\sqrt{54}} \text{Å}$$

$$\lambda = 1.67 \text{ Å}.$$

(xii) This value agrees very well with the experimentally observed wavelength of 1.65Å. Thus this experiment directly verifies de Broglie's hypothesis of the wave nature of moving particles.

37. (a) Consider a conductor with area of cross section A and let an electric field $\vec{E}$ be applied to it from right to left. Suppose there are $n$ electrons per unit volume in the conductor and assume that all the electrons move with the same drift velocity $\vec{v}_d$.




**Microscopic model of current**

The drift velocity of the electrons = $v_d$

If the electrons move through a distance $dx$ within a small interval of $dt$, then

$$v_d = \frac{dx}{dt} \; ; dx = v_d \, . \, dt \qquad \text{...... (1)}$$

Since A is the area of cross section of the conductor, the electrons available in the volume of length $dx$ is

= volume × number of electrons per unit volume

$$= A dx \times n \qquad \text{...... (2)}$$

Substituting for $dx$ from equation (1) in (2)

$$= (A \, v_d \, dt) \, n$$

Total charge in the volume element

$dQ$ = (charge) × (number of electrons in the volume element)

$$dQ = (e) \, (A \, v_d \, dt) \, n$$

Hence the current $I = \frac{dQ}{dt}$

$$I = ne \, Av_d \qquad \text{...... (3)}$$

**Current density (J)**

The current density $(J)$ is defined as the current per unit area of cross section of the conductor.

$$J = \frac{1}{A}$$

The S.I unit of current density is $\frac{A}{m^2}$ (or) $Am^{-2}$

$$J = \frac{neAv_d}{A} \text{ (from equation 3)}$$

$$J = nev_d \qquad \text{...... (4)}$$

The above expression is valid only when the direction of the current is perpendicular to the area A. In general, the current density is a vector quantity and it is given by

$$\vec{J} = ne\vec{v}_d$$

Substituting $\vec{v_d}$ from equation

$$\vec{J} = -\frac{n.e^2\tau}{m}\vec{E} \quad \text{...... (5)}$$

$$\vec{J} = -\sigma\vec{E}$$

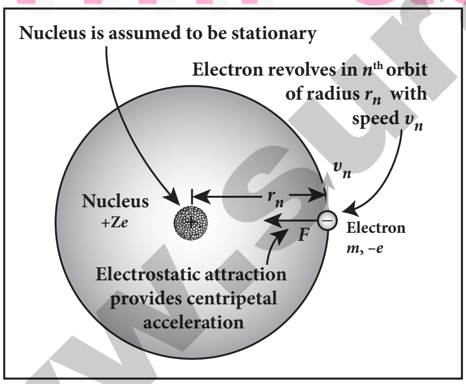
But conventionally, we take the direction of (conventional) current density as the direction of electric field. So the above equation becomes

$$\vec{J} = \sigma\vec{E} \quad \text{...... (6)}$$

where $\sigma = \frac{ne^2\tau}{m}$ is called conductivity. The equation (6) is called microscopic form of ohm's law.

**(OR)**

(b) **Radius of the orbit and velocity of the electron :** Consider an atom which contains the nucleus at rest and an electron revolving around the nucleus in a circular orbit of radius $r_n$.




**Electron revolving around the nucleus**

Let $Z$ be the atomic number of the atom, then $+Ze$ is the charge of the nucleus. Let $-e$ be the charge of the electron. From Coulomb's law, the force of attraction between the nucleus and the electron is

$$\vec{F}_{coloumb} = \frac{1}{4\pi\varepsilon_0}\frac{(+Ze)(-e)}{r_n^2}\hat{r}$$

$$= -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n^2}\hat{r}$$

This force provides necessary centripetal force

$$\vec{F}_{centripetal} = -\frac{m\upsilon_n^2}{r_n}\hat{r}$$

where $m$ be the mass of the electron that moves with a velocity $\upsilon_n$ in a circular orbit. Therefore,

$$|\vec{F}_{coloumb}| = |\vec{F}_{centripetal}|$$

$$\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n^2} = \frac{m\upsilon_n^2}{r_n}$$

Multiplied and divided by '$m$'

$$r_n = \frac{4\pi\varepsilon_0(m\upsilon_n r_n)^2}{Zme^2}$$

From Bohr's assumption, the angular momentum quantization condition,

$$m\upsilon_n r_n = l = n\hbar,$$

$$\therefore r_n = \frac{4\pi\varepsilon_0(m\upsilon_n r_n)^2}{Zme^2}$$

$$r_n = \frac{4\pi\varepsilon_0(n\hbar)^2}{Zme^2} = \frac{4\pi\varepsilon_0 n^2\hbar^2}{Zme^2}$$

$$r_n = \left(\frac{\varepsilon_0 h^2}{\pi me^2}\right)\frac{n^2}{Z} \quad (\because \hbar = \frac{h}{2\pi})$$

where $n \in \mathbb{N}$. Since, $\varepsilon_0$, $h$, $e$ and $\pi$ are constants. Therefore, the radius of the orbit becomes

$$r_n = a_0\frac{n^2}{Z}$$

where $a_0 = \frac{\varepsilon_0 h^2}{\pi me^2} = 0.529$ Å. This is known as Bohr radius which is the smallest radius of the orbit in hydrogen atom.

Bohr radius is also used as unit of length called Bohr. 1 Bohr = 0.53 Å. For hydrogen atom (Z = 1), the radius of $n^{th}$ orbit is, $r_n = a_0 n^2$.

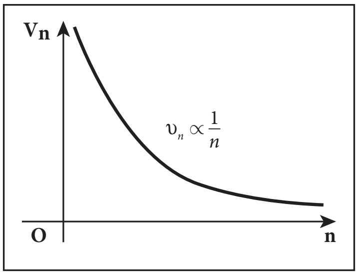
Thus the radius of the orbit from centre increases with n, that is, $r_n \propto n^2$

Further, Bohr's angular momentum quantization condition leads to

$$\frac{mv_n a_0 n^2}{Z} = n\frac{h}{2\pi}\left[\because r_n = a_0\frac{n^2}{Z}\right]$$

$$v_n = \frac{h}{2\pi m a_0}\frac{Z}{n}$$

in atomic physics $v_n \alpha = \frac{1}{n}$




Variation of velocity

**The energy of an electron in the $n^{th}$ orbit :**

The electrostatic force is a conservative force, the potential energy for the $n^{th}$ orbit is

$$U_n = \frac{1}{4\pi\varepsilon_0}\frac{(+Ze)(-e)}{r_n} = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n}$$

$$= -\frac{1}{4\varepsilon_0^2}\frac{Z^2me^4}{h^2n^2}\left(\because r_n = \frac{\varepsilon_0 h^2}{\pi me^2}\frac{n^2}{Z}\right)$$

The kinetic energy of the electron in $n^{th}$ orbit is

$$KE_n = \frac{1}{2}mv_n^2 = \frac{me^4}{8\varepsilon_0^2h^2}\frac{Z^2}{n^2}$$

This implies that $U_n = -2\ KE_n$. Total energy of the electron in in the $n^{th}$ orbit is

$E_n = KE_n + U_n = KE_n - 2KE_n = -KE_n$

$$E_n = -\frac{me^4}{8\varepsilon_0^2h^2}\frac{Z^2}{n^2}$$

For hydrogen atom (Z = 1),

$$E_n = -\frac{me^4}{8\varepsilon_0^2h^2}\frac{1}{n^2}\text{ joule} \qquad (1)$$

where $n$ stands for principal quantum number. The negative sign in equation (1) indicates that the electron is bound to the nucleus.

38. (a) **(i) Properties of electromagnetic waves :**

(i) Electromagnetic waves are produced by any accelerated charge.

(ii) Electromagnetic waves do not require any medium for propagation. So electromagnetic wave is a non-mechanical wave.

(iii) Electromagnetic waves are transverse in nature. The oscillating electric field vector, oscillating magnetic field vector and propagation vector (gives direction of propagation) are mutually perpendicular to each other.

(iv) Electromagnetic waves travel with speed which is equal to the speed of light in vacuum or free space.

(v) In a medium with permittivity ε and permeability μ, the speed of electromagnetic wave $v$ is less than that in free space or vacuum ($v < c$).

(vi) Electromagnetic waves are not deflected by electric field or magnetic field.

(vii) Electromagnetic waves can exhibit interference, diffraction and polarization.

(viii) Electromagnetic waves also carry energy, linear momentum and angular momentum.

**(ii)** Dielectric constant (relative permittivity of the medium), $\varepsilon_r = 2.25$

Magnetic permeability, $\mu_r = 2.5$

Refractive index of the medium,

$$n = \sqrt{\varepsilon_r \mu_r} = \sqrt{2.25 \times 2.5} = 2.37$$

**(OR)**

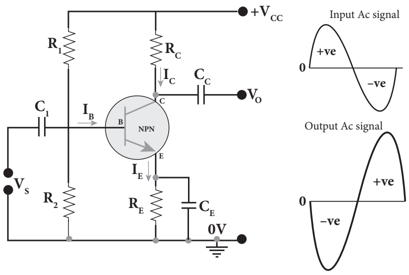
(b) A transistor operating in the active region has the capability to amplify weak signals.

**Principle :**

(i) Amplification is the process of increasing the signal strength (increase in the amplitude).

(ii) If a large amplification is required, the transistors are cascaded with coupling elements like resistors, capacitors, and transformers and they are called multistage amplifiers.

(iii) Here, the amplification of an electrical signal is explained with a single stage transistor amplifier is shown in Figure.




(a) Transistor as an amplifier
(b) Input and output waveform showing 180° phase reversal.

**Construction :**

(i) Single stage indicates that the circuit consists of one transistor with the allied components. An NPN transistor is connected in the common emitter configuration.

(ii) The Q point or the operating point of the transistor is fixed so as to get the maximum signal swing at the output (neither towards saturation point nor towards cut-off).

(iii) A load resistance, $R_C$ is connected in series with the collector circuit to measure the output voltage.

(iv) The capacitor $C_1$ allows only the AC signal to pass through.

(v) The emitter bypass capacitor $C_E$ provides a low reactance path to the amplified AC signal.

(vi) The coupling capacitor $C_C$ is used to couple one stage of the amplifier with the next stage while constructing multistage amplifiers. $V_S$ is the sinusoidal input signal source applied across the base-emitter.

(vii) The output is taken across the collector-emitter.

Collector current, $I_C = \beta I_B \left[\because \beta = \frac{I_C}{I_B}\right]$

(viii) Applying Kirchhoff's voltage law to the output loop, the collector-emitter voltage is given by

$$V_{CE} = V_{CC} - I_C R_C$$

**Working of the amplifier :**

(i) **During the positive half cycle :** Input signal ($V_s$) increases the forward voltage across the emitter-base. As a result, the base current ($I_B$) increases.

(ii) Consequently, the collector current ($I_C$) increases β times.

(iii) This increases the voltage drop across $R_C$ ($I_C R_C$) which in turn decreases the collector-emitter voltage ($V_{CE}$).

(iv) Therefore, the input signal during the positive half cycle produces negative half cycle of the amplified signal at the output. Hence, the output signal is reversed by 180°.

**During the negative half cycle :**

(i) Input signal ($V_s$) decreases the forward voltage across the emitter-base.

(ii) As a result, base current ($I_B$) decreases and in turn increases the collector current ($I_C$).

(iii) The decrease in collector current ($I_C$) decreases the potential drop across $R_C$ and increases the collector-emitter voltage ($V_{CE}$).

(iv) Thus, the input signal during the negative half cycle produces positive half cycle of the amplified signal at the output.

(v) Therefore, 180° phase reversal is observed during the negative half cycle of the input signal.

★ ★ ★