XII PHYSICS (OUTSIDE DELHI 2015)

Time allowed : 3 hours   *Maximum Marks : 70*

General Instructions :

(i)   *There are 26 questions in all. All questions are compulsory.*

(ii)   *This question paper has five sections : Section A, Section B, Section C, Section D and Section E.*

(iii)   *Section A contains five questions of one mark each, Section B contains five questions of two marks each, Section C contains twelve questions of three marks each, Section D contains one value based question of four marks and Section E contains three questions of five marks each.*

(iv)   *There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all the three questions of five marks weightage. You have to attempt only one of the choices in such questions.*

(v)   *You may use the following values of physical constants wherever necessary :*

$c = 3 \times 10^8$ m/s

$h = 6.63 \times 10^{-34}$ Js

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

$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}
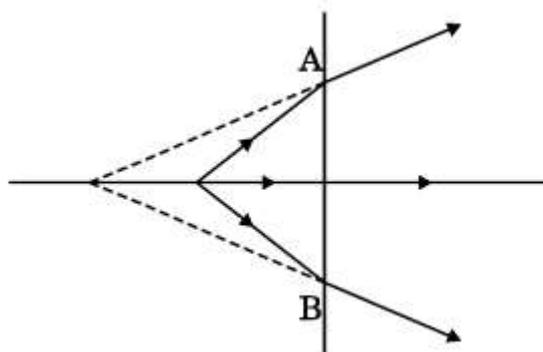
$\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}

$\dfrac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^2 C^{-2}

$m_e = 9.1 \times 10^{-31}$ kg

1) Depict the electric field lines due to two positive charges kept a certain distance apart.

2) The line AB in the ray diagram represents a lens. State whether the lens is convex or concave.

---

3) Define the term 'wattless current'.

4) Why are repeaters used in communication system ?

5) I - V graph for two identical conductors of different materials A and B is shown in the figure. Which one of the two has higher resistivity ?
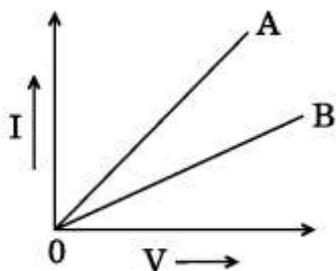
SECTION - B

6) Deuterons and α - particles are accelerated through the same potential. Find the ratio of the associated de Broglie wavelengths of the two.

7) The energy levels of an atom are given below in the diagram.
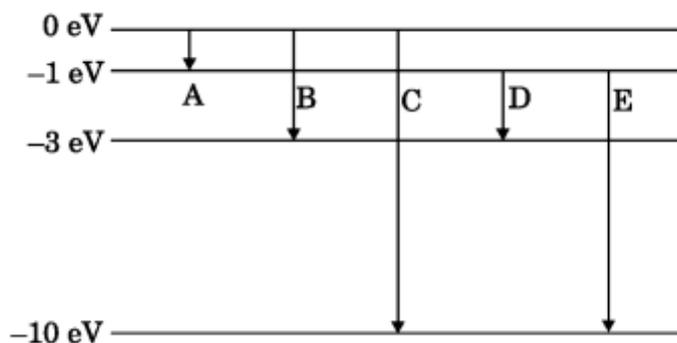
Which of the transitions belong to Lyman and Balmer series ? Calculate the ratio of the shortest wavelengths of the Lyman and the Balmer series of the spectra.

8) For an amplitude modulated wave, the maximum amplitude is found to be 10 V while the minimum amplitude is 2 V. Determine the value of modulation index μ.

What would be the value of μ if the minimum amplitude is zero volt ? Why is p generally kept less than 1 ?

9) A ray of light incident on one of the faces of a glass prism of angle 'A' has angle of incidence 2A. The refracted ray in the prism strikes the opposite face which is silvered, the reflected ray from it retracing its path. Trace the ray diagram and find the relation between the refractive index of the material of the prism and the angle of the prism.

OR

An object is placed 40 cm from a convex lens of focal length 30 cm. If a concave lens of focal length 50 cm is introduced between the convex lens and the image formed such that it is 20 cm from the convex lens, find the change in the position of the image.

10) In the circuit diagram shown, AB is a uniform wire of resistance 15 n and length 1 m. It is connected to a cell E_1 of emf 2 V and negligible internal resistance and a resistance R. The balance point with another cell E_2 of emf 75 mV is found at 30 cm from end A. Calculate the value of the resistance R.
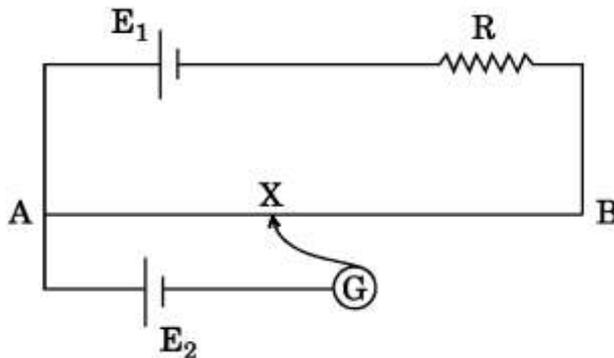
SECTION C

11) A 600 pF capacitor is charged by a 200 V supply. It is then disconnected from the supply and is connected to another uncharged 300 pF capacitor. Calculate how much electrostatic energy is lost in the process. What is the source of energy loss ?

12) How are the following types of electromagnetic waves produced :

(i) Microwaves

(i i)   Infra-red waves Write two important uses of each of the above electromagnetic radiations.

13) Draw the circuit arrangement for studying the V – I characteristics of a p-n junction diode (i) in forward bias and (ii) in reverse bias. Draw the typical V – I characteristics of a silicon diode. Describe briefly the following terms :

(i) "minority carrier injection" in forward bias

(i i) "breakdown voltage" in reverse bias

14) (a) Give a brief description of the basic elementary process involved in the photoelectric emission in Einstein's picture.

(b) When a photosensitive material is irradiated with the light of frequency ν , the maximum speed of electrons is given by v_{max} . A plot of v_{max}^2 is found to vary with frequency as shown in the figure.
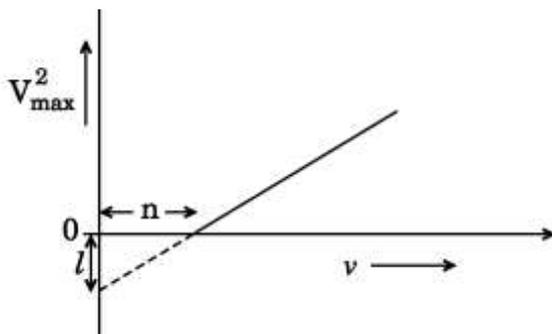
Use Einstein's photoelectric equation to find the expressions for (i) Planck's constant and (ii) work function of the given photosensitive material, in terms of the parameters l, n and mass m of the electron.

15) Draw a circuit diagram to study the input and output characteristics of an n-p-n transistor in common emitter configuration. Explain briefly how this arrangement is used to obtain the typical input/output characteristics of a transistor. Draw the graphs showing the nature of input/output curves.

OR

Draw a labelled circuit diagram of a full wave rectifier. Explain its underlying principle and working. Depict the input and output waveforms.

Describe briefly the role of a capacitor in filtering.

16) Draw a schematic sketch of a cyclotron. Explain its working principle

Obtain the necessary mathematical expression to show how this machine is used to accelerate charged particles.

17) Write the expression for the resultant intensity at a point due to the superposition of two monochromatic waves $y_1 = a \cos \omega t$, $y_2 = a \cos (\cos \omega t + \phi)$

where ϕ is the phase difference between the two waves and a and ω denote the amplitude and angular frequency.

In Young's double slit experiment using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ is k units. Find the intensity at a point on the screen where path difference is $\lambda/4$.

18) Suppose you wish to transmit an electronic signal in the audio frequency range over a long distance directly. Write briefly the three important factors which prevent you from doing so and explain how you overcome these factors.

19) (a) Plot a graph showing the variation of binding energy per nucleon as a function of mass number. Which property of nuclear force explains the approximate constancy of binding energy in the range $30 < A < 170$?

(b) A radioactive nucleus 'A' undergoes series of decays shown in the following scheme :

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\gamma} A_3$$
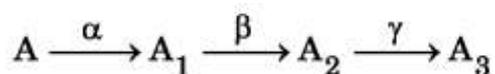
If the mass number and atomic number of A_3 are 176 and 69 respectively, find the mass number and atomic number of A.

20) Discuss briefly, with the help of a suitable diagram, what happens when unpolarised light passes through two identical polaroids where the orientation of one polaroid is fixed and the second is rotated with respect to the one. Draw a graph showing the dependence of intensity of transmitted light on the angle between the polariser and analyser. Explain clearly how one understands this variation using Malus' law.

21) A resistor of 100 Ω and a capacitor of 100/π µF are connected in series to a 220 V, 50 Hz a.c. supply.

(a) Calculate the current in the circuit.

(b) Calculate the (rms) voltage across the resistor and the capacitor. Do you find the algebraic sum of these voltages more than the source voltage ? If yes, how do you resolve the paradox ?

22) When a metallic conductor is subjected to a certain potential V across its ends, discuss briefly how the phenomenon of drift occurs. Hence define the term 'drift velocity' of charge carriers and show that the current density $\vec{j}$ is related to the applied electric field $\vec{E}$ by the relation

$\vec{j} = \sigma \vec{E}$ where σ defines the conductivity of the material.

SECTION D

23) Deepika and Ruchika were asked by their teacher to perform an experiment using a galvanometer. Before doing the experiment they were very keen to know the different parts of the galvanometer which was given to them in the form of a small box. They approached the teacher and asked for the permission. The teacher thought it would be a good idea if the galvanometer be opened before the whole class and explained its construction and working to all of them.

Based on the above paragraph, answer the following questions :

(a) What, in your opinion, were the qualities displayed by Deepika, Ruchika and the teacher ?

(b) State briefly the working principle of the galvanometer.

(c) What is the shape of the magnets used and why is it so designed ?

24) A right circular cylinder of length 'a' and radius 'r' has its centre at the origin and its axis along the x-axis so that one face is at x = + a/2 and the other at x = − a/2, as shown in the figure. A uniform electric field is acting parallel to the x-axis such that $\vec{E} = E_0 \hat{i}$ for x > 0 and $\vec{E} = E_0 \hat{i}$ for x < 0.
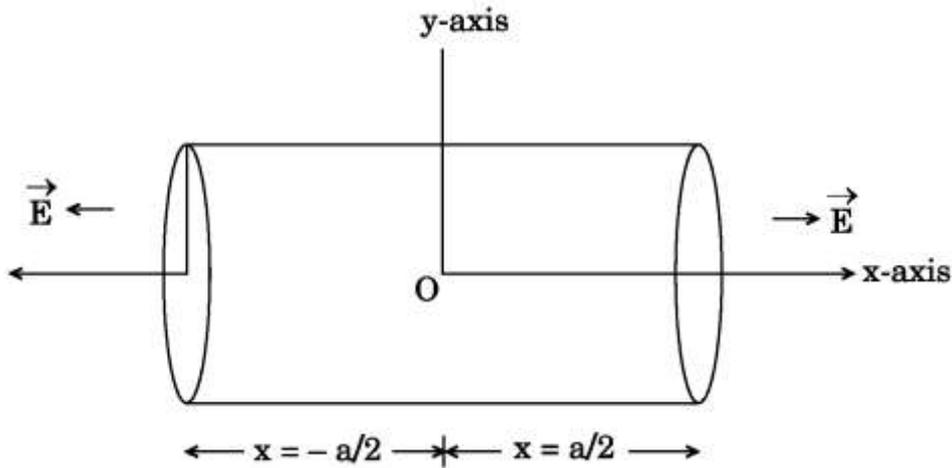
Find out the flux (i) through the flat faces, (ii) through the curved surface of the cylinder. What is the net outward flux through the cylinder and the net charge inside the cylinder ?

OR

(a)   Show, using Gauss's law, that for a parallel plate capacitor consisting of two large plane parallel conductors having surface charge densities $+\sigma$ and $-\sigma$, separated by a small distance in vacuum, the electric field

(i) in the outer regions of both the plates is zero,

(ii)   is $\dfrac{\sigma}{\varepsilon_0}$ in the inner region between the charged plates.

Hence obtain the expression for the capacitance of a parallel plate capacitor.

(b)   Explain what is the effect of inserting a dielectric slab of dielectric constant k in the intervening space inside the plates on

(i)   the electric field,
(ii) the capacitance of the capacitor.

25) (a) State two main considerations taken into account while choosing the objective in optical telescopes with large diameters.

(b) Draw a ray diagram for the formation of image by a reflecting type telescope. What is its magnifying power ?

(c) What are the advantages of a reflecting type telescope over the refracting type ?

OR

(a) Draw a ray diagram for the formation of image by a compound microscope in normal adjustment.

(b) Obtain the expression for the minimum separation between the two points seen as distinct in a microscope. What is its relation with the resolving power ? Mention the factors by which the resolving power of a microscope can be increased.

26) (a) Explain the meaning of mutual inductance of a solenoid S_1 with respect to the solenoid S_2.

(b) Consider two concentric circular coils, one of radius r_1 and the other of larger radius r_2 ($r_1 << r_2$), placed coaxially with centres coinciding with each other. Obtain the expression for the mutual inductance of the arrangement.

(c) In an experimental arrangement of two coils C_1 and C_2 placed coaxially parallel to each other, find out the expression for the emf induced in the coil C_1 (of N_1 turns) corresponding to the change of current I_2 in the coil C_2 (of N_2 turns).

OR

(a) State Ampere's circuital law. Show that the magnetic field B at a distance r outside the straight infinite wire carrying current I is tangential and is given by $B = \mu_o I / (2\pi r)$.

(b) Consider a long straight cylindrical wire of circular cross-section of radius a, as shown in the figure. The current I is uniformly distributed across this cross-section. Calculate the magnetic field B in the region $r <$ a and $r >$ a. Plot a graph of B versus r from the centre of the wire.
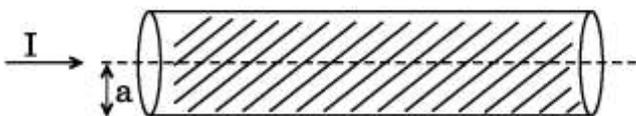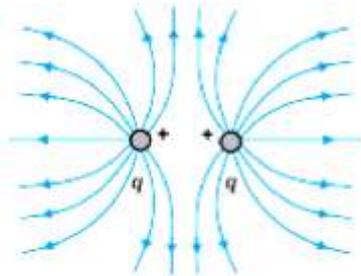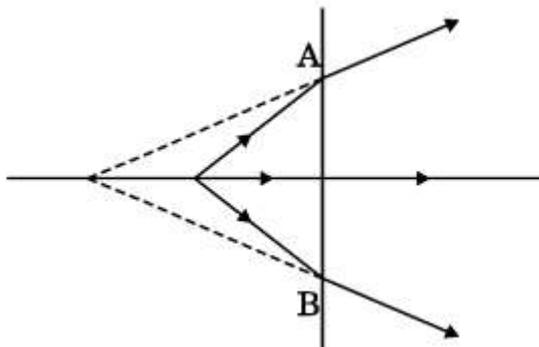
SOLUTIONS

2015 OUT SIDE DELHI

1) **Depict the electric field lines due to two positive charges kept a certain distance apart.**

SOL:

2) **The line AB in the ray diagram represents a lens. State whether the lens is convex or concave.**

SOL: Convex lens OR Converging lens

3) **Define the term 'wattless current'.**

SOL: A current is said to be wattless if the average power consumed over one complete cycle is zero.

Alternatively,

In a a.c. circuit containing pure inductor or pure capacitor the phase difference between voltage and current is $\dfrac{\pi}{2}$. Hence $\cos\phi = 0$ and no power is dissipated even though a current is flowing in the circuit. This current is referred as wattless current.

Alternatively,

The component of the current perpendicular to the applied voltage does not contribute power in an LCR circuit. Hence it is referred as wattless current.

4) **Why are repeaters used in communication system ?**

SOL: Repeaters are used to increase/extend the range of a communication system.

5) **I - V graph for two identical conductors of different materials A and B is shown in the figure. Which one of the two has higher resistivity ?**
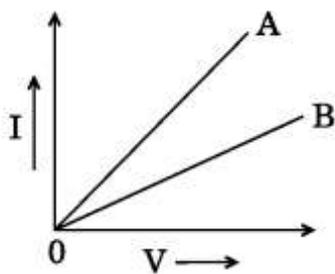
Sol: B has higher resistivity.

SECTION - B

6) **Deuterons and α - particles are accelerated through the same potential. Find the ratio of the associated de Broglie wavelengths of the two.**
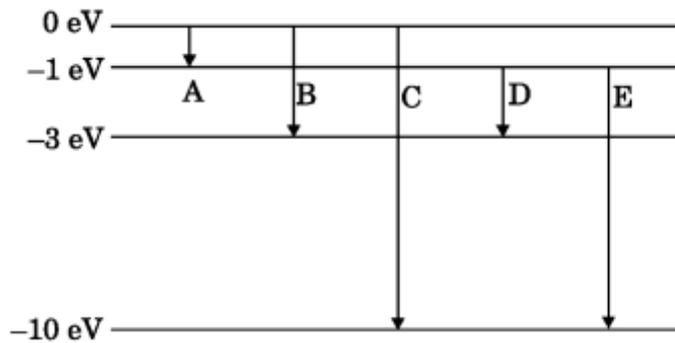
Sol:

De-Broglie wavelength $\lambda = \dfrac{h}{\sqrt{2mqV}}$

Ratio of de-Broglie wavelengths of deuterons and ∝ - particle

$$= \frac{\lambda_D}{\lambda_\propto} = \frac{\sqrt{2m_\propto q_\propto V}}{\sqrt{2m_d q_d V}}$$

$$= \frac{\sqrt{2 \times 4m_p \times 2qV}}{\sqrt{2 \times 2m_p \times q \times V}}$$

$$= 2$$

7) **The energy levels of an atom are given below in the diagram.**

Which of the transitions belong to Lyman and Balmer series ? Calculate the ratio of the shortest wavelengths of the Lyman and the Balmer series of the spectra.

Sol:

Lyman series - C and E
Blamer Series – B and D

Ratio of the shortest wavelength $\frac{\lambda_L}{\lambda_B} = \frac{3}{10} = 0.3$

Alternatively

Ratio of the shortest wavelength $\frac{\lambda_L}{\lambda_B} = \frac{n_1^2}{n_2^2} = \frac{1}{4}$

8) **For an amplitude modulated wave, the maximum amplitude is found to be 10 V while the minimum amplitude is 2 V. Determine the value of modulation index µ.**

What would be the value of µ if the minimum amplitude is zero volt ? Why is p generally kept less than 1 ?

Sol:

$$A_c + A_m = 10\,V$$
$$A_c - A_m = 2\,V$$

On solving we get Modulation Index $\mu = \frac{A_m}{A_c} = \frac{4}{6} = \frac{2}{3}$

If the value of minimum amplitude $A_c - A_m = 0$, $A_c = A_m = 5V$

Then $\mu = \frac{A_m}{A_c} = 1$

μ is kept less than one to avoid distortion.

9) **A ray of light incident on one of the faces of a glass prism of angle 'A' has angle of incidence 2A. The refracted ray in the prism strikes the opposite face which is silvered, the reflected ray from it retracing its path. Trace the ray diagram and find the relation between the refractive index of the material of the prism and the angle of the prism.**

Sol:
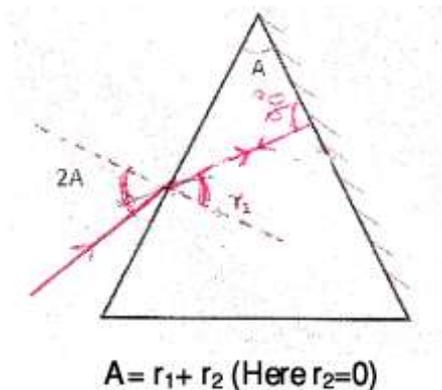
$A = r_1 + r_2$ (Here $r_2 = 0$)

OR

An object is placed 40 cm from a convex lens of focal length 30 cm. If a concave lens of focal length 50 cm is introduced between the convex lens and the image formed such that it is 20 cm from the convex lens, find the change in the position of the image.

Sol:

For convex lens
$u = -40$ cm , $f = +30$ cm
$\therefore \dfrac{1}{30} = \dfrac{1}{v} - \dfrac{1}{-40}$

$\therefore v = 120$ cm

On introducing concave lens of focal length $f = -50$ cm
$f = -50$ cm , $u = +(120-20)$ cm $= +100$ cm

$\therefore \dfrac{1}{-50} = \dfrac{1}{v} - \dfrac{1}{100}$

$\therefore \dfrac{1}{v} = \dfrac{1}{100} - \dfrac{1}{50} = -\dfrac{1}{100}$

$\therefore v = -100$ cm

Change in the position of the image = 200 cm to the left of its original position.

10) **In the circuit diagram shown, AB is a uniform wire of resistance 15 n and length 1 m. It is connected to a cell E_1 of emf 2 V and negligible internal resistance and a resistance R. The balance point with another cell E_2 of emf 75 mV is found at 30 cm from end A. Calculate the value of the resistance R.**
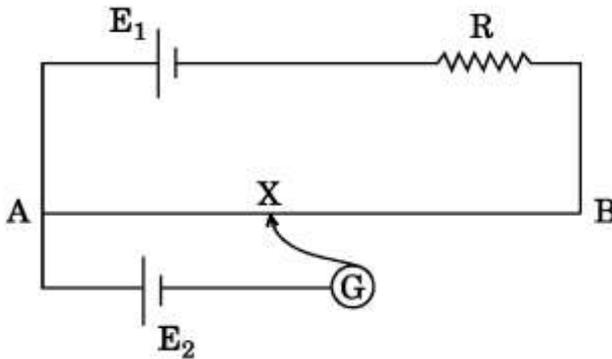
Sol:

Current through the wire $I = \dfrac{E}{R+r}$

$$= \dfrac{2}{R + 15}$$

$\therefore$ Potential gradient $= \left(\dfrac{2}{R+15}\right) \times \dfrac{15}{100}$

Now $E_2 =$ Potential drop across 30 cm

$\therefore 75 \times 10^{-3} = \left(\dfrac{2}{R + 15}\right) \times 0.15 \times 30$

$\therefore R = 105 \ \Omega$

SECTION C

11) **A 600 pF capacitor is charged by a 200 V supply. It is then disconnected from the supply and is connected to another uncharged 300 pF capacitor. Calculate how much electrostatic energy is lost in the process. What is the source of energy loss ?**

Sol:

We have, energy stored $= \frac{1}{2}\frac{Q}{C^2}$

and Equivalent Capacitance $= C_1 + C_2$

$$= (600 + 300) \text{ pF}$$

Charge on the capacitor $= Q = 600 \times 200 \times 10^{-12}$

$$= 12 \times 10^{-8} \text{ C}$$

Initial Energy $= \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{Q^2}{600 \times 10^{-12}}$

Final Energy $= \frac{1}{2}\frac{Q^2}{900 \times 10^{-12}}$

Loss in energy $= \frac{1}{2}\frac{144 \times 10^{-16}}{10^{-12}}\left[\frac{1}{600} - \frac{1}{900}\right]$

$$= 4 \times 10^{-6} \text{ J}$$

The source of energy loss is the energy converted into heat due to sharing of charge between the two capacitors.

12) How are the following types of electromagnetic waves produced :

(i i i)   Microwaves

(i v)   Infra-red waves Write two important uses of each of the above electromagnetic radiations.

Sol: (i) Microwaves are produced by special vacuum tubes called Klystrons / Magnetrons / Gun diodes / Point contact diodes. (any one)

Uses: Radar system, Ovens, Communication (any two)

(ii) Infrared waves are produced by vibration of atoms and hot bodies.

Uses: Physical therapy, remote switches in household electronic systems, detectors in earth satellites (any two)

13) Draw the circuit arrangement for studying the V – I characteristics of a p-n junction diode (i) in forward bias and (ii) in reverse bias. Draw the typical V – I characteristics of a silicon diode.

Describe briefly the following terms :

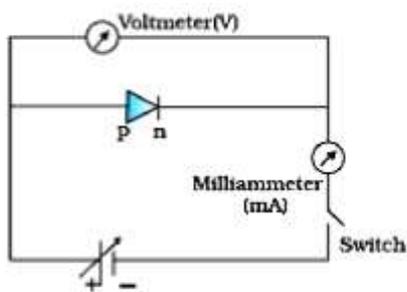**(i i i)   "minority carrier injection" in forward bias**

(iv)   **"breakdown voltage" in reverse bias**

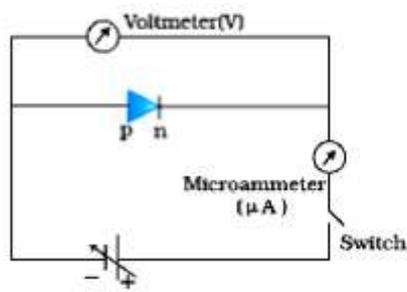**Sol:** Drawing circuit diagrams of a p - n junction diode in

      i)   forward bias

      ii)   reverse bias
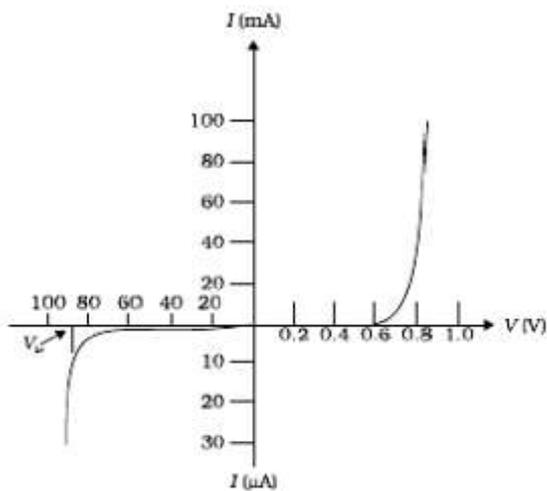
Drawing the characteristic curves

Describing the terms minority carrier injection and break down voltage

a) Forward bias   b) Reverse bias

(i)   During forward bias majority carriers (electrons) enter from n to p side which are actually minority carriers in p. This is called minority carrier injection.

Alternatively

Majority carriers holes enter from p side and enter into n side

(ii)   At very high reverse bias voltage, the current suddenly increases. This voltage is called breakdown voltage.

Alternatively

It is the critical voltage in reverse bias at which current is independent of applied voltage.

14) (a) Give a brief description of the basic elementary process involved in the photoelectric emission in Einstein's picture.

(b) When a photosensitive material is irradiated with the light of frequency ν, the maximum speed of electrons is given by v_{max}. A plot of v_{max}^2 is found to vary with frequency as shown in the

figure.
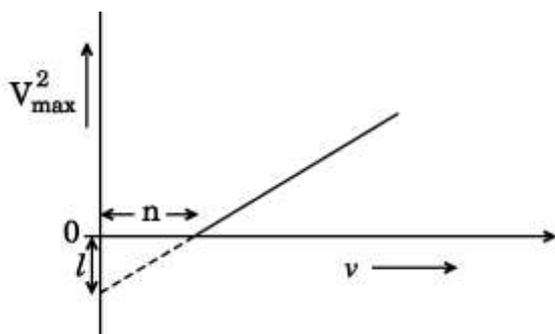
Use Einstein's photoelectric equation to find the expressions for (i) Planck's constant and (ii) work function of the given photosensitive material, in terms of the parameters l, n and mass m of the electron.

Sol: According to Einstein, packets of energy called photons, which are absorbed completely by electrons. This absorbed energy is used to eject the electron and also provide kinetic energy to the emitted electron.

(b)   i) $\frac{1}{2} m V_{max}^2 = hv - \phi_0$

$\therefore V_{max}^2 = \left(\frac{2h}{m}\right)v - \left(\frac{2\phi_0}{m}\right)$
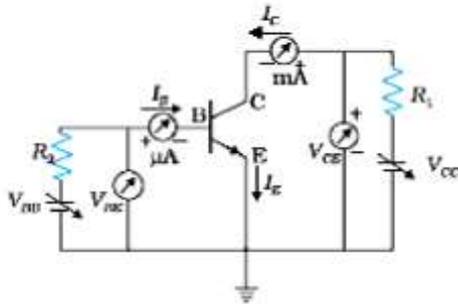
Slope $= \frac{2h}{m} = \frac{l}{n}$

$\therefore h = \frac{m\,l}{2\,n}$

Intercept $= \frac{2\,\phi_0}{m} = l$

$\therefore \phi_0 = \frac{ml}{2}$

15) Draw a circuit diagram to study the input and output characteristics of an n-p-n transistor in common emitter configuration. Explain briefly how this arrangement is used to obtain the typical input/output characteristics of a transistor. Draw the graphs showing the nature of input/output curves.
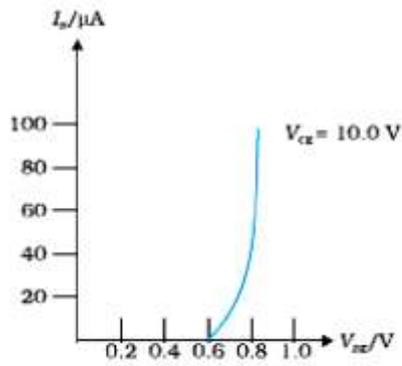
Sol:

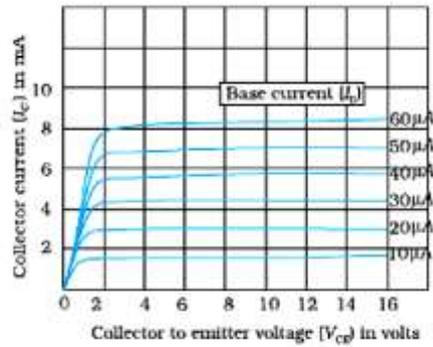For input charateristics,

Keep V_{CE} as fixed value

Study the dependence of I_B on V_{BE}

For output charateristics, Keep I_B as constant

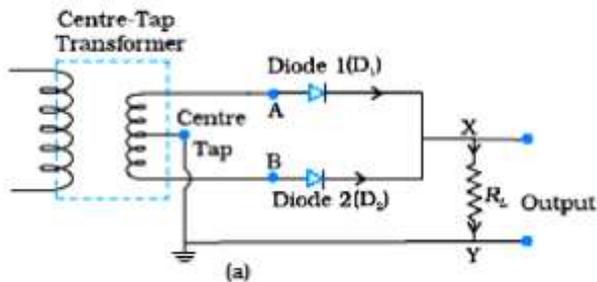Study the dependence of I_C on V_{CE} (Any one)

(i) Input characteristics

(ii) Output charcteristics

OR

Draw a labelled circuit diagram of a full wave rectifier. Explain its underlying principle and working. Depict the input and output waveforms.

Describe briefly the role of a capacitor in filtering.

Sol:

Principle: When the diode is forward biased, it conducts and when it is reverse biased, it does not conduct.

Working: Secondary of the transformer has a center tap. The two diodesconduct during alternate half cycles but the current, in the load, flows in the same direction during both the half cycles.
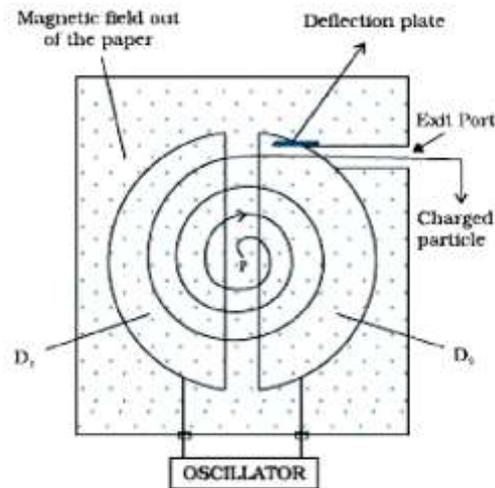
Input Waveform

Output Waveform
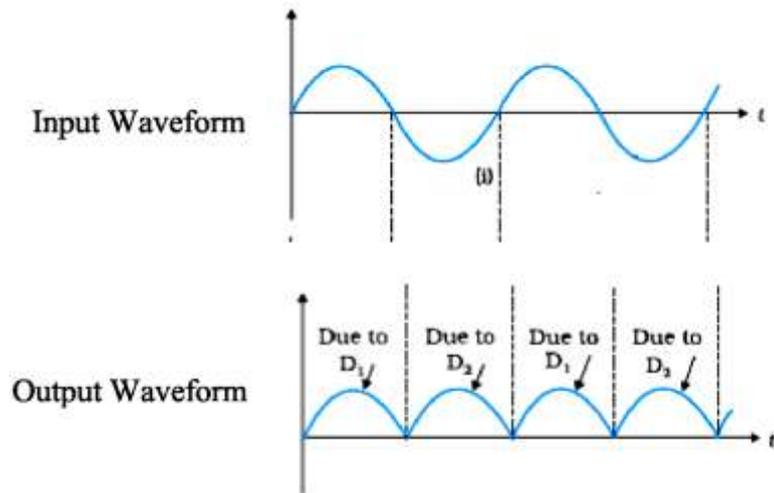
Role of capacitor is to smoothen the output. (also accept any other answer)

16) Draw a schematic sketch of a cyclotron. Explain its working principle

Obtain the necessary mathematical expression to show how this machine is used to accelerate charged particles.

SOL:

A charged particle can be accelerated to very high energy by subjecting it to an oscillating electric field applied between the dees. When the charged particle is subjected to a uniform magnetic field, it moves in a circular path. Both the fields are perpendicular to each other. The time for one revolution of the charged particle is independent of its speed or radius of its orbit.

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

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

$$\because T = \frac{2\pi r}{v}$$

$$\therefore T = \frac{2\pi m}{Bq}$$

17) Write the expression for the resultant intensity at a point due to the superposition of two monochromatic waves $y_1 = a \cos \omega t$, $y_2 = a \cos (\cos \omega t + \phi)$

where ϕ **is the phase difference between the two waves and a and ω denote the amplitude and angular frequency.**

In Young's double slit experiment using monochromatic light of wavelength λ **, the intensity of light at a point on the screen where path difference is** λ **is k units. Find the intensity at a point on the screen where path difference is** λ **/4.**

SOL:

Resultant Intensity

$$I = 4I_o cos^2 \left(\frac{\phi}{2}\right)$$

Alternatively : $I_R = I_o + I_o + 2I_o \, cos\phi$

When the path difference is λ , phase difference is 2π
$$\therefore \ I_R = I_o + I_o + 2I_o$$
$$= 4I_o = K$$
If path difference is $\frac{\lambda}{4}$, phase difference is $\frac{\pi}{2}$
$$\therefore \ I_R = I_o + I_o + 0$$
$$= 2I_o = \frac{K}{2}$$

18) Suppose you wish to transmit an electronic signal in the audio frequency range over a long distance directly. Write briefly the three important factors which prevent you from doing so and explain how you overcome these factors.

Sol: Three factors that prevent us from sending the signals directly are:

(i)   Size of antenna

(ii)   Power radiated by the antenna

(iii) Intermixing of signals

To overcome these factors

(i) Size of antenna should be comparable to wavelength (around   ).

(ii) Power depends inversely on λ^2 Power radiated increases with decrease of wavelength.

(iii) Message signal should be used to modulate a high frequency carrier wave so that a band of frequencies can be alloted to each message signal.

19) (a) Plot a graph showing the variation of binding energy per nucleon as a function of mass number. Which property of nuclear force explains the approximate constancy of binding energy in the range 30 < A < 170 ?

(b) A radioactive nucleus 'A' undergoes series of decays shown in the following scheme :

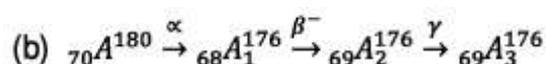$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\gamma} A_3$$
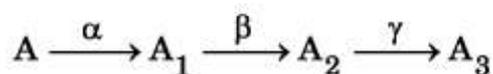
If the mass number and atomic number of A$_3$ are 176 and 69 respectively, find the mass number and atomic number of A.

Sol:
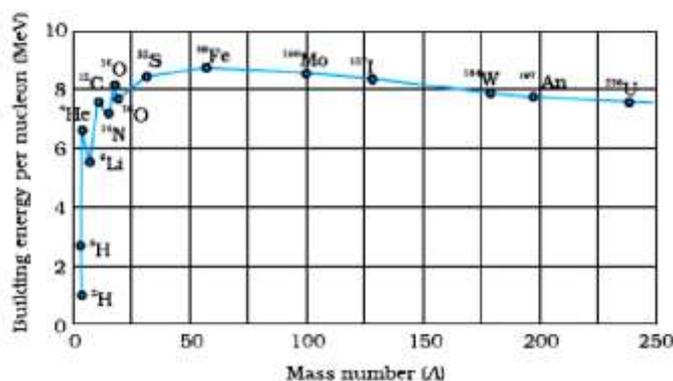
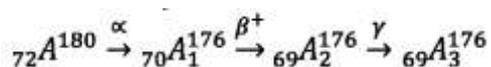Nuclear forces are short ranged / saturated (any one)

(b) $_{70}A^{180} \xrightarrow{\alpha} {}_{68}A_1^{176} \xrightarrow{\beta^-} {}_{69}A_2^{176} \xrightarrow{\gamma} {}_{69}A_3^{176}$

Mass number of A is 180 Atomic number of A is 70 *Alternatively*

$$_{72}A^{180} \xrightarrow{\propto} {}_{70}A_1^{176} \xrightarrow{\beta^+} {}_{69}A_2^{176} \xrightarrow{\gamma} {}_{69}A_3^{176}$$

Mass number of A is 180 <u>Atomic number of A is 72</u>

20) Discuss briefly, with the help of a suitable diagram, what happens when unpolarised light passes through two identical polaroids where the orientation of one polaroid is fixed and the second is rotated with respect to the one. Draw a graph showing the dependence of intensity of transmitted light on the angle between the polariser and analyser. Explain clearly how one understands this variation using Malus' law.

Sol:
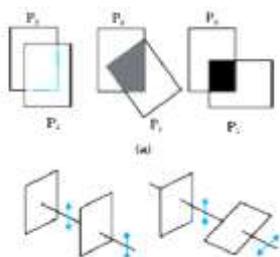
When light from an ordinary source passes through a polaroid sheet P1, its intensity is reduced by half. When the second polaroid (identical to the first one) is rotated with respect to the first one, the intensity of the light transmitted by the second polaroid varies from zero to maximum.
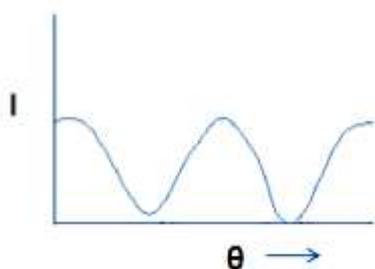
According to Mauls's law when the angle between the two polaroids is , the intensity of the transmitted light by the second polaroid is given by the relation $I = I_0 \cos^2 \theta$.

As θ keep on changes, intensity of the transmitted light by the second polaroid changes.

21) **A resistor of 100 Ω and a capacitor of 100/π μF are connected in series to a 220 V, 50 Hz a.c. supply.**

(c) **Calculate the current in the circuit.**

(d) **Calculate the (rms) voltage across the resistor and the capacitor. Do you find the algebraic sum of these voltages more than the source voltage ? If yes, how do you resolve the paradox ?**

Sol: (a) Current in the circuit

$$I = \frac{V}{\sqrt{R^2 + \left(\frac{1}{C\omega}\right)^2}}$$

$$I = \frac{220}{\sqrt{100^2 + \left(\dfrac{1}{\dfrac{100}{\pi} \times 10^{-6} \times 2\pi \times 50}\right)^2}}$$

$$= \frac{2.2}{\sqrt{2}} \, A = 1.55 \, A$$

(b) Voltage across the resistor = 100×1.55 = 155 V

Voltage across the capacitor =   100×1.55 = 155 V

Yes , The sum of the two voltages is greater than 220 V but the voltage across the resistor and the capacitor are not in phase.

22) **When a metallic conductor is subjected to a certain potential V across its ends, discuss briefly how the phenomenon of drift occurs. Hence define the term 'drift velocity' of charge carriers and show that the current density $\vec{j}$ is related to the applied electric field $\vec{E}$ by the relation**

$\vec{j} = \sigma \vec{E}$ **where σ defines the conductivity of the material.**

SOL: When metal conductor is subjected to a certain potential the electron get accelerated due to electric field. Each electron experiences acceleration for an average time, τ, called the relaxation time. It then undergoes a collision and its velocity again becomes random. The average(drift) velocity of all the electrons contributes to the flow of current.

The average velocity of electrons, acquired through their acceleration for a time τ is called drift velocity.

$$v_d = \frac{eE}{m}\tau$$

Current density

$$j = \frac{I}{A}$$

$$= \frac{neAv_d}{A}$$

$$= ne\left\{\frac{eE}{m}\tau\right\}$$

$$= \left(\frac{ne^2\tau}{m}\right)E$$

$$\therefore \vec{j} = \sigma \vec{E}$$

SECTION D

23) **Deepika and Ruchika were asked by their teacher to perform an experiment using a galvanometer. Before doing the experiment they were very keen to know the different parts of the galvanometer which was given to them in the form of a small box. They approached the teacher and asked for the permission. The teacher thought it would be a good idea if the galvanometer be opened before the whole class and explained its construction and working to all of them.**

Based on the above paragraph, answer the following questions :

   (d) **What, in your opinion, were the qualities displayed by Deepika, Ruchika and the teacher ?**
   (e) **State briefly the working principle of the galvanometer.**

(f) **What is the shape of the magnets used and why is it so designed ?**

SOL:

    a) The values displayed by Deepika and Ruchika are their inquisitiveness for practical knowledge.

    The teacher displayed concern for the students.

    b) Principle: When a current passes through a coil, placed in a uniform magnetic field, it experiences a torque.

    c) The pole pieces of the magnet are given a concave shape. This is done to produce a radial magnetic field.

24) **A right circular cylinder of length 'a' and radius 'r' has its centre at the origin and its axis along the x-axis so that one face is at x = + a/2 and the other at x = − a/2, as shown in the figure. A uniform electric field is acting parallel to the x-axis such that $\vec{E} = E_0 \hat{i}$ for x > 0 and $\vec{E} = E_0 \hat{i}$ for x < 0.**
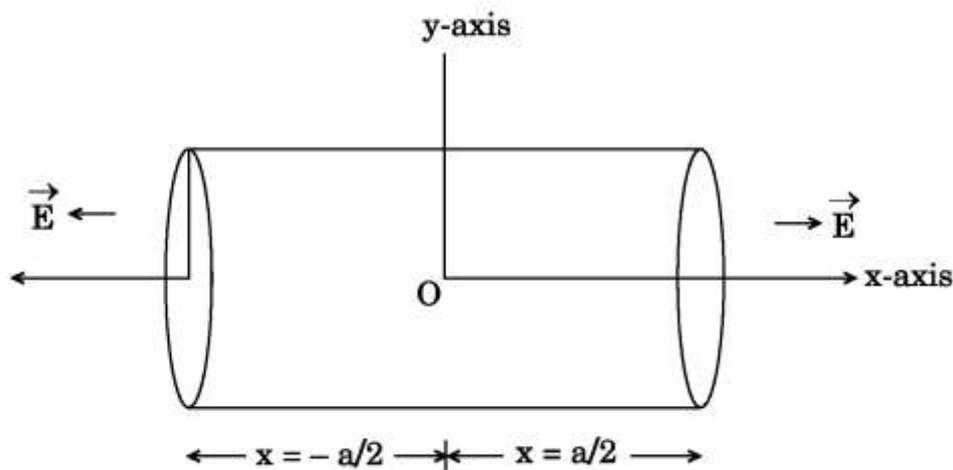
Find out the flux (i) through the flat faces, (ii) through the curved surface of the cylinder. What is the net outward flux through the cylinder and the net charge inside the cylinder ?

SOL:

(i)   Flux $= \int \vec{E}.\overrightarrow{ds}$
       Flux through the flat surface on the:
       i.   right side $= E_o . \pi \, r^2$ (outwards)
       ii.   left side $= E_o . \pi \, r^2$ (outwards)

  (ii)Flux through the curved surface $= 0$
[As electric field and area vector are perpendicular to each other]

Net outward flux $= \pi r^2 E_o + \pi r^2 E_o + 0 = 2\pi r^2 E_o$

Charge inside the cylinder = Net flux $\times \varepsilon_o$
$$= (2 \, \pi \, r^2 E_o) \times \varepsilon_o$$
$$= 2 \, \pi \, \varepsilon_o \, r^2 E_o$$

OR

(a)   Show, using Gauss's law, that for a parallel plate capacitor consisting of two large plane parallel conductors having surface charge densities $+ \sigma$ and $- \sigma$, separated by a small distance in vacuum, the electric field

> **(iii)   in the outer regions of both the plates is zero,**
>
> **(iv)   is $\dfrac{\sigma}{\varepsilon_0}$ in the inner region between the charged plates.**

Hence obtain the expression for the capacitance of a parallel plate capacitor.

(b)   Explain what is the effect of inserting a dielectric slab of dielectric constant k in the intervening space inside the plates on

> **(iii)   the electric field,**
> **(iv)   the capacitance of the capacitor.**

SOL:

(a) Calculation of electric field

(i) Electric field outside the plates: $\frac{\sigma}{2\varepsilon_0} + \frac{(-\sigma)}{2\varepsilon_0} = 0$ on both the sides of the capacitor.

(ii) Electric fields between the two plates

due to the left plate = $\frac{\sigma}{2\varepsilon_0}$ towards right

due to the right plate = $\frac{\sigma}{2\varepsilon_0}$ towards right

$\therefore$ Net Electric field = $\frac{\sigma}{\varepsilon_0}$ (towards right)

Capacitance, $C = \frac{Q}{V}$

$= \frac{Q}{Ed} = \frac{\sigma A}{\left(\frac{\sigma d}{\varepsilon_0}\right)}$

$= \varepsilon_0 A/d$

(b) (i) When a dielectric slab is introduced, the Electric field decreases to $\frac{E}{K} = \frac{\sigma}{K\varepsilon_0}$ where K is the dielectric constant. This is because of the (oppositely directed) field due to the polarized dielectric.

(ii) Capacitance with dielectric increases by a factor K because the electric field (and hence p.d.) decreases by a factor K.

25) (a) State two main considerations taken into account while choosing the objective in optical telescopes with large diameters.

(b) Draw a ray diagram for the formation of image by a reflecting type telescope. What is its magnifying power ?

(c) What are the advantages of a reflecting type telescope over the refracting type ?

SOL: a) Better Light gathering power and higher resolving power
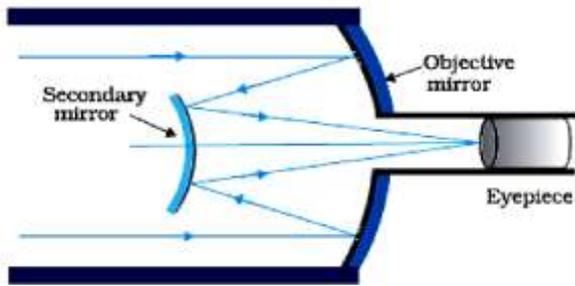
Magnifying power of the telescope is the ratio of the angle subtended at the eye by the final image to the angle subtended by the object at the lens or the eye.

[Also accept if the student just writes $\quad m = \dfrac{f_o}{f_e}$]

1) Larger objective size
2) No spherical aberration,
3) No chromatic aberration,
4) More light gathering power
5) Mounting and polishing is easier
6) More economical [any two points]

OR

(c) **Draw a ray diagram for the formation of image by a compound microscope in normal adjustment.**

(d) **Obtain the expression for the minimum separation between the two points seen as distinct in a microscope. What is its relation with the resolving power ? Mention the factors by which the resolving power of a microscope can be increased.**

SOL:
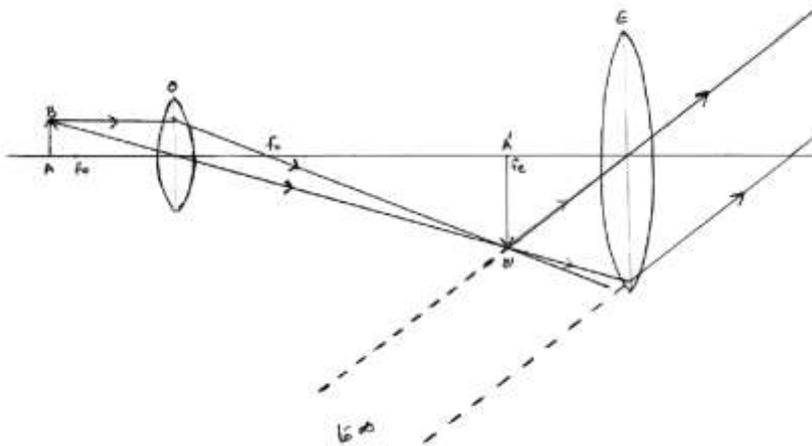
or
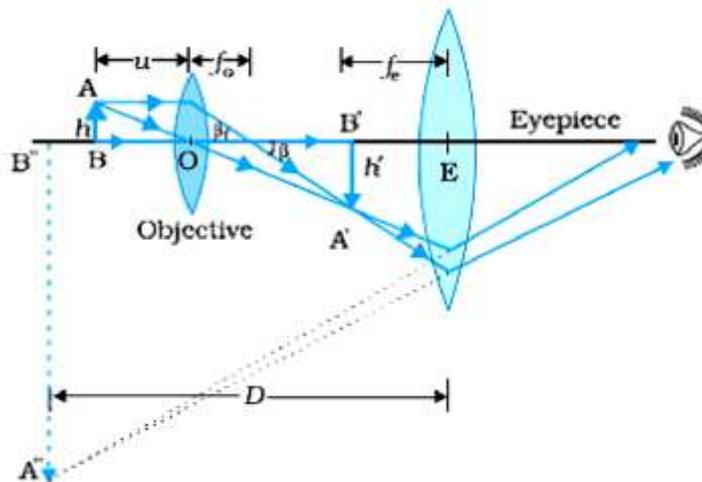
(b) S = Size of image of a point object in the image plane = $v\left(\dfrac{1.22\,\lambda}{d}\right)$

Minimum separation between two distinctly seen points in the object plane = $\dfrac{S}{Magnifying\ Power}$

$$= \dfrac{S}{\left(\frac{v}{f}\right)} = \dfrac{1.22\,f\,\lambda}{D}$$

[Also give this mark if the student writes

(i) Minimum separation = $\dfrac{1.22\,f\,\lambda}{D}$

Or (ii) Minimum separation equals the separation at which their images are just resolved

Or (iii) Minimum separation corresponds to 'limit of resolution'.]

Resolving power $= \dfrac{1}{d} = \dfrac{2\mu\sin\theta}{1.22\,\lambda}$

[Also accept: Resolving power $\propto \dfrac{1}{(minimum\ seperation)}$]

Resolving power can be increased by

(i) increasing the aperture of the objective
(ii) using a medium with higher refractive index
(iii) by decreasing the wavelength of the light used for illuminating the object

26) (a) Explain the meaning of mutual inductance of a solenoid S_1 with respect to the solenoid S_2.

(b) Consider two concentric circular coils, one of radius r_1 and the other of larger radius r_2 ($r_1 \ll r_2$), placed coaxially with centres coinciding with each other. Obtain the expression for the mutual inductance of the arrangement.

(c) In an experimental arrangement of two coils C_1 and C_2 placed coaxially parallel to each other, find out the expression for the emf induced in the coil C_1 (of N_1 turns) corresponding to the change of current I_2 in the coil C_2 (of N_2 turns).

SOL: (a) Consider two long co-axial solenoids. When a varying current flows through one coil, an induced emf is set up in the second coil due to the

variation in the magnetic field associated with the second coil. This phenomena is known as mutual induction

(b) Flux (φ_1) associated with S_1 when I_2 current flows through S_2

$$N_1\phi_1 = M_{12}I_2 \text{ -----(1)}$$

The magnetic field due to the current I_2 in S_2 is $\mu_o n_2 I_2$

$$\therefore N_1\phi_1 = (n_1 l)(\pi r_1{}^2)(\mu_o n_2 I_2)$$
$$= \mu_o n_1 n_2 \pi r_1{}^2\, l I_2 \text{ ----(2)}$$

From (1) and (2), we get

$$M_{12} = \mu_o n_1 n_2 \pi r_1{}^2\, l$$

(c) Induced emf in coil C_1 due to the change in current through C_2

We have $N_1\phi_1 = MI_2$

For varying currents,

$$N_1\left(\frac{d\phi_1}{dt}\right) = M\left(\frac{dI_2}{dt}\right)$$

$$\therefore \qquad\qquad -\varepsilon_1 = M\left(\frac{dI_2}{dt}\right)$$

or $\qquad\qquad\qquad \varepsilon_1 = -M\left(\frac{dI_2}{dt}\right)$

OR

(c) State Ampere's circuital law. Show that the magnetic field B at a distance r outside the straight infinite wire carrying current I is tangential and is given by B = μ_oI / (2π r).

(d) Consider a long straight cylindrical wire of circular cross-section of radius a, as shown in the figure. The current I is uniformly distributed across this cross-section. Calculate the magnetic field B in the region r < a and r > a. Plot a graph of B versus r from the centre of the wire.
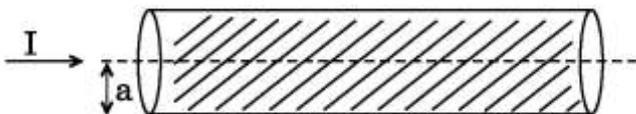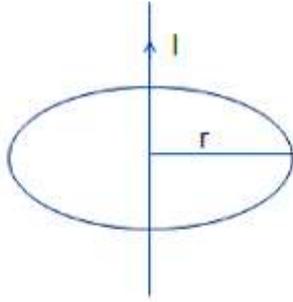
SOL:

(a) Ampere's Circuital law states that the line integral of the magnetic field, over a closed loop is equal to μ_o times the total current passing through the surface enclosed by the loop.

Alternatively, $\oint \vec{B}.\ \vec{dl} = \mu_o I$

Let an infinite straight wire carry a current I. We consider a circle of radius r, centered on the wire, and having its plane perpendicular to the wire.

By right hand rule, the magnetic field is tangential at every point of this circular loop.

∴ By Ampere's circuital law,

$$\oint \vec{B}.\ \vec{dl} = B.\,2\pi r = \mu_0 I$$

$$\therefore B = \frac{\mu_0 I}{2\pi r}$$

(b) For r < a, we have

$$B.\,2\pi r = \mu_0 I_{enclosed}$$

$$= \mu_o \left(\frac{\pi r^2}{\pi a^2}\right) I$$

$$= \frac{\mu_0 r^2}{a^2} I$$

$$\therefore B = \frac{\mu_o}{2\pi} \frac{I}{a^2} r$$

For r > a

$$B.\,2\pi r = \mu_0 I$$

$$or\ B = \frac{\mu_0 I}{2\pi r}$$