Date: 06/03/2023

Question Paper Code

55/5/3

Corporate Office : Aakash Tower, 8, Pusa Road, New Delhi-110005 | Ph.: 011-47623456

Time: 3 hrs.

Class-XII

Max. Marks: 70

PHYSICS (Theory)

(CBSE 2023)

GENERAL INSTRUCTIONS

Read the following instructions very carefully and strictly follow them:

(i) This question paper contains **35** questions. **All** questions are compulsory.

(ii) Question paper is divided into **FIVE** sections – Sections **A**, **B**, **C**, **D** and **E**.

(iii) **In Section – A :** Questions No. **1** to **18** are Multiple Choice (MCQ) type questions, carrying **1** mark each.

(iv) **In Section – B :** Questions No. **19** to **25** are Very Short Answer (VSA) type questions, carrying **2** marks each.

(v) **In Section – C :** Questions No. **26** to **30** are Short Answer (SA) type questions, carrying **3** marks each.

(vi) **In Section – D :** Questions No. **31** and **33** are Long Answer (LA) type questions, carrying **5** marks each.

(vii) **In Section – E :** Questions No. **34** to **35** are case based questions, carrying **4** marks each.

(viii) There is no overall choice. However, an internal choice has been provided in 2 questions in Section B, 2 questions in Section C, 3 questions in Section D and 2 questions in Section E. You have to attempt only one of the choices in such questions.

(ix) Use of calculators is **NOT** allowed.

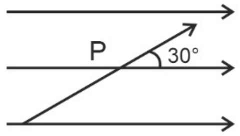
SECTION-A

1. An electric dipole of length 2 cm is placed at an angle of 30° with an electric field 2 × 10^5 N/C. If the dipole experiences a torque of 8 × 10^{-3} Nm, the magnitude of either charge of the dipole is **[1]**

(A) 4 μC
(B) 7 μC
(C) 8 mC
(D) 2 mC

Answer (A)

Sol. 2l = 2 cm



E = 2 × 10^5 N/C
τ = 8 × 10^{-3} Nm

$\vec{\tau} = \vec{P} \times \vec{E}$

= PEsinθ

8 × 10^{-3} = q × (2l) × 2 × 10^5 × sin30°

$8 \times 10^{-3} = q \times 2 \times 10^{-2} \times 2 \times 10^5 \times \frac{1}{2}$

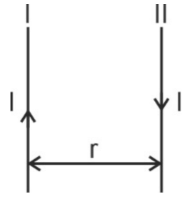
q = 4 μC

2. Two horizontal thin long parallel wires, separated by a distance r carry current I each in the opposite directions. The net magnetic field at a point midway between them, will be **[1]**

(A) Zero
(B) $\left(\frac{\mu_0 I}{2\pi r}\right)$ vertically downward
(C) $\left(\frac{2\mu_0 I}{r}\right)$ vertically upward
(D) $\left(\frac{\mu_0 I}{\pi r}\right)$ vertically downward

Answer (*)

Sol.



$B = \frac{\mu_0}{2\pi} \cdot \frac{I}{d}$ (Finite wire)

$B_I = \frac{\mu_0}{2\pi}\left(\frac{I}{r/2}\right) \otimes$

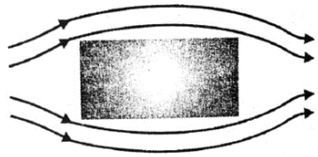
$B_{II} = \frac{\mu_0}{2\pi}\left(\frac{I}{r/2}\right) \otimes$

$\vec{B}_{net} = \vec{B}_I + \vec{B}_{II}$

$= \frac{2\mu_0}{2\pi} \frac{I}{(r/2)} = \frac{2\mu_0 I}{\pi r}$

* No answer is correct. According to different combinations of current (direction), field may be in upward or downward direction.

3. Which of the following **cannot** modify an external magnetic field as shown in the figure? **[1]**



(A) Nickel (B) Silicon

(C) Sodium Chloride (D) Copper

Answer (A)

Sol. The given diagram represents diamagnetic property and among given options silicon, sodium chloride and copper are diamagnetic so Nickel will not be able to modify external magnetic field as shown in diagram.

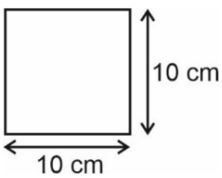
4. A square shaped coil of side 10 cm, having 100 turns is placed perpendicular to a magnetic field which is increasing at 1 T/s. The induced emf in the coil is **[1]**

(A) 0.1 V (B) 0.5 V

(C) 0.75 V (D) 1.0 V

Answer (D)

Sol.



$N = 100$

$$\frac{dB}{dt} = 1 \text{ T/s}$$

$$e = \left|\frac{-d\phi}{dt}\right|$$

$$= \text{NA}\left(\frac{dB}{dt}\right)$$

$= 100 \times 100 \times 10^{-4} \times 1$

$= 1$ V

5. Which one of the following electromagnetic radiations has the least wavelength? **[1]**

(A) Gamma rays (B) Microwaves

(C) Visible light (D) X-rays

Answer (A)

Sol. $\lambda_{gamma} < \lambda_{x\text{-}ray} < \lambda_{uv} < \lambda_{visible} < \lambda_{infrared} < \lambda_{microwave} < \lambda_{radio}$

Hence, among the given options gamma rays has the least wavelength.

6. In a Young's double-slit experiment, the screen is moved away from the plane of the slits. What will be its effect on the following? **[1]**

(i) Angular separation of the fringes.

(ii) Fringe-width

(A) Both (i) and (ii) remain constant

(B) (i) remains constant, but (ii) decreases

(C) (i) remains constant, but (ii) increases

(D) Both (i) and (ii) increase

Answer (C)

Sol. Fringe width

$$\beta = \frac{\lambda D}{d}$$

as *D* increases

$\therefore$ Fringe-width increases

Angular separation $= \frac{\lambda}{d}$

$\therefore$ it remains constant

So; (i) remains constant but (ii) increases.

7. E, c and ν represent the energy, velocity and frequency of a photon. Which of the following represents its wavelength? **[1]**

(A) $\frac{h\nu}{c^2}$

(B) $h\nu$

(C) $\frac{hc}{E}$

(D) $\frac{h\nu}{c}$

Answer (C)

Sol. $E = h\nu$

$$E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E}$$

8. The ratio of the nuclear densities of two nuclei having mass numbers 64 and 125 is **[1]**

(A) $\frac{64}{125}$

(B) $\frac{4}{5}$

(C) $\frac{5}{4}$

(D) 1

Answer (D)

Sol. Radius of nucleus having mass number *A* is

$r = r_0 A^{1/3}$

So, *M*(mass of nucleus) $= \frac{4}{3}\pi r_0^3 A\rho$

Density, $\rho = \frac{3M}{4\pi r_0^3 A} = \frac{3mA}{4\pi r_0^3 A}$ $[\because M = mA]$

$$= \frac{3m}{4\pi r_0^3} = \text{constant}$$

Nuclear density is independent of mass number.

9. The energy required by an electron to jump the forbidden band in silicon at room temperature is about **[1]**

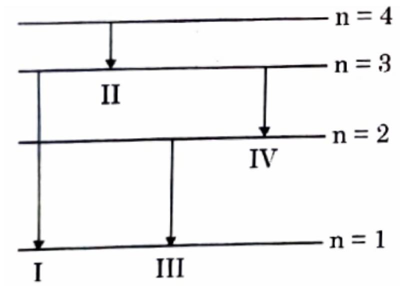
(A) 0.01 eV (B) 0.05 eV

(C) 0.7 eV (D) 1.1 eV

Answer (D)

Sol. The forbidden gap for a pure Si at room temperature is 1.1 eV.

10. The diagram shows four energy level of an electron in Bohr model of hydrogen atom. Identify the transition in which the emitted photon will have the highest energy. **[1]**

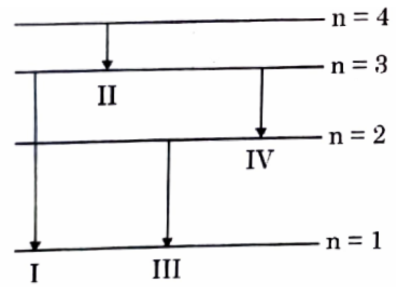


(A) I (B) II

(C) III (D) IV

Answer (A)

Sol.



$E_I = E_3 - E_1 = -1.51 - (-13.6) = 12.09$ eV

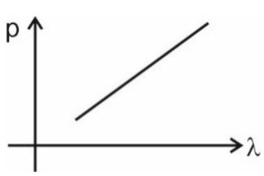
$E_{II} = E_4 - E_1 = -0.85 - (-1.51) = 0.66$ eV

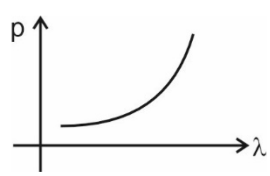
$E_{III} = E_2 - E_1 = -3.4 - (-13.6) = 10.2$ eV

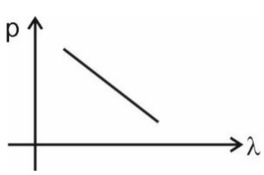
$E_{IV} = E_3 - E_2 = (-1.51) - (-3.4) = 1.89$ eV

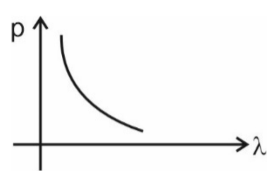
Hence, transition I have the highest energy

11. Which of the following graphs correctly represents the variation of a particle momentum with its associated de-Broglie wavelength? [1]

(A) 

(B) 

(C) 

(D) 

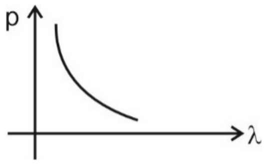
Answer (D)

Sol. de-broglie wavelength associated with a particle having momentum p is

$$\lambda = \frac{h}{p}$$

$$\lambda \propto \frac{1}{p} \text{ or } p \propto \frac{1}{\lambda}$$

so, correct graph should be D



12. The capacitors, each of 4 μF are to be connected in such a way that the effective capacitance of the combination is 6 μF. This can be achieved by connecting. **[1]**

(A) All three in parallel

(B) All three in series

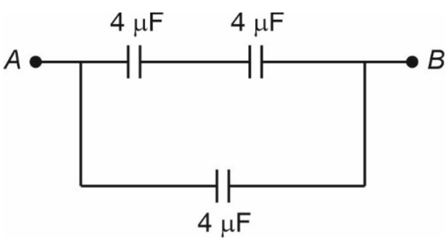
(C) Two of them connected in series and the combination in parallel to the third

(D) Two of them connected in parallel and the combination in series to the third

Answer (C)

Sol. Each capacitor is of 4 μF.

To get effective capacitance of 6 μF, we should connect two of them in series and the combination in parallel to the third capacitor



C_{AB} = (4 + 2) μF = 6 μF.

13. What is the ratio of inductive and capacitive reactance in an ac circuit? **[1]**

(A) $\omega^2 LC$ (B) LC^2

(C) $\frac{LC}{\omega^2}$ (D) $\omega^2 L$

Answer (A)

Sol. Inductive reactance $X_L = \omega L$

Capacitive reactance $X_C = \frac{1}{\omega C}$

Hence $\frac{X_L}{X_C} = \frac{\omega_L}{(1/\omega C)} = \omega^2 LC$

14. In an interference experiment, third bright fringe is obtained at a point on the screen with a light of 700 nm. What should be the wavelength of the light source in order to obtain the fifth bright fringe at the same point? **[1]**

(A) 420 nm (B) 750 nm

(C) 630 nm (D) 500 nm

Answer (A)

Sol. In YDSE, for n^{th} bright fringe

$$y = \frac{n\lambda D}{d}$$

Given, $\dfrac{3 \times 700 \text{ nm} \times D}{d} = \dfrac{5 \times \lambda D}{d}$

λ = 420 nm

15. The radius of the n^{th} orbit in Bohr model of hydrogen atom is proportional to **[1]**

(A) n^2 (B) $\frac{1}{n^2}$

(C) n (D) $\frac{1}{n}$

Answer (A)

Sol. Radius of n^{th} orbit of hydrogen atom

$$r_n = 0.529\frac{n^2}{Z}\text{Å}$$

$= 0.529n^2$Å

Hence $r_n \propto n^2$

Note: In question number **16** to **18** two statements are given – one labelled **Assertion (A)** and the other labelled **Reason (R)**. Select the correct answer to these questions from the codes **(a)**, **(b)**, **(c)** and **(d)** as given below :

(A) Both Assertion (A) and Reason (R) are true and (R) is the correct explanation of (A)

(B) Both Assertion (A) and Reason (R) are true and (R) is NOT the correct explanation of (A).

(C) Assertion (A) is true and Reason (R) is false.

(D) Assertion (A) is false and Reason (R) is also false.

16. **Assertion (A) :** The resistance of an intrinsic semiconductor decreases with increase in its temperature. **[1]**

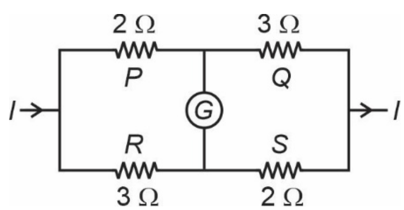
Reason (R) : The number of conduction electrons as well as hole increase in an intrinsic semiconductor with rise in its temperature.

Answer (A)

Sol. Resistance of an intrinsic semiconductor decreases with increases in temperature, because number of conduction electrons as well as hole increase in an intrinsic semiconductor with rise in its temperature even relaxation time decreases

Hence both A and R are correct also R is the correct explanation of A.

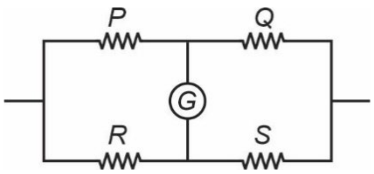
17. **Assertion (A):** The given figure does not show a balanced Wheatstone bridge.



Reason (R): For a balanced bridge small current should flow through the galvanometer.

Answer (C)

Sol. • For a balanced Wheatstone bridge



$$\frac{P}{R} = \frac{Q}{S}$$

Hence, given circuit is not a balanced Wheatstone bridge.

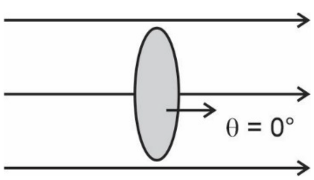
• In balanced Wheatstone bridge there is no current through galvanometer branch.

18. **Assertion (A):** The deflecting torque acting on a current carrying loop is zero when its plane is perpendicular to the direction of magnetic field.

Reason (R): The deflecting torque acting on a loop of magnetic moment $\vec{m}$ in a magnetic field $\vec{B}$ is given by the dot product of $\vec{m}$ and $\vec{B}$

Answer (C)

Sol. • Torque on current carrying loop in magnetic field



$\vec{\tau} = \vec{M} \times \vec{B}$

$|\vec{\tau}| = MB\sin\theta$

$= MB\sin 0°$

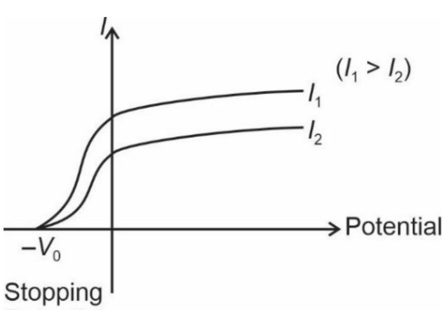
$=$ Zero

• Torque $\vec{\tau} = \vec{M} \times \vec{B}$

SECTION-B

19. Plot a graph showing the variation of photo electric current, as a function of anode potential for two light beams having the same frequency but different intensities I_1 and I_2 ($I_1 > I_2$). Mention its important features.

Sol. **[1]**



• For a material stopping potential is independent of intensity but depends on frequency of light. **[½]**

• For higher intensity of light at a given frequency saturation current will be higher. **[½]**

20. (a) How will the De Broglie wavelength associated with an electron be affected when the (i) velocity of the electron decreases? And (ii) accelerating potential is increased? Justify your answer. **[2]**

OR

(b) How would the stopping potential for a given photosensitive surface change if (i) the frequency of the incident radiation were increased? And (ii) the intensity of incident radiation were decreased? Justify your answer. **[2]**

Sol. (a) De Broglie wavelength, $\lambda = \frac{h}{mv}$

(i) If velocity of the electron decreases, then its De-Broglie wavelength increases $\boxed{\lambda \propto \frac{1}{v}}$. **[1]**

(ii) When electron is accelerated through potential difference then

$$\text{K.E.} = Ve = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2Ve}{m}}$$

$$\lambda = \frac{h}{mv} = \frac{h}{m \times \sqrt{\frac{2Ve}{m}}} = \frac{h}{\sqrt{2mVe}}$$

When V is increased then λ decreases. **[1]**

OR

(b) (i) Greater frequency, greater will be the maximum kinetic energy of photoelectrons and hence greater will be the stopping potential. **[1]**

(ii) When the intensity of incident radiation is decreased keeping the frequency constant then saturation current decrease but stopping potential will remain same. **[1]**

21. How are electromagnetic waves produced? Write their two characteristics. **[2]**

Sol. Electromagnetic waves are produced by accelerating charged particle. When charge moves with acceleration, both the magnetic and electric field change continuously. This produces the electromagnetic waves. **[1]**

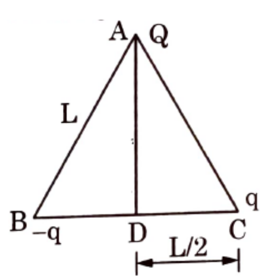
Characteristic of electromagnetic waves are as follows:

(i) They do not require any material medium for their propagation.

(ii) The oscillations of electric field and magnetic field are perpendicular to each other and are in same phase.

[1]

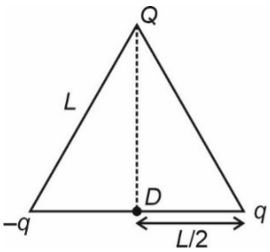
22. Three-point charges Q, q and –q are kept at the vertices of an equilateral triangle of side L as shown in figure. What is **[2]**



(i) The electrostatic potential energy of the arrangement? and

(ii) The potential at point D?

Sol.

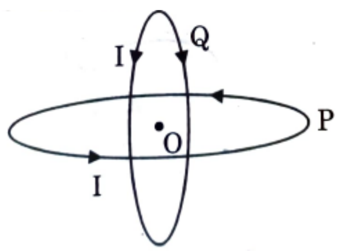


(i) Electrostatic potential energy of system = $\frac{1}{4\pi\varepsilon_0}\frac{Q(-q)}{L}+\frac{1}{4\pi\varepsilon_0}\frac{(-q)(q)}{L}+\frac{1}{4\pi\varepsilon_0}\frac{Q\times q}{L}$

$\Rightarrow \frac{-Qq}{4\pi\varepsilon_0 L}+\frac{-q^2}{4\pi\varepsilon_0 L}+\frac{Qq}{4\pi\varepsilon_0 L}=\frac{-q^2}{4\pi\varepsilon_0 L}$ **[1]**

(ii) Potential at point, D = $\frac{K\times q}{\frac{L}{2}}+\frac{(-Kq)}{\frac{L}{2}}+\frac{K\times Q}{\frac{\sqrt{3}L}{2}}=\frac{1}{4\pi\varepsilon_0}\times\frac{2Q}{\sqrt{3}L}=\frac{Q}{2\sqrt{3}\pi\varepsilon_0 L}$ **[1]**

23. (a) Two identical circular loops P and Q, each of radius R carrying current I are kept in perpendicular planes such that they have a common centre O as shown in the figure.

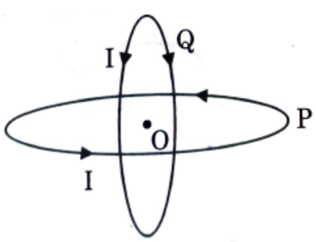


Find the magnitude and direction of the net magnetic field at point O. **[2]**

OR

(b) A long straight conductor kept along X′X axis, carries a steady current I along + x direction. At an instant t, a particle of mass m and charge q at point (x, y) moves with a velocity $\vec{v}$ along + y direction. Find the magnitude and direction of the force on the particle due to the conductor. **[2]**

Sol.

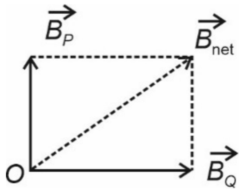


$\vec{B}_{net}=\vec{B}_P+\vec{B}_Q$

$\because\ |\vec{B}_P|=|\vec{B}_Q|=\frac{\mu_0 I}{2R}$ **[1]**

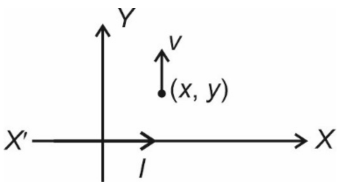
$|\vec{B}_{net}|=\sqrt{B_P^2+B_Q^2}$

$\therefore\ |\vec{B}_{net}|=\frac{\mu_0 I}{2R}\sqrt{2}=\frac{\mu_0 I}{\sqrt{2}R}$



[1]

OR



Magnetic field due to the current carrying long wire is

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

Where r is perpendicular distance from wire **[1]**

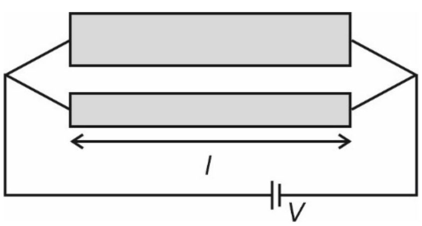
Now from Lorentz force

$$\vec{F}_m = q\left(\vec{v} \times \vec{B}\right) = q\left[v \cdot \hat{j} \times \frac{\mu_0 I}{2\pi y}\left(\hat{k}\right)\right]$$

$$\vec{F}_m = \frac{\mu_0 I (qv)}{2\pi y}\hat{i}$$ **[1]**

24. Two conductors, made of the same material have equal lengths but different cross-sectional areas A_1 and A_2 ($A_1 > A_2$). They are connected in parallel across a cell. Show that the drift velocities of electrons in two conductors are equal. **[2]**

Sol.



Drift velocity is given by

$$v_d = \frac{-eE}{m}\tau$$ **[1]**

where,

$e \to$ is electronic charge having value 1.6×10^{-19} C

$E \to$ is electric field across the conductor.

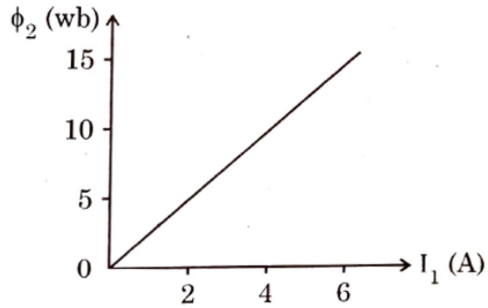
Since $E = \frac{V}{l}$, V is same across both conductor and l is also same for both

$\tau \to$ it is mean relaxation time depends upon the temperature and material but both temperature and material are same for both conductor

$m \to$ mass of electron which is constant therefore v_d will be same in both the conductors

Hence, v_d is equal for both the conductors. **[1]**

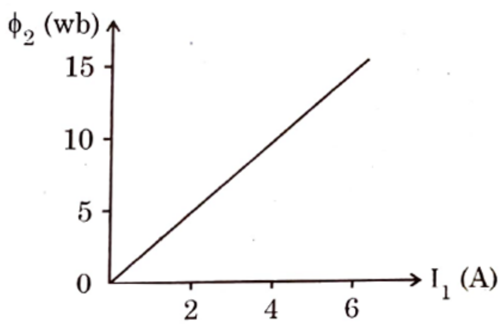
25. Two coils C_1 and C_2 are placed close to each other. The magnetic flux ϕ_2 linked with the coil C_2 varies with the current I_1, flowing in coil C_1, as shown in the figure. Find **[2]**



(i) the mutual inductance of the arrangement, and

(ii) the rate of change of current $\left(\frac{dI_1}{dt}\right)$ that will induce an emf of 100 V in coil C_2.

Sol.



(i) we know that

$\phi_2 = M_{12}I_1$

From the given graph at any instant

I_1 = 2A, ϕ_2 = 5 wb

On putting these value in equation

$5 = M_{12} \times 2$

M_{12} = 2.5 H **[1]**

(ii) We know that emf induced in secondary $E_2 = -M_{12}\frac{dI_1}{dt}$

Here, E_2 = 100 V, M_{12} = 2.5 H

On putting these values in above equation $100 = -2.5\frac{dI_1}{dt}$

$\frac{dI_1}{dt} = -40$ A/s **[1]**

SECTION-C

26. (a) A plane wave-front propagating in a medium of refractive index 'μ_1' is incident on a plane surface making an angle of incidence (i). It enters into a medium of refractive index μ_2 ($\mu_2 > \mu_1$). **[3]**

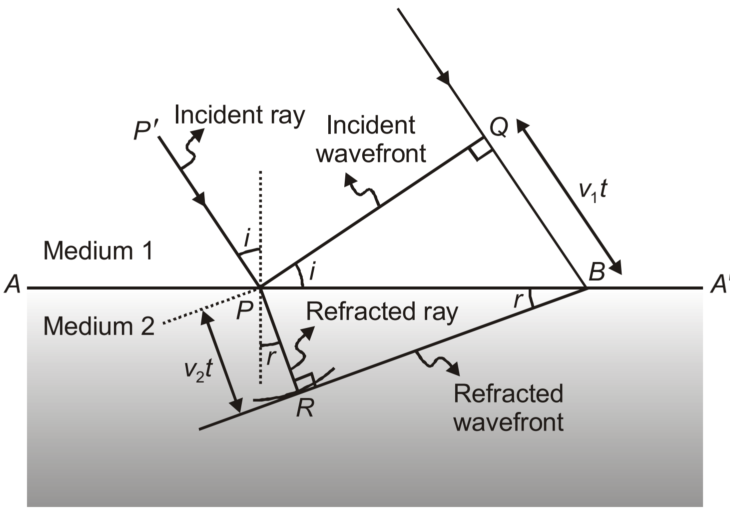
Use Huygen's construction of secondary wavelets to trace the retracted wave-front. Hence verify Snell's law of refraction.

OR

(b) Using Huygen's construction, show how a plane wave is reflected from a surface. Hence verify the law of reflection. **[3]**

Sol. Refraction of a Plane Wave: With the help of Huygens' Principle we can derive Snell's law.

(a) Refraction from Rarer to Denser Medium : Let v_1 and v_2 represents the speed of light in medium-1 and medium-2 respectively. Consider a plane wavefront PQ propagating in the direction $P'P$, incident on the medium boundary at point P at an angle of incidence i. Let t be the time taken to travel from Q to B.



[1]

$\therefore \quad QB = v_1t$

From the point P, draw a sphere of radius v_2t, let BR represent the forward tangent plane. It is refracted wavefront at t.

$\therefore \quad PR = v_2t$

From ΔPQB, $\quad \sin i = \dfrac{QB}{PB} = \dfrac{v_1t}{PB} \Rightarrow PB = \dfrac{v_1t}{\sin i}$ ...(i)

Also from ΔPRB, $\quad \sin r = \dfrac{PR}{PB} = \dfrac{v_2t}{PB} \Rightarrow PB = \dfrac{v_2t}{\sin r}$ ...(ii)

Equating (i) and (ii), we have

$$\frac{v_1t}{\sin i} = \frac{v_2t}{\sin r} \Rightarrow \frac{\sin i}{\sin r} = \frac{v_1}{v_2} \quad \text{...(iii)}$$ **[1]**

Now, if $r < i$ (*i.e.*, ray bends towards the normal)

$\sin r < \sin i$

$$\Rightarrow \quad \frac{\sin i}{\sin r} > 1 \Rightarrow \frac{v_1}{v_2} > 1 \Rightarrow v_1 > v_2$$

i.e., speed of light in medium 1 is greater than that in medium 2. This is exactly what we studied in Geometrical (Ray) optics.

This prediction is opposite to the prediction as per the Newton's Corpuscular Theory.

Also, if μ_1 be the refractive index of light in medium 1, then

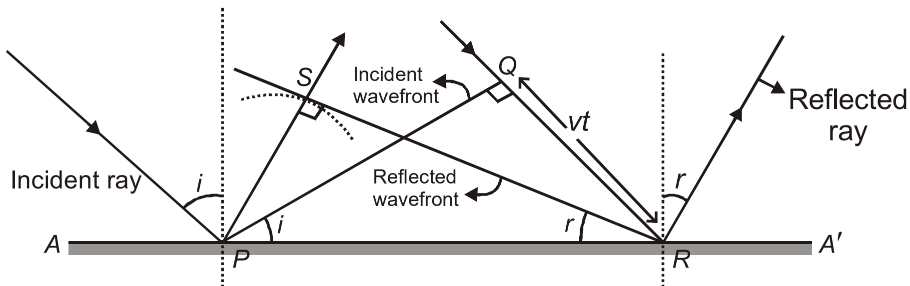
$$\mu_1 = \frac{c}{v_1} \Rightarrow v_1 = \frac{c}{\mu_1}$$

Similarly, $\mu_2 = \frac{c}{v_2}$ and $v_2 = \frac{c}{\mu_2}$

Hence, from eq. (iii), $\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\mu_2}{\mu_1}$

$\Rightarrow$ $\boxed{\mu_1 \sin i = \mu_2 \sin r}$ Snell's law of refraction **[1]**

(b) **Reflection of a Plane Wave by a Plane Reflecting Surface :** After refraction let us now study laws of reflection from Huygens' wave model. To prove the laws of reflection let us consider a plane wave *PQ* incident at an angle *i* on a reflecting surface *AA′*.



[1]

Time taken by the wave to advance to point *R* from point *Q* will be *t*.

Hence *QR* = *vt*

Now, in order to construct the reflected wavefront we draw a sphere of radius *vt* from point *P*. Let *RS* represent a tangent drawn from *R* to wavefront from *P* to the spherical wavefront.

$\therefore$ $PS = vt$ **[1]**

Consider, ΔPSR and ΔRQP

$PR = PR$ (Common side)

$\angle PSR = \angle RQP$ (Each 90°)

$PS = QR$ (Each *vt*)

Hence, ΔPSR ΔRQP

$\Rightarrow$ $\angle i = \angle r$

which proves law of reflection. **[1]**

27. An alternating current $I = 14\sin(100\pi t)$ A passes through a series combination of a resistor of 30 Ω and an inductor of $\left(\frac{2}{5\pi}\right)$ H. Taking $\sqrt{2} = 1.4$, calculate the **[3]**

(i) rms value of the voltage drops across the resistor and the inductor, and

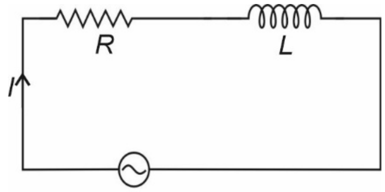
(ii) power factor of the circuit.

Sol. Given $I = 14\sin(100\pi t)$ A

$R = 30\ \Omega$

$$L = \left(\frac{2}{5\pi}\right) \text{ H}$$

Thus angular frequency, $\omega = 100\pi$



(i) rms value of voltage drop across resistor = V_R

$$\Rightarrow V_R = I_{rms}R = \left(\frac{14}{\sqrt{2}}\right)(30) = \frac{14}{1.4}\times 30 = 300 \text{ V}$$ **[1]**

rms value of voltage drop across inductor = V_L

$$\Rightarrow V_L = I_{rms}X_L = \frac{14}{\sqrt{2}}\times \omega L = 10\times 100\pi\times\frac{2}{5\pi}$$

= 400 V **[1]**

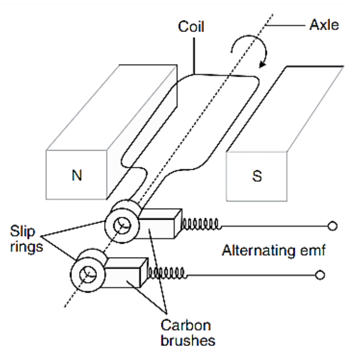
(ii) Power factor $= \cos\phi = \dfrac{R}{\sqrt{R^2+X_L^2}}$

$$= \frac{30}{\sqrt{30^2+\left(100\pi\times\frac{2}{5\pi}\right)^2}} = \frac{30}{\sqrt{30^2+40^2}} = \frac{3}{5}$$

Thus power factor $= \dfrac{3}{5}$ **[1]**

28. State the basic principle behind the working of an ac generator. Briefly describe its working and obtain the expression for the instantaneous value of emf induced. **[3]**

Sol. **Principle:** The AC generator is based on the principle that change in loop's orientation and effective area of loop as it rotates in magnetic field, leads to induction emf and current.



[1]

Basic Elements and working:

It consists of a coil mounted on a rotor shaft. The axis of rotation of the coil is perpendicular to the direction of the magnetic field. The coil (called armature) is mechanically rotated in the uniform magnetic field by some external means. The rotation of the coil causes the magnetic flux through it to change, so an emf is induced in the coil. The ends of the coil are connected to an external circuit by means of slip rings and brushes.

When the coil is rotated with a constant angular speed ω, the angle θ between the magnetic field vector B and the area vector A of the coil at any instant t is $\theta = \omega t$ (assuming $\theta = 0°$ at $t = 0$). As a result, the effective area of the coil exposed to the magnetic field lines changes with time, the flux at any time t is

$\phi_B = BA\cos\theta = BA\cos\omega t$ **[1]**

From Faraday's law, the induced emf for the rotating coil of N turns is then,

$$\varepsilon = -N\frac{d\phi_B}{dt} = -NBA\frac{d}{dt}(\cos\omega t)$$

Thus, the instantaneous value of the emf is

$\varepsilon = NBA\omega\sin\omega t$

Where $NBA\omega$ is the maximum value of the emf which occurs when $\sin\omega t = \pm 1$. If we denote $NBA\omega$ as ε_0, then

$\varepsilon = \varepsilon_0 \sin\omega t$

Since the value of the sine function varies between +1 and –1, the sign, or polarity of the emf changes with time. The emf has its extremum value when θ = 90° or θ = 270°, as the change of flux is greatest at these points.

Thus expression of instantaneous value of emf is

$\varepsilon = \varepsilon_0 \sin(\omega t)$ **[1]**

29. (a) Briefly describe how the current sensitivity of a moving coil galvanometer can be increased.

(b) A galvanometer shows full scale deflection for current I_g. A resistance R_1 is required to convert it into a voltmeter of range (0 – V) and a resistance R_2 to convert it into a voltmeter of range (0 – 2V). Find the resistance of the galvanometer. **[3]**

Sol. (a) Current sensitivity of moving coil galvanometer $= \dfrac{\phi}{I} = \dfrac{NBA}{K}$ **[1]**

Where

N: Number of turns in coil,

B: Magnetic field.

A: area of coil

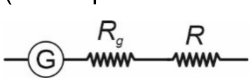
K : torsional constant

Current sensitivity can be increased by

- increasing number of turn (N) of the coil.
- increasing magnetic field (B) **[½]**
- increasing area of coil (A).

(b) **Case 1:** converting galvanometer to voltmeter of range (0 – 1V)

(* The question has a typing error as range is mentioned as (0 – V))



$I_g \times (R_g + R_1) = 1 \quad \ldots(1)$ **[½]**

Case 2: Range of voltmeter = (0 – 2V)

$I_g (R_g + R_2) = 2 \quad \ldots(2)$ **[½]**

dividing (2) and (1)

$$\frac{R_g + R_2}{R_g + R_1} = 2$$

$\Rightarrow \quad R_g + R_2 = 2R_g + 2R_1$

$R_g = R_2 - 2R_1$ **[½]**

30. (a) Calculate the binding energy of an alpha particle in MeV. Given **[3]**

mass of a proton = 1.007825 u

mass of a neutron = 1.008665 u

mass of He nucleus = 4.002800 u

1u = 931 MeV/c^2

OR

(b) A heavy nucleus P of mass number 240 and binding energy 7.6 MeV per nucleon splits into two nuclei Q and R of mass number 110 and 130 and binding energy per nucleon 8.5 MeV and 8.4 MeV respectively. Calculate the energy released in the fission. **[3]**

Sol. (a) Mass defect = (Mass of protons + mass of neutrons) – (Mass of He nucleus)

$\Delta m = \left(2m_p + 2m_n\right) - m_{He}$ **[1]**

$= (2\times 1.00782\text{u}) + (2\times 1.008665\text{u}) - 4.002800\text{u}$

$\Delta m = 4.03297 - 4.002800$ = 0.03017 u **[1]**

Binding energy = $\Delta m \times c^2$

Given 1 u = 931 MeV/c^2

$\therefore$ Binding energy = 0.03017 u × 931 MeV

= 28.088 MeV **[1]**

OR

(b) P $\rightarrow$ Q + R

P	Q	R
240	110	130
7.6 MeV	8.5 MeV	8.4 MeV

[1]

Binding energy = Binding energy per nucleon × number of nucleons

$\therefore$ Binding energy of P = 240 × 7.6 = 1824 MeV

Binding energy of Q = 110 × 8.5 = 935 MeV

Binding energy of R = 130 × 8.4 = 1092 MeV **[1]**

Energy released in the fission = (935 + 1092) – 1824 = 203 MeV **[1]**

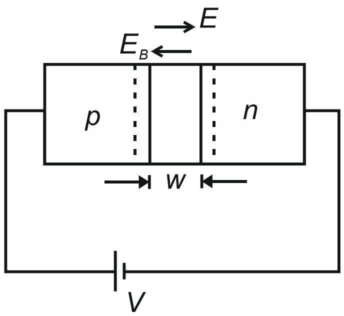
SECTION-D

31. (a) Draw the circuit arrangement for studying V-I characteristics of a p-n junction diode in (i) forward biasing and (ii) reverse biasing. Draw the typical V-I characteristics of a silicon diode. Describe briefly the following terms: (i) minority carrier injection in forward biasing and (ii) breakdown voltage in reverse biasing. **[5]**

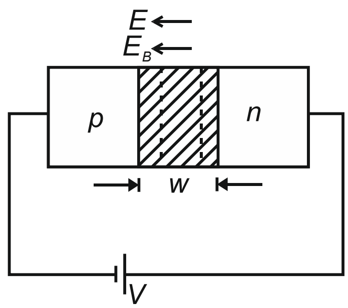
OR

(b) Name two important processes involved in the formation of a p-n junction diode. With the help of a circuit diagram, explain the working of junction diode as a full wave rectifier. Draw its input and output waveforms. State the characteristic property of a junction diode that makes it suitable for rectification. **[5]**

Sol. (a) Consider the *p-n* junction diode in biased condition



p-n junction under forward biasing



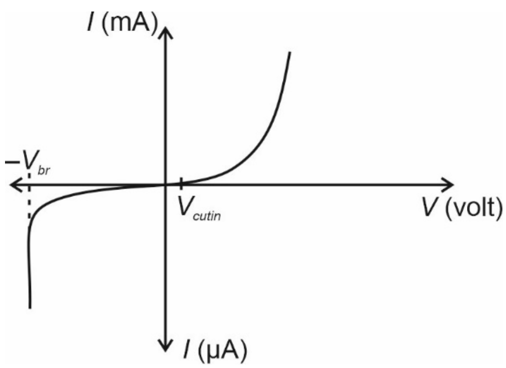
p-n junction under reverse bias **[2]**

In forward biasing positive terminal of battery is connected to the *p* side and negative terminal to *n* side. Due which *p-n* junction width becomes slightly narrower.

In reverse biasing negative terminal of battery is connected to p-side and positive terminal of battery to n-side. Here junction width is slightly widen. **[1]**

<u>I-V characteristics of p-n junction diode</u>

I-V characteristics of a junction diode is given as



[1]

With increase in forward biasing current increases very slowly up to knee voltage (cut in voltage). Beyond it current increase rapidly. (exponentially)

<u>Minority carrier injection:</u>

In forward biasing hole from *p* side is injected toward the *n*-side of diode this is called as minority carrier injection. After that hole diffuses in *n* region to reach up to terminal of *p*-*n* junction diode. **[½]**

<u>Breakdown voltage In reverse biasing</u>

In case of reverse bias the reverse current is approximately independent of reverse biasing after increasing the reverse voltage up to a certain value, the junction gets breakdown. This voltage is called breakdown voltage.

The breakdown is of two types:

(1) Zener breakdown

(2) Avalanche breakdown **[½]**

OR

(b) ***<u>p-n</u>*** **<u>junction formation</u>**

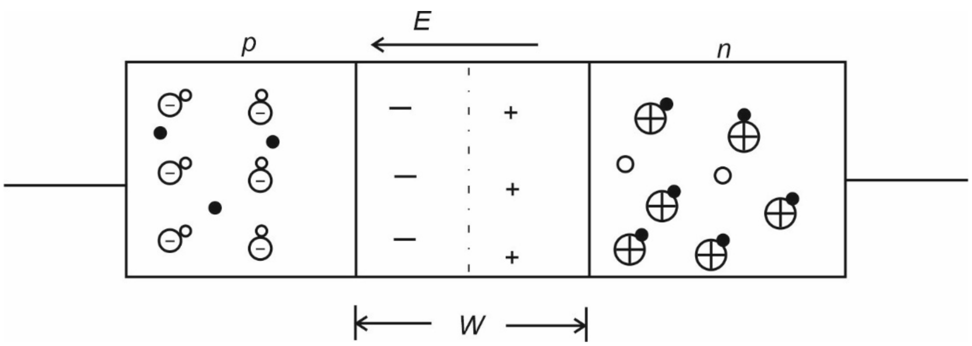
p-n junction is formed either when a *p*-type semiconductor is grown in *n*-type or *n*-type is grown in *p*-type semiconductor.

The *p-n* junction is formed due to diffusion of charge carriers.

The two main process in *p-n* junction formation are

(1) Diffusion of charge carriers

(2) Drifting of charge Carriers **[½]**

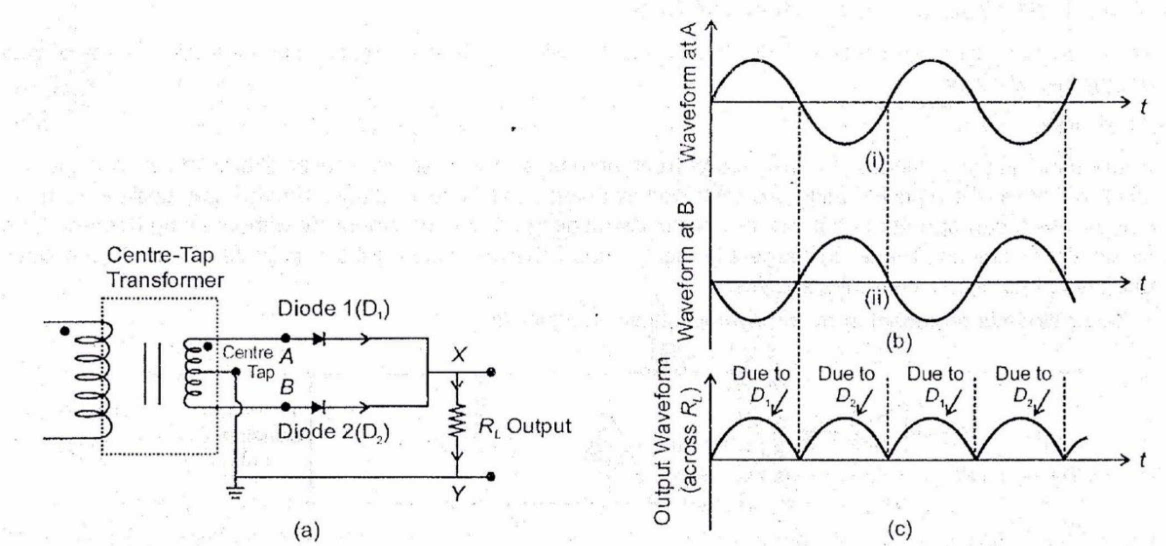


[½]

Full wave Rectifier:

As diode has unique property that it allow the current in one direction and offer large (ideally infinite) resistance in other direction. This property makes suitable to use diode in a rectifier circuit.

The schematic diagram of a full wave centre tap rectifier is shown in the figure (a). **[½]**



[2]

Consider the input voltage to *A* with respect to the centre tap at any instant is positive then at that instant, voltage at *B* will be negative and vice-versa.

During the positive half-cycle of the input voltage sine wave, the diode D_1 is forward-biased and diode D_2 is reverse-biased, and the current flows in the direction shown in the figure. During the negative half-cycle, the diode D_2 is forward-biased and diode D_1 is reverse-biased. Hence, during this time also, a current flows through R_L in the same direction as in the previous half-cycle. Thus, the current flows (in the same direction) through R_L during the positive as well as the negative half-cycles of the input ac voltage. Hence, the dc voltage shape across R, is as shown in figure (c). This process is known as **full-wave rectification.** **[1½]**

32. (a) (i) Draw a ray diagram to show the working of a compound microscope. Obtain the expression for the total magnification for the final image to be formed at the near point. **[3]**

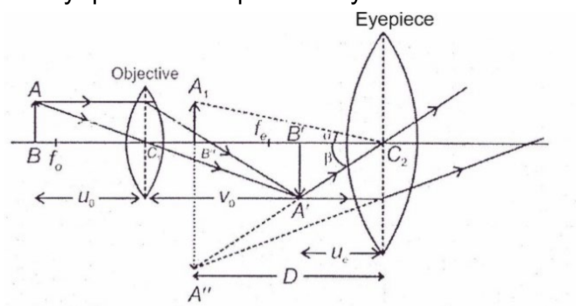
(ii) In a compound microscope an object is placed at a distance of 1.5 cm from the objective of focal length 1.25 cm. If the eye-piece has a focal length of 5 cm and the final image is formed at the near point, find the magnifying power of the microscope. **[2]**

OR

(b) (i) Draw a ray diagram for the formation of image of an object by an astronomical telescope, in normal adjustment. Obtain the expression for its magnifying power.

(ii) The magnifying power of an astronomical telescope in normal adjustment is 2.9 and the objective and the eyepiece are separated by a distance of 150 cm. Find the focal lengths of the two lenses. **[5]**

Sol. (a) (i) **[1]**



Magnifying power, $M = \dfrac{\beta}{\alpha}$

$$M = \frac{\tan\beta}{\tan\alpha}$$

$$= \frac{A''B''}{C_2B''} \times \frac{C_2B''}{AB} \left[A_1B'' = AB\right] \quad \textbf{[1]}$$

$$M = m_e \times m_0$$

$$= \left(1 + \frac{D}{f_e}\right) \times m_0$$

$$= \frac{v_0}{-u_0}\left(1 + \frac{D}{f_e}\right) \quad \textbf{[1]}$$

(ii) $u_0 = -1.5$ cm

$f_0 = 1.25$ cm

$$\frac{1}{f_0} = \frac{1}{v_0} - \frac{1}{u_0}$$

$$\frac{1}{1.25} = \frac{1}{v_0} + \frac{1}{1.5}$$

$$\Rightarrow \frac{1}{v_0} = \frac{1}{1.25} - \frac{1}{1.5}$$

$$= \frac{100}{125} - \frac{10}{15}$$

$$= \frac{1500 - 1250}{1875}$$

$$\Rightarrow \frac{1}{v_0} = \frac{250}{1875} \quad \textbf{[1]}$$

$\Rightarrow$ v_0 = +7.5 cm

f_e = +5 cm

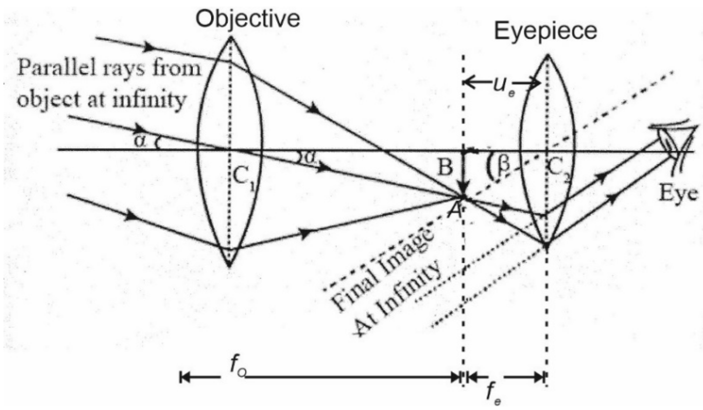
$$m = -\frac{v_0}{u_0}\left[1+\frac{D}{f_e}\right]$$

$$m = \frac{7.5}{-1.5}\left[1+\frac{25}{5}\right]$$

$$= \frac{-7.5}{1.5}\times 6$$

m = –30 **[1]**

(b) (i) **[1]**



Magnifying power = $\frac{\beta}{\alpha} = \frac{\left[\frac{BA}{-u_e}\right]}{\frac{BA}{f_o}} = -\frac{f_0}{u_e}$ **[1]**

Since the final image is formed at the infinity hence

$|u_e| = |f_e|$.

$\Rightarrow$ $m = \frac{-f_o}{f_e}$, for the formation of image in the normal adjustment.

(ii) $m = -\frac{f_o}{f_e}$ [for normal adjustment] **[1]**

$\Rightarrow$ also, $L = f_o + f_e \Rightarrow 150 = f_0 + f_e$ ...(1)

and $\frac{f_o}{f_e} = 2.9 \Rightarrow f_o = 2.9 f_e$ ...(2) **[1]**

putting the value obtained from equation (2) in equation (1)

$\Rightarrow$ $2.9f_e + f_e = 150 \Rightarrow f_e = \frac{150}{3.9}$ = 38.46 cm

and f_o = 2.9 f_e $\Rightarrow$ f_0 = 111.538 cm

$\Rightarrow$ f_o = 111.538 cm and f_e = 38.46 cm **[1]**

33. (a) (i) Explain how free electrons in a metal at constant temperature attain an average velocity under the action of an electric field. Hence obtain an expression for it. **[3]**

(ii) Consider two conducting wires A and B of the same diameter but made of different materials joined in series across a battery. The number density of electrons in A is 1.5 times that in B. Find the ratio of drift velocity of electrons in wire A to that in wire B. **[2]**

OR

(b) (i) A cell emf of (E) and internal resistance (r) is connected across a variable load resistance (R). Draw plots showing the variation of terminal voltage V with (i) R and (ii) the current (I) in the load. **[2]**

(ii) Three cells, each of emf E but internal resistances 2r, 3r and 6r are connected in parallel across a resistor R. **[3]**

Obtain expressions for (i) current flowing in the circuit, and (ii) the terminal potential difference across the equivalent cell.

Sol. (a) (i) No net movement of electrons when no external electric field is applied across a conductor. When electric field (E) is applied, then

$$\vec{F} = -\vec{E}e \quad \text{...(i)}$$

$$\vec{F} = m\vec{a} \quad \text{...(ii)}$$

$$\therefore \quad \vec{a} = -\frac{\vec{E}e}{m}$$ **[1]**

Drift velocity or average velocity is given by

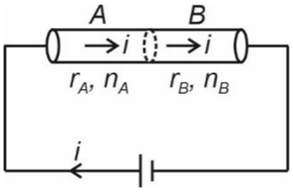
$$\vec{v}_d = \left(\vec{v}_i\right)_{\text{average}} - \frac{e\vec{E}}{m}(t)_{\text{average}}$$ **[1]**

$(\vec{v}_i)_{\text{average}} = 0$ and $(t)_{\text{average}} = \tau$(Relaxation time)

$$\therefore \quad \vec{v}_d = \frac{eE}{m}\tau$$

Relaxation time (τ) remains constant at constant temperature (T). **[1]**

(ii)



Since wires are connected in series, therefore some current will flow in the two wires.

we know that,

$$I = neAv_d$$ **[1]**

$$\therefore \quad I_A = I_B \Rightarrow n_A eA_A \times (\vec{v}_d)_A = n_B eA_B \times (\vec{v}_d)_B$$

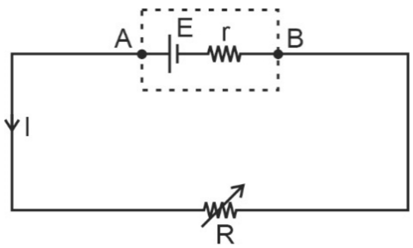
Given $n_A = 1.5n_{B,}\ A_A = A_B$

$$\therefore \quad 1.5n_B \times (\vec{v}_d)_A = n_B \times (\vec{v}_d)_B$$

$$\frac{(\vec{v}_d)_A}{(\vec{v}_d)_B} = \frac{1}{1.5} = \frac{2}{3}$$ **[1]**

OR

(b) (i) The given situation is shown in figure



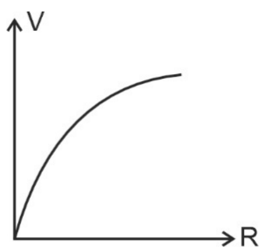
$V_A - V_B = V \Rightarrow$ Terminal voltage of the battery

$$I = \frac{E}{R+r} \qquad \text{...(i)}$$

(I) Variation of V with R

$$V = E - Ir \Rightarrow V = E - \left(\frac{E}{R+r}\right)r$$ **[1]**

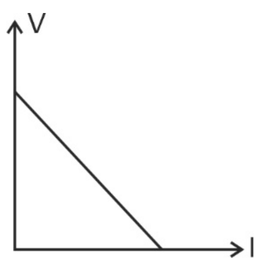
$$V = \frac{ER}{r+R}$$



[½]

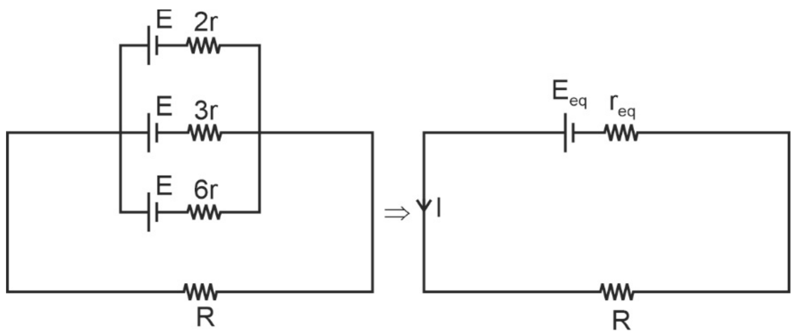
(II) Variation of V with I

$V = E - Ir$



[½]

(ii) Given condition is shown in figure.



[1]

In parallel combination:

$$E_{eq} = \frac{\frac{E_1}{r_1}+\frac{E_2}{r_2}+\frac{E_3}{r_3}}{\frac{1}{r_1}+\frac{1}{r_2}+\frac{1}{r_3}} \Rightarrow E_{eq} = \frac{\frac{E}{2r}+\frac{E}{3r}+\frac{E}{6r}}{\frac{1}{2r}+\frac{1}{3r}+\frac{1}{6r}}$$

$$E_{eq} = \frac{\frac{3E+2E+E}{6r}}{\frac{3+2+1}{6r}} \Rightarrow E_{eq} = \frac{6E}{6} = E \quad \text{...(i)}$$ **[1]**

$$\frac{1}{r_{eq}} = \frac{1}{r_1}+\frac{1}{r_2}+\frac{1}{r_3} = \frac{1}{2r}+\frac{1}{3r}+\frac{1}{6r}$$

$r_{eq} = r$ ...(ii)

Current flowing in the circuit

$$I = \frac{E_{eq}}{R+r_{eq}} = \frac{E}{R+r} \quad \text{...(iii)}$$

Terminal potential difference across the equivalent cells

$V = E - Ir$

$$\Rightarrow V = E - \left(\frac{E}{R+r}\right)r$$

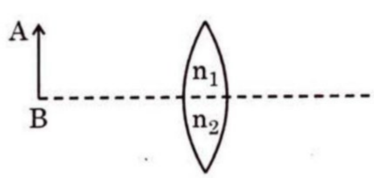
$$V = \frac{ER}{R+r} \quad \text{...(iv)}$$ **[1]**

SECTION-E

Note : Questions number 34 and 35 are Case Study based questions. Read the following paragraph and answer the questions.

34. A lens is a transparent optical medium bounded by two surfaces; at least one of which should be spherical. Considering image formation by a single spherical surface successively at the two surfaces of a lens, lens maker's formula is obtained. It is useful to design lenses of desired focal length using surfaces of suitable radii of curvature. This formula helps us obtain a relation between u, v and f for a lens. Lenses form images of objects and they are used in a number of optical devices, for example microscopes and telescopes. **[4]**

(i) An object AB is kept in front of a composite convex lens, as shown in figure. Will the lens produce one image? If not, explain.



(ii) A real image of an object formed by a convex lens is observed on a screen. If the screen is removed, will the image still be formed? Explain.

(iii) A double convex lens is made of glass of refractive index 1.55 with both faces of the same radius of curvature. Find the radius of curvature required if focal length is 20 cm.

OR

(iii) Two convex lenses A and B of focal lengths 15 cm and 10 cm respectively are placed coaxially 'd' distance apart. A point object is kept at a distance of 30 cm in front of lens A. Find the value of 'd' so that the rays emerging from lens B are parallel to its principal axis.

Sol. (i) No, given composite lens produces two images. We know that focus of the lens $\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$. In the given lens two materials are used therefore it has two focal length and it will form two images. **[1]**

(ii) If screen is removed, the image will still be formed because image formation is due to converging of refracted rays by convex lens which is unaffected by presence of screen. **[1]**

Screen is used only to observe the image.

(iii) By lens maker formula

$$\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

Here μ = 1.55, $R_1 = R_2$ = R and f = 20

On putting these values in lens maker's formula

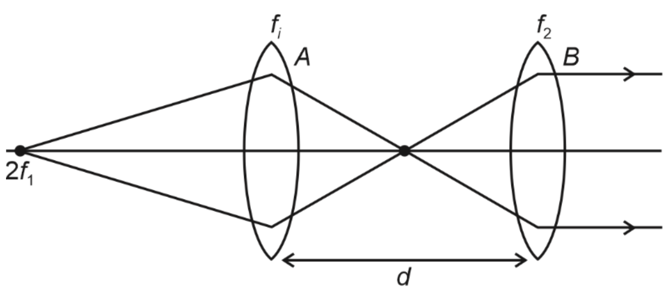
$$\frac{1}{20}=(1.55-1)\left(\frac{1}{R}+\frac{1}{R}\right)$$ **[1]**

$$\frac{1}{20}=\frac{55}{100}\times\frac{2}{R}$$

R = 22 cm **[1]**

OR

(iii) By ray diagram



[1]

Emerging ray will be parallel to principal axis if image of lens *A* is formed at the focus of lens *B*

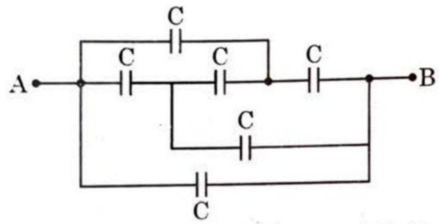
$d = 2f_1 + f_2$

= 30 + 10

= 40 cm **[1]**

35. A capacitor is a system of two conductors separated by an insulator. The two conductors have equal and opposite charges with a potential difference between them. The capacitance of a capacitor depends on the geometrical configuration (shape, size and separation) of the system and also on the nature of the insulator separating the two conductors. They are used to store charges. Like resistors, capacitors can be arranged in series or parallel or a combination of both to obtain desired value of capacitance. **[4]**

(i) Find the equivalent capacitance between points A and B in the given diagram.

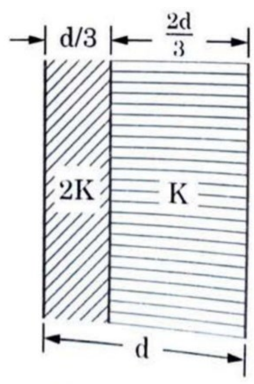


(ii) A dielectric slab is inserted between the plates of a parallel plate capacitor. The electric field between the plates decreases. Explain.

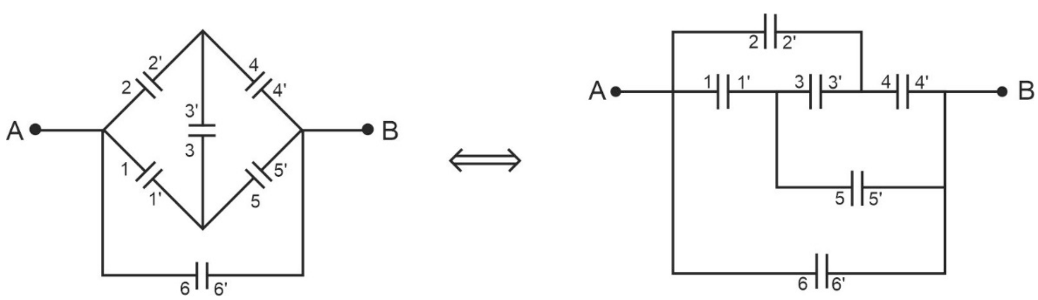
(iii) A capacitor A of capacitance C, having charge Q is connected across another uncharged capacitor B of capacitance 2C. Find an expression for (a) the potential difference across the combination and (b) the charge lost by capacitor A.

OR

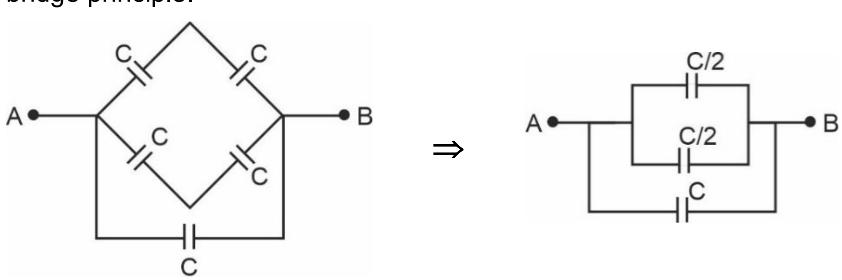
(iii) Two slabs of dielectric constants 2K and K fill the space between the plates of a parallel plate capacitor of plate area A and plate separation d as shown in figure. Find an expression for capacitance of the system.



Sol. (i)

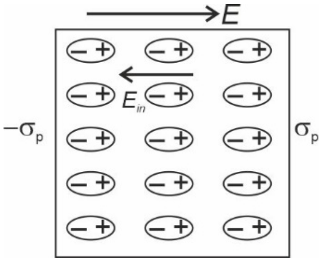


In the above circuit diagram, we can remove capacitor with plate number 33′ by applying Wheatstone bridge principle.



$$C_{eq} = \frac{C}{2} + \frac{C}{2} + C \quad \textbf{[1]}$$

$C_{eq} = 2C$

(ii) 

When a dielectric slab is inserted between the charged plates of a capacitor, due to polarization of molecules of dielectric slab an internal electric field is generated in slab in the direction opposite to that of between the plates of capacitor. Hence, net electric field between the plates of capacitor decreases.

$E_{net} = E - E_{in}$ **[1]**

(iii) (a) Given $C_A = C$

Charge on $C_A = Q$

$Q = CV$

When two capacitors are connected in parallel then

$C_{eq} = C + 2C$

$= 3C$

$Q_{net} = Q$ (Because charge will be conserved)

$$V' = \frac{Q}{3C}$$

Potential difference across each capacitor = $\frac{Q}{3C}$ **[1]**

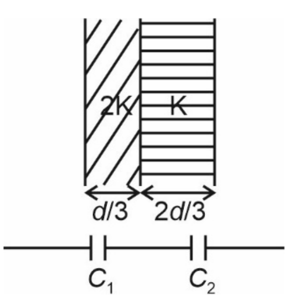
(b) Now final charge on capacitor

$$A = C \times \frac{Q}{3C}$$

$$= \frac{QC}{3C} = \frac{Q}{3}$$

Therefore, charge lost by capacitor $A = Q - \frac{Q}{3} = \frac{2Q}{3}$ **[1]**

OR

(iii) 

$$C = \frac{K\varepsilon_0 A}{d}$$

$$C_1 = \frac{2K\varepsilon_0 A}{d/3} = \frac{6K\varepsilon_0 A}{d}$$

$$C_2 = \frac{K\varepsilon_0 A}{2d/3} = \frac{3K\varepsilon_0 A}{2d}$$ **[1]**

Since the two capacitors are in series therefore

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\frac{1}{C_{eq}} = \frac{d}{6K\varepsilon_0 A} + \frac{2d}{3K\varepsilon_0 A}$$

$$\frac{1}{C_{eq}} = \frac{d}{6K\varepsilon_0 A} + \frac{4d}{6K\varepsilon_0 A}$$

$$\frac{1}{C_{eq}} = \frac{5d}{6K\varepsilon_0 A}$$

$$\boxed{C_{eq} = \frac{6K\varepsilon_0 A}{5d}}$$ **[1]**

❑ ❑ ❑