CBSE Sample Question Paper, Delhi–2021(Solved)

Time Allowed: 3 hours **Max. Marks: 70**

General Instructions:

(i) All questions are compulsory. There are 33 questions in all.

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

(iii) Section A contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each, Section B has two case based questions of 4 marks each, Section C contains nine short answer questions of 2 marks each, Section D contains five short answer questions of 3 marks each and Section E contains three long answer questions of 5 marks each.

(iv) There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.

SECTION–A

All questions are compulsory. In case of internal choices, attempt any one of them.

1. Name the physical quantity having unit J/T.

2. Mention one use of part of electromagnetic spectrum to which a wavelength of 21 cm (emitted by hydrogen in interstellar space) belongs.

OR

Give the ratio of velocity of the two light waves of wavelengths 4000 Å and 8000 Å travelling in vacuum.

3. An electron with charge $-e$ and mass m travels at a speed v in a plane perpendicular to a magnetic field of magnitude B. The electron follows a circular path of radius R. In a time t, the electron travels halfway around the circle. What is the amount of work done by the magnetic field?

4. A solenoid with N loops of wire tightly wrapped around an iron-core is carrying an electric current I. If the current through this solenoid is reduced to half, then what change would you expect in inductance L of the solenoid?

OR

An alternating current from a source is given by $i = 10 \sin 314t$. What is the effective value of current and frequency of source?

5. What is the value of angular momentum of electron in the second orbit of Bohr's model of hydrogen atom?

6. In a photoelectric experiment, the potential required to stop the ejection of electrons from cathode is 4 V. What is the value of maximum kinetic energy of emitted photoelectrons?

7. In decay of free neutron, name the elementary particle emitted along with proton and electron in nuclear reaction.

OR

In the following nuclear reaction, identify unknown labelled X.

$$^{22}_{11}\text{Na} + \text{X} \longrightarrow {}^{22}_{10}\text{Ne} + \nu_e$$

8. How does the width of depletion region of a *p–n* junction vary if doping concentration is increased?

OR

In half wave rectification, what is the output frequency if input frequency is 25 Hz?

9. When a voltage drop across a *p–n* junction diode is increased from 0.70 V to 0.71V, the change in the diode current is 10 mA .What is the dynamic resistance of diode?

10. Which specially fabricated *p–n* junction diode is used for detecting light intensity?

For question numbers 11, 12, 13 and 14, 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 A and R are true and R is the correct explanation of A.

(b) Both A and R are true but R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false and R is also false.

11. Assertion(A): In a non-uniform electric field, a dipole will have translatory as well as rotatory motion.

Reason (R): In a non-uniform electric field, a dipole experiences a force as well as torque.

12. Assertion(A): Electric field is always normal to equipotential surfaces and along the direction of decreasing order of potential.

Reason (R): Negative gradient of electric potential is electric field.

13. Assertion(A): A convex mirror cannot form real images.

Reason (R): Convex mirror converges the parallel rays that are incident on it.

14. Assertion(A): A convex lens of focal length 30 cm can't be used as a simple microscope in normal setting.

Reason (R): For normal setting, the angular magnification of simple microscope is $M = D/f$.

SECTION–B

Questions 15 and 16 are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

15. Faraday Cage: A Faraday cage or Faraday shield is an enclosure made of a conducting material. The fields within a conductor cancel out with any external fields, so the electric field within the enclosure is zero. These Faraday cages act as big hollow conductors you can put things in to shield them from electrical fields. Any electrical shocks the cage receives, pass harmlessly around the outside of the cage.

(*i*) Which of the following material can be used to make a Faraday cage?

(*a*) Plastic (*b*) Glass (*c*) Copper (*d*) Wood

(*ii*) Example of a real-world Faraday cage is

(*a*) car (*b*) plastic box (*c*) lightning rod (*d*) metal rod (*iii*) What is the electrical force inside a Faraday cage when it is struck by lightning?

(*a*) The same as the lightning (*b*) Half that of the lightning

(*c*) Zero (*d*) A quarter of the lightning

(*iv*) An isolated point charge $+q$ is placed inside the Faraday cage. Its surface must have charge equal to

(*a*) zero (*b*) $+q$ (*c*) $-q$ (*d*) $+2q$

(*v*) A point charge of 2 μC is placed at centre of Faraday cage in the shape of cube with surface of 9 cm edge. The number of electric field lines passing through the cube normally will be

(*a*) 1.9×10^5 Nm^2/C entering the surface

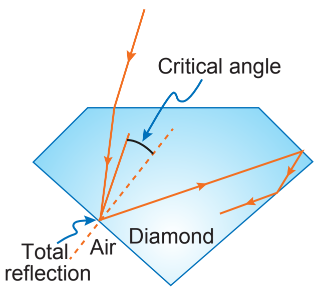
(*b*) 1.9×10^5 Nm^2/C leaving the surface

(*c*) 2.0×10^5 Nm^2/C leaving the surface

(*d*) 2.0×10^5 Nm^2/C entering the surface

16. Sparking Brilliance of Diamond:

The total internal reflection of the light is used in polishing diamonds to create a sparking brilliance. By polishing the diamond with specific cuts, it is adjusted so that the most of the light rays approaching the surface are incident with an angle of incidence more than critical angle. Hence, they suffer multiple reflections and ultimately come out of diamond from the top. This gives the diamond a sparking brilliance.



(*i*) Light cannot easily escape a diamond without multiple internal reflections. This is because:

(*a*) Its critical angle with reference to air is too large.

(*b*) Its critical angle with reference to air is too small.

(*c*) The diamond is transparent.

(*d*) Rays always enter at angle greater than critical angle.

(*ii*) The critical angle for a diamond is 24.4°. Then its refractive index is:

(*a*) 2.42 (*b*) 0.413 (*c*) 1 (*d*) 1.413

(*iii*) The basic reason for the extraordinary sparkle of suitably cut diamond is that

(*a*) it has low refractive index (*b*) it has high transparency

(*c*) it has high refractive index (*d*) it is very hard

(*iv*) A diamond is immersed in a liquid with a refractive index greater than water. Then the critical angle for total internal reflection will

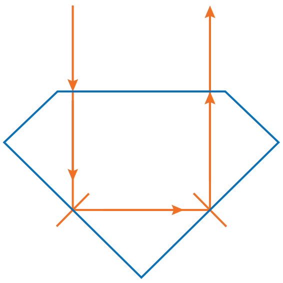
(*a*) depend on the nature of the liquid

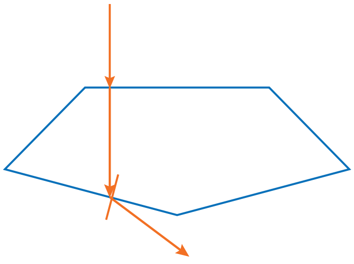
(*b*) decrease

(*c*) remain the same

(*d*) increase

(*v*) The following diagram shows same diamond cut in two different shapes.





The brilliance of diamond in the second diamond will be:

(*a*) less than the first (*b*) greater than first

(*c*) same as first (*d*) will depend on the intensity of light

All questions are compulsory. In case of internal choices, attempt any one.

17. Two straight infinitely long wires are fixed in space so that the current in the left wire is 2 A and directed out of the plane of the page and the current in the right wire is 3 A and directed into the plane of the page. In which region(s) is/are there a point on the x-axis, at which the magnetic field is equal to zero due to these currents carrying wires? Justify your answer.

18. Draw the graph showing intensity distribution of fringes with phase angle due to diffraction through single slit.

OR

What should be the width of each slit to obtain n maxima of double slit pattern within the central maxima of single slit pattern?

19. Deduce an expression for the potential energy of a system of two point charges q_1 and q_2 located at positions r_1 and r_2 respectively in an external field $(\vec{E})$.

OR

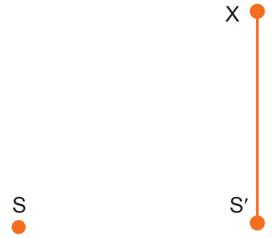
Establish the relation between electric field and electric potential at a point.

Draw the equipotential surface for an electric field pointing in +Z direction with its magnitude increasing at constant rate along –Z direction.

20. Explain with help of circuit diagram, the action of a forward biased *p-n* junction diode which emits spontaneous radiation. State the least band gap energy of this diode to have emission in visible region.

21. A coil of wire enclosing an area 100 cm^2 is placed with its plane making an angle 60^0 with the magnetic field of strength 10^{-1}T. What is the flux through the coil? If magnetic field is reduced to zero in 10^{-3} s, then find the induced emf.

22. Two waves from two coherent sources S and S' superimpose at X as shown in the figure. If X is a point on the second minima and SX – S'X is 4.5 cm. Calculate the wavelength of the waves.



23. Draw the energy band diagram when intrinsic semiconductor (Ge) is doped with impurity atoms of Antimony (Sb). Name the extrinsic semiconductor so obtained and majority charge carriers in it.

24. Define the terms magnetic inclination and horizontal component of earth's magnetic field at a place. Establish the relationship between the two with help of a diagram.

OR

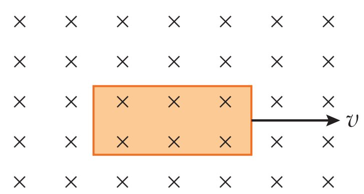
Horizontal component of earth's magnetic field at a place is $\sqrt{3}$ times the vertical component. What is the value of inclination at that place?

25. Write two characteristics of image formed when an object is placed between the optical centre and focus of a thin convex lens. Draw the graph showing variation of image distance v with object distance u in this case.

SECTION–D

All questions are compulsory. In case of internal choices, attempt any one.

26. A rectangular loop which was initially inside the region of uniform and time - independent magnetic field, is pulled out with constant velocity v as shown in the figure.



(*a*) Sketch the variation of magnetic flux, the induced current, and power dissipated as Joule heat as function of time.

(*b*) If instead of rectangular loop, circular loop is pulled out; do you expect the same value of induced current? Sketch the variation of flux in this case with time. Justify your answer.

27. A variable resistor R is connected across a cell of emf E and internal resistance r.

(*a*) Draw the circuit diagram.

(*b*) Plot the graph showing variation of potential drop across R as function of R.

(*c*) At what value of R current in circuit will be maximum?

OR

A storage battery of emf 8 V and internal resistance 0.5 ohm is being charged by d.c. supply of 120 V using a resistor of 15.5 ohm.

(*a*) Draw the circuit diagram.

(*b*) Calculate the potential difference across the battery.

(*c*) What is the purpose of having series resistance in this circuit?

28. (*a*) Explain de-Broglie argument to propose his hypothesis. Show that de-Broglie wavelength of photon equals electromagnetic radiation.

(*b*) If deuterons and alpha particle are accelerated through same potential, find the ratio of the associated de-Broglie wavelengths of two.

OR

State the main implications of observations obtained from various photoelectric experiments. Can these implications be explained by wave nature of light? Justify your answer.

29. Derive an expression for the frequency of radiation emitted when a hydrogen atom de-excites from level n to level $(n-1)$. Also show that for large values of n, this frequency equals to classical frequency of revolution of an electron.

30. (*a*) Give one point of difference between nuclear fission and nuclear fusion.

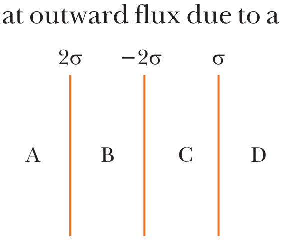
(*b*) Suppose we consider fission of a $^{56}_{26}Fe$ into two equal fragments of $^{28}_{13}Al$ nucleus. Is the fission energetically possible? Justify your answer by working out Q value of the process. Given $(m)\ ^{56}_{26}Fe = 55.93494$ u and $(m)\ ^{28}_{13}Al = 27.98191$

SECTION–E

All questions are compulsory. In case of internal choices, attempt any one.

31. (*a*) State Gauss's law in electrostatics. Show with help of suitable figure that outward flux due to a point charge Q, in vacuum within gaussian surface, is independent of its size and shape.

(*b*) In the figure there are three infinite long thin sheets having surface charge density $+2\sigma$, -2σ and $+\sigma$ respectively. Give the magnitude and direction of electric field at a point to the left of sheet of charge density $+2\sigma$ and to the right of sheet of charge density $+\sigma$.



OR

(*a*) Define an ideal electric dipole. Give an example.

(*b*) Derive an expression for the torque experienced by an electric dipole in a uniform electric field. What is net force acting on this dipole?

(*c*) An electric dipole of length 2 cm is placed with its axis making an angle of 60^0 with respect to uniform electric field of 10^5 N/C.

If it experiences a torque of $8\sqrt{3}$ Nm, calculate the magnitude of charge on the dipole, and its potential energy.

32. (*a*) Derive the expression for the current flowing in an ideal capacitor and its reactance when connected to an *ac* source of voltage $V=V_0\sin\omega t$.

(*b*) Draw its phasor diagram.

(*c*) If resistance is added in series to capacitor, what changes will occur in the current flowing in the circuit and phase angle between voltage and current?

OR

(*a*) State the principle of *ac* generator.

(*b*) Explain with the help of a well labelled diagram, its working and obtain the expression for the emf generated in the coil.

(*c*) Is it possible to generate emf without rotating the coil? Explain.

33. (*a*) Define a wave front.

(*b*) Draw the diagram to show the shape of plane wave front as they pass through (*i*) a thin prism and (*ii*) a thin convex lens. State the nature of refracted wave front.

(*c*) Verify Snell's law of refraction using Huygens's principle.

OR

(*a*) State two main considerations taken into account while choosing the objective of astronomical telescope.

(*b*) Draw a ray diagram of reflecting type telescope. State its magnifying power.

(*c*) State the advantages of reflecting type telescope over the refracting type.

Answers

SECTION–A

1. Magnetic dipole moment **1**

$$m = iA$$

Unit of m = (Unit of i) × (Unit of A)

$$= \text{A m}^2 = \frac{\text{N}}{\text{Tm}}\text{m}^2 = \frac{\text{Nm}}{\text{T}} = \text{JT}^{-1}$$

2. This wavelength belongs to microwaves. It is used in radar system in aircraft navigation. **1**

OR

In vacuum, the light waves travel with a constant velocity *i.e.*, 3×10^8 m/s irrespective of the wavelengths and frequency. So, the ratio of the two wavelengths is 1:1.

3. Zero, as force acting on charge particle is always perpendicular to the displacement in circular motion. **1**

4. The inductance is given as, **1**

$$L = \mu_0 \frac{N^2 A}{l}$$

Since the inductance does not depend upon the amount of current, the inductance of solenoid remains same.

OR

$$i_{rms} = \frac{i_0}{\sqrt{2}} = \frac{10}{\sqrt{2}} = 7.07 \text{ A}$$

$$\omega = 2\pi\nu \;\Rightarrow\; \nu = \frac{\omega}{2\pi} = \frac{314}{2 \times 3.14} = 50 \text{ Hz.}$$

5. According to Bohr, **1**

The angular momentum of an orbiting electron = $\frac{nh}{2\pi}$

Here, $n = 2$

$$\text{Angular momentum} = \frac{2 \times h}{2\pi} = \frac{h}{\pi}$$

6. $K.E_{max} = \frac{1}{2}mv_{max}^2 = eV_0$ **1**

$= 1.6 \times 10^{-19} \times 4$

$= 4$ eV

7. A free neutron is unstable and it decays into a proton and an electron with emission of antineutrino. The process is β-decay and represented as: **1**

$$n \longrightarrow p + e^- + \bar{\nu}$$

OR

$$^{22}_{11}\text{Na} + X^A_Z \longrightarrow \; ^{22}_{10}\text{Na} + \nu_e$$

On comparing both sides

$22 + A = 22$

∴ $A = 0$

$Z + 11 = 10$

$Z = -1$

∴ X is electron as $^{0}_{-1}$X.

8. When doping concentration is kept high in p–n junction, then there will be less space for electron to travel and equilibrium is achieved by recombination between charge carriers in nearby region. So, depletion width is decreased with doping. **1**

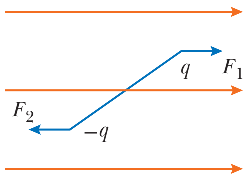
OR

For a half wave rectifier, the output frequency is equal to the input frequency. So, the frequency after rectification is 25 Hz.

9. Dynamic resistance $= \frac{\Delta V}{\Delta I} = \frac{0.71 - 0.70}{10 \times 10^{-3}} = \frac{0.01}{10^{-2}} = 1\,\Omega$ **1**

10. Photodiode is used for detecting light intensity. **1**

11. (*a*) Both A and R are true and R is the correct explanation of A. **1**



As $F_1 = qE_1$

$F_2 = qE_2$

$E_1 \neq E_2$ So, $F_1 \neq F_2$

$F_{net} = F_2 - F_1$

and dipole has a torque, τ.

12. (*b*) Both A and R are true but R is not the correct explanation of A. **1**

There is no potential gradient along any direction parallel to the surface and no electric field is parallel with the surface. This means electric field are always at right angle to equipotential surface.

Also, electric field, $E = -\frac{dV}{dr}$

i.e., it is negative potential gradient and thus in the direction of decreasing potential.

13. (*c*) A is true but R is false. **1**

Convex mirror is diverging in nature, in convex mirrors light rays from a point always gets diverged. Since image is formed behind of mirror, they can't be received on screen *i.e.*, always form virtual image.

14. (*b*) Both A and R are true but R is not the correct explanation of A. **1**

For normal setting, the angular magnification of simple microscope

$$m = \frac{D}{f} = \frac{25}{30} = 0.83$$

$\because m < 1$, so assertion (A) is correct statement.

SECTION–B

15. (*i*) (*c*) Copper (Electric field inside a conductor is zero.) **4**

(*ii*) (*a*) car (Body of the car is made up of conductor.)

(*iii*) (*c*) Zero (As electric field inside it is zero.)

(*iv*) (*c*) $-q$ (As from Gauss's law q_{in} must be zero for electric field inside it is zero.)

(*v*) (*c*) $q = 2\ \mu C = 2 \times 10^{-6}$ C

$$\varepsilon_0 = 8.85 \times 10^{-12} \frac{Nm^2}{C^2}$$

Now, total number of electric field lines $= \frac{q_{in}}{\varepsilon_0} = \frac{2 \times 10^{-6}}{8.85 \times 10^{-12}}$

$= 2.2 \times 10^5 \frac{Nm^2}{C}$ leaving the surface

16. (*i*) (*b*) Its critical angle with reference to air is too small. **4**

(*ii*) (*a*) 2.42 ($\because$ $n = \sin i_c$)

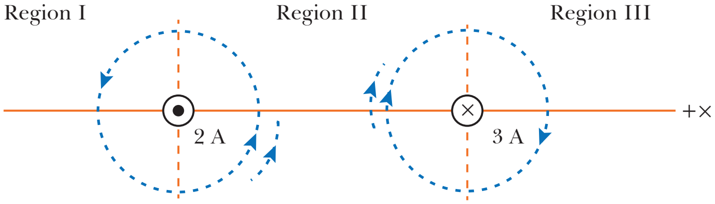
(*iii*) (*c*) it has high refractive index

(*iv*) (*d*) increase ($\because n = \sin i_c$)

(*v*) (*a*) less than first

SECTION–C

17. **2**



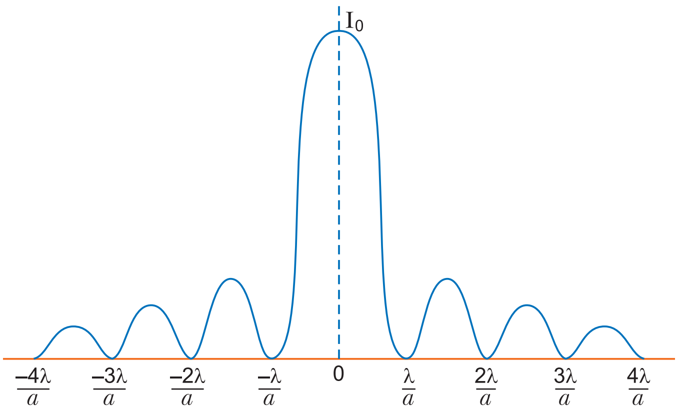
The direction of magnetic field produced by upward current is anticlockwise and downward current is clockwise.

(*i*) In region I, both the fields are in opposite direction and magnetic field is inversely proportional to distance. Since the higher current is farther, so the magnitude may be equal, hence net field may be zero.

(*ii*) In region II, both the fields are in same direction. Addition of two vectors in same direction cannot be zero.

(*iii*) In region III, fields are in opposite direction but at farther point, field due to 2 A cannot be equal to the magnitude of 3 A. Hence net field cannot be zero.

18. **2**



Intensity distribution of diffraction pattern.

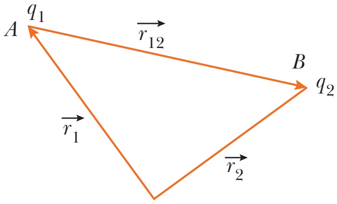
OR

Width of maxima in interference = Width of central fringe

$$\frac{n\lambda}{d} = \frac{2\lambda}{a}$$

$$d = \frac{na}{2} \text{ or } n = \frac{2d}{a}$$

19. **2**



$$r_{12} = \left|\vec{r}_{12}\right| = \left|\vec{r}_2 - \vec{r}_1\right|$$

Work done in bringing q_1 from infinity in electric field E,

$$W_1 = q_1 V(\vec{r_1})$$

Work done on q_2 against the field E,

$$W_2 = q_2 V(\vec{r_2})$$

Work done on q_2 against the field E due to q_1

$$W_3 = \frac{q_1 q_2}{4\pi\varepsilon_0 (r_{12})}$$

$\therefore$ Potential energy of the system = Total work done in assembling the system

$$U = W_1 + W_2 + W_3$$

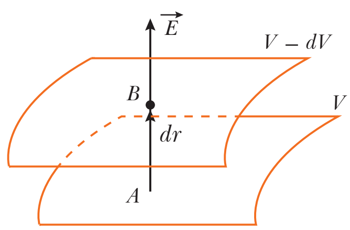
$$= q_1 V(\vec{r_1}) + q_2 V(\vec{r_2}) + \frac{q_1 q_2}{4\pi\varepsilon_0 (r_{12})}$$

$$= q_1 V(\vec{r_1}) + q_2 V(\vec{r_2}) + \frac{q_1 q_2}{4\pi\varepsilon_0 |\vec{r_2} - \vec{r_1}|}$$

OR

Let us consider two closely spaced equipotential surfaces A and B as shown in figure.

Let the potential of A be $V_A = V$ and potential of B be $V_B = V - dV$ where dV is decrease in potential in the direction of electric field $\vec{E}$ normal to A and B.



Let dr be the perpendicular distance between the two equipotential surfaces. When a unit positive charge is moved along this perpendicular from the surface B to surface A against the electric field, the work done in this process is

$$W_{BA} = -|\vec{E}|(dr)$$

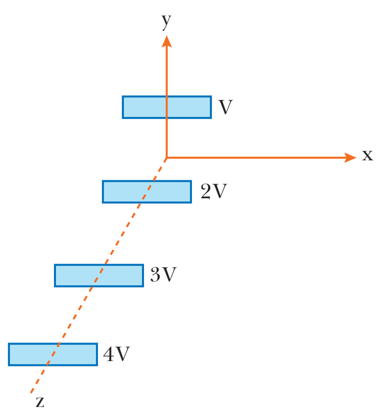
This work done equals the potential difference $V_A - V_B$.

$$\therefore \quad W_{BA} = V_A - V_B = V - (V - dV) = dV$$

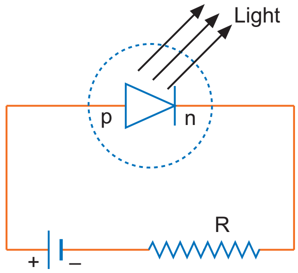
$$\therefore \quad -|\vec{E}|dr = dV$$

or, $$|\vec{E}| = -\frac{dV}{dr} = \text{negative of potential gradient.}$$

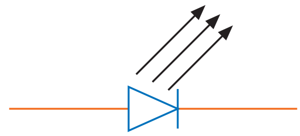
Equipotential surface is the planes parallel to plane. For same potential difference, the planes are equidistant.



20. 2



LED



LED symbol

When p–n junction diode is forward biased, the electrons move from n-side to p-side and holes move from p-side to n-side. These charge carriers recombine near the junction and energy in the form of photons is released. The colour of light emitted by LED depends upon the band-gap energy.

The least band gap energy of LED to have emission in visible region is 1.8 eV.

21. Given, $A = 100 \text{ cm}^2 = 100 \times 10^{-4} \text{ m}^2 = 10^{-2} \text{ m}^2$ 2

$B = 10^{-1}$ T

Angle made by coil with magnetic field = 60°

Angle made by normal to plane of coil with magnetic field = 30°

Flux, $\phi = BA \cos\theta$

$$= 10^{-1} \times 10^{-2} \times \cos 30° = \frac{\sqrt{3}}{2} \times 10^{-3} \text{ Wb}$$

After $t = 10^{-3}$ s, $B = 0$ (zero)

Induce emf, $E = -\dfrac{d\phi}{dt} = -\left(\dfrac{0 - \dfrac{\sqrt{3}}{2} \times 10^{-3}}{10^{-3}}\right) = \dfrac{\sqrt{3}}{2}$ V

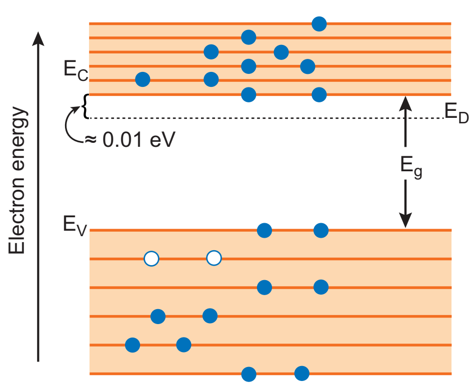
22. Path difference $= \dfrac{xd}{D} = 4.5 \text{ cm} = \dfrac{9}{2}$ cm 2

For 2nd minima, $x = \left(\dfrac{2n-1}{2d}\right)D\lambda = \dfrac{3}{2d}D\lambda$

$\therefore$ Path difference $= \dfrac{3}{2}\dfrac{D}{d}\dfrac{d}{D}\lambda = \dfrac{3}{2}\lambda$

Now, $\dfrac{3\lambda}{2} = \dfrac{9}{2}, \qquad \lambda = \dfrac{9}{3} = 3$ cm

23. 2

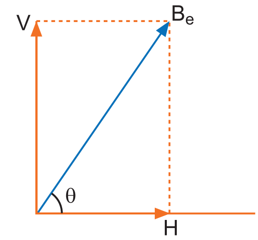


n-type semiconductor at T > 0 K

When Ge is doped with a pentavalent impurity Sb, *an* n–type extrinsic semiconductor is obtained and electrons are the majority charge carriers in it.

24. **Magnetic inclination:** It is the angle made by resultant magnetic field B_e with the horizontal. It is also called angle of dip (θ). **2**

Horizontal component of earth's magnetic field: It is the component of earth's total magnetic field B_e in horizontal direction.



$$H = B_e \cos\theta$$

Vertical component of B_e is $V = B_e \sin\theta$

$$\therefore \quad B_e = \sqrt{H^2 + V^2} \quad \text{and} \quad \tan\theta = \frac{V}{H}$$

OR

$$\tan\theta = \frac{B\sin\theta}{B\cos\theta} = \frac{B_V}{B_H}$$

$$B_H = \sqrt{3}\,B_V \qquad \text{[Given]}$$

$$\therefore \quad \tan\theta = \frac{B_V}{\sqrt{3}\,B_V} \quad \text{or} \quad \tan\theta = \frac{1}{\sqrt{3}}$$

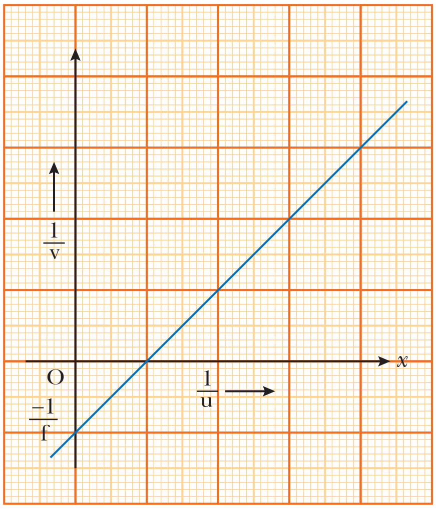
$$\therefore \quad \tan\theta = \tan 30^\circ$$

$$\therefore \quad \theta = 30^\circ$$

25. Characteristics of the images formed: **2**

(*i*) Virtual and enlarged image

(*ii*) Same side of the object



We know that,

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

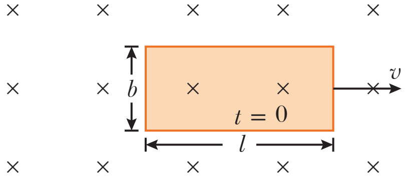
As both image and object lie on the same side, both v and u are negative,

$$\frac{-1}{v} + \frac{1}{u} = \frac{1}{f} \quad \text{or} \quad \frac{1}{v} = \frac{-1}{f} + \frac{1}{u} = \frac{1}{u} - \frac{1}{f}.$$

Comparing with $y = mx + c$, the graph is shown.

SECTION–D

26. (*a*) We know that **3**



$$\phi = \vec{B}\,\vec{A}$$

$$= Blb = \text{constant}$$

at t,

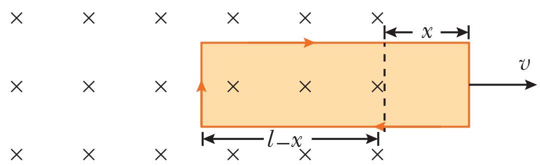
$$\phi = \vec{B}.\vec{A}$$

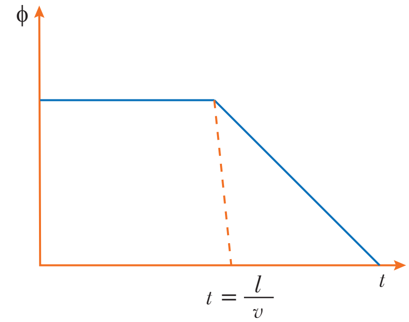
$$= B(l - x)b$$

$$\phi = Bb(l - vt)$$

$$= Bbl - Bvbt$$

$$\phi = \begin{cases} Blb & t = 0 \\ Blb - Bbvt & t = t \end{cases}$$





Now

$$\varepsilon = -\frac{d\phi}{dt} = \frac{d}{dt}(Blb - Bvbt)$$

$$\varepsilon = Bvb$$

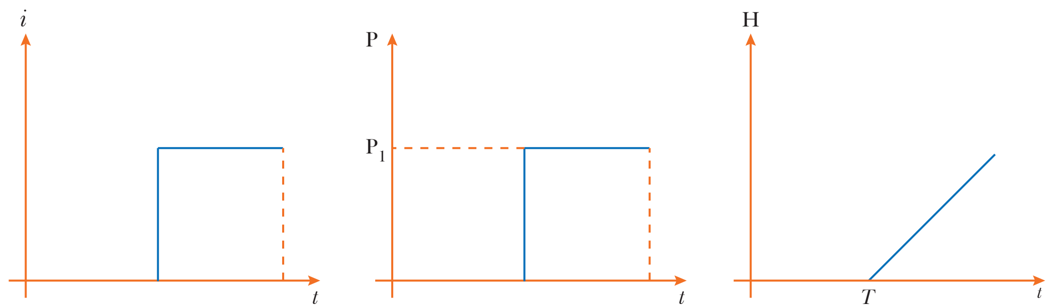
$$i = \frac{\varepsilon}{R} = \frac{Bvb}{R}$$

$$\varepsilon = \begin{cases} 0 \Rightarrow i = 0 \text{ at } t = 0 \\ Bvb \Rightarrow i = \dfrac{Bvb}{R} = \text{constant } at\ t \end{cases}$$

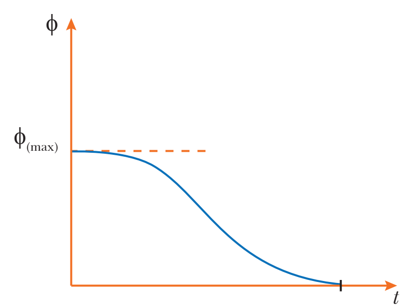
$$P = VI$$

$$P = \begin{cases} 0 \text{ at } t = 0 \\ (Bvb)\left(\dfrac{Bvb}{R}\right) = P_1 \text{ (let) at } t \end{cases}$$

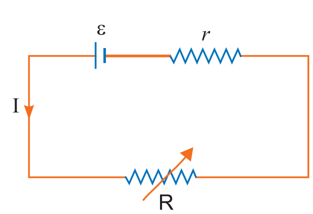
$$H = Pt = \begin{cases} 0 \ \text{ at } t = 0 \\ P_1 t = P_1(t - T) \text{ at } t \end{cases}$$



(*b*) When a circular loop is pulled out of a region of uniform magnetic field, the rate of change of area is not constant and hence the induced current varies accordingly.
The variation of flux is shown in the graph below.

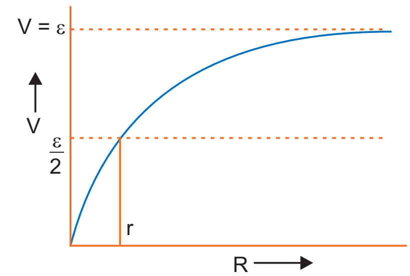


27. (*a*) **3**



(*b*) $V = IR$

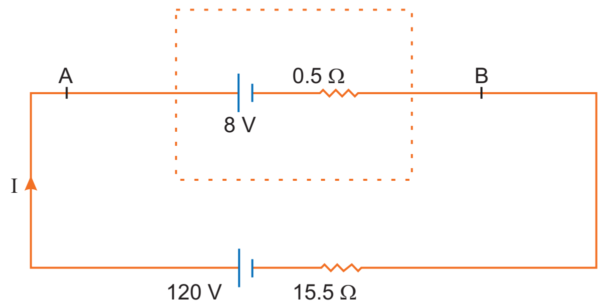
$$= \left(\frac{\varepsilon}{R+r}\right)R = \frac{\varepsilon}{(R+r)/R} = \frac{\varepsilon}{1+\frac{r}{R}}$$



(*c*) Maximum current is drawn when $R = 0$, $I = \frac{V}{R} = \frac{V}{0} = \infty$.

OR

(*a*)



(*b*) $I_{net} = \frac{V_{net}}{R+r} = \frac{120-8}{15.5+0.5} = \frac{112}{16} = 7\text{A}$

Applying Kirchoff's rule,

$V_B + 0.5(7) + 8 = V_A$

$3.5 + 8 = 11.5 = V_A - V_B$

∴ Potential difference = 11.5 V

(*c*) Series resistance limits the current through the source.

28. (*a*) Light exhibits particle aspects in certain phenomena (*e.g.*, photoelectric effect, emission and absorption of radiation), while wave aspects in other phenomena (*e.g.*, interference, diffraction and polarisation). That is, light has dual nature. In analogy with dual nature of light, de Broglie thought in terms of dual nature of matter. **3**

Louis de Broglie postulated that the **material particles** (*e.g.*, electrons, protons, α-particles, atoms, etc.) may exhibit wave aspect. Accordingly, a moving material particle behaves as wave and the wavelength associated with material particle is

$$\lambda = \frac{h}{p}, \quad \text{where } p \text{ is momentum.} \qquad \ldots(i)$$

Momentum of photon of frequency ν is given as $p = \frac{h\nu}{c}$

Equation (*i*) becomes

$$\lambda = \frac{h}{\frac{h\nu}{c}} = \frac{c}{\nu}$$

∴ The wavelength of photon is equal to the wavelength of electromagnetic wave.

(*b*) $\lambda = \dfrac{h}{\sqrt{2mK}} = \dfrac{h}{\sqrt{2meV}}$

$$\frac{\lambda_d}{\lambda_\alpha} = \frac{h}{h}\frac{\sqrt{2m_\alpha 2eV}}{\sqrt{2m_d eV}} = \frac{\sqrt{2\times m_\alpha}}{\sqrt{m_d}} = \frac{\sqrt{2\times 4m_p}}{\sqrt{2m_p}} = \frac{\sqrt{4}}{1} = \frac{2}{1}$$

$$= 2 : 1$$

OR

The observed characteristics of photoelectric effect could not be explained on the basis of wave theory of light due to the following reasons.

(*i*) According to wave theory, the light propagates in the form of wavefronts and the energy is distributed uniformly over the wavefronts. With increase of intensity of light, the amplitude of waves and the energy stored by waves will increase. These waves will then, provide more energy to electrons of metal; consequently, the energy of electrons will increase.

Thus, according to **wave theory**, ***the kinetic energy of photoelectrons must depend on the intensity of incident light; but according to experimental observations, the kinetic energy of photoelectrons does not depend on the intensity of incident light*****.**

(*ii*) According to wave theory, the light of any frequency can emit electrons from metallic surface provided the intensity of light be sufficient to provide necessary energy for emission of electrons, but according to experimental observations, the light of frequency less than threshold frequency cannot emit electrons; whatever the intensity of incident light may be.

29. Here, $n_1 = n, n_2 = n - 1$ **3**

We know that

$$\frac{1}{\lambda} = R\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)$$

$$\frac{1}{\lambda} = R\left(\frac{1}{(n-1)^2} - \frac{1}{n^2}\right)$$

$$= R\left(\frac{n^2-(n-1)^2}{n^2(n-1)^2}\right) = R\left(\frac{n^2 - n^2 - 1 + 2n}{n^2(n-1)^2}\right)$$

$$\frac{1}{\lambda} = R\left(\frac{2n-1}{n^2(n-1)^2}\right)$$

Also, $\nu = \dfrac{c}{\lambda} = Rc\left(\dfrac{2n-1}{n^2(n-1)^2}\right)$ … (*i*)

where R is Rydberg constant and

$$R = \frac{me^4}{8\varepsilon_0^2 ch^3}$$

Put this in equation (*i*)

$$\nu = \frac{me^4(2n-1)}{8\varepsilon_0^2 ch^3 n^2(n-1)^2}$$

For larger values of n, $(2n-1) \approx 2n$ and $n-1 \approx n$

$$\therefore \nu = \frac{me^4 2n}{8\varepsilon_0^2 ch^3 n^4} = \frac{me^4}{4\varepsilon_0^2 h^3 n^3}$$ …(*ii*)

Classical relation of frequency of revolution in n^{th} orbit is given as

$$\nu = \frac{v}{2\pi r}$$

where $v = \dfrac{nh}{2\pi mr}$

$\therefore\ \nu = \dfrac{nh}{4\pi^2 mr^2}$

Put $r = \dfrac{\varepsilon_0 h^2 n^2}{\pi me^2}$

$$\nu = \frac{nh\pi^2 m^2 e^4}{4\pi^2 m\varepsilon_0^2 h^4 n^4}$$

$$\nu = \frac{me^4}{4\varepsilon_0^2 h^3 n^3} \qquad \ldots(iii)$$

From equation (*ii*) and (*iii*), the frequency of radiation emitted by hydrogen atom is equal to classical orbital frequency.

30.

(*a*) 3

Nuclear fission	Nuclear fusion
Heavy nucleus splits into two smaller nuclei.	Two lighter nuclei combine to form a heavy nuclei.
It takes place at ordinary temperature.	It requires extremely high temperature of the order of 10^7 K.

(*b*) Q value $= (m_{Fe} - 2m_{Al})c^2$
$= (55.93494 - 2 \times 27.98191)c^2$
$= (-\,0.02888\ c^2)$u $= -\,0.02888 \times 931.5$ MeV
$= -\,26.902$ MeV

For a fisison to be energetically possible, the Q-value should be positive. Since, the Q-value is negative, this fission is not energetically possible.

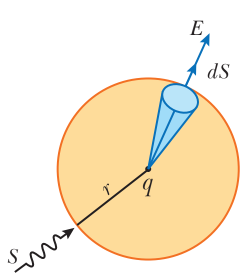
SECTION–E

31. (*a*) **Statement:** The net-outward normal electric flux through any closed surface of any shape is equal to $1/\varepsilon_0$ times the total charge contained within that surface, *i.e.*, 5

$$\oint_S \vec{E}\cdot d\vec{S} = \frac{1}{\varepsilon_0}\Sigma q$$

where $\oint_S$ indicates the surface integral over the whole of the closed surface, Σq is the algebraic sum of all the charges (*i.e.*, net charge in coulombs) enclosed by surface S and remain unchanged with the size and shape of the surface.

Proof: Let a point charge $+q$ be placed at centre O of a sphere S. Then S is a Gaussian surface.



Electric field at any point on S is given by

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

The electric field and area element points radially outwards, so $\theta = 0°$.

Flux through area $d\vec{S}$ is

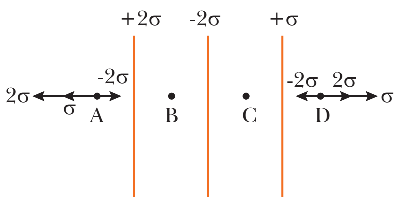
$$d\phi = \vec{E}\,.\,d\vec{S} = E\,dS\cos 0° = E\,dS$$

Total flux through surface S is

$$\phi = \oint_S d\phi = \oint_S EdS = E\oint_S dS = E \times \text{Area of sphere}$$

$$\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}4\pi r^2 \quad \text{or,} \quad \phi = \frac{q}{\varepsilon_0}$$ which proves Gauss's theorem.

(*b*) At *A*, both σ and 2σ will act in left and -2σ will act in right, so, charge density at *A* can be given as



$$E_A = \frac{2\sigma}{2\varepsilon_0} - \frac{2\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{2\varepsilon_0}$$

The net electric field at A is towards left.

Similarly at point *D*, σ and 2σ will act in right and -2σ will act in left

So, charge density $E_D = \frac{\sigma}{2\varepsilon_0} - \frac{2\sigma}{2\varepsilon_0} + \frac{2\sigma}{2\varepsilon_0} = \frac{\sigma}{2\varepsilon_0}$

The net electric field at *D* is towards right.

OR

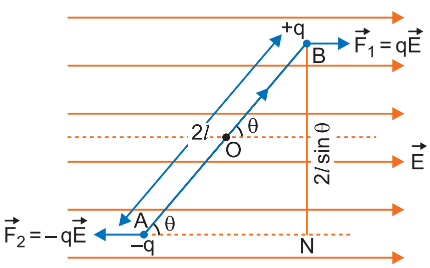
(*a*) A system containing two equal and opposite charges separated by a finite distance is called an ***electric dipole***.

Example of electric dipole is a polar molecule like carbon monoxide.

(*b*) Consider an electric dipole placed in a uniform electric field of strength *E* in such a way that its dipole moment $\vec{p}$ makes an angle θ with the direction of $\vec{E}$. The charges of dipole are $-q$ and $+q$ at separation $2l$, the dipole moment of electric dipole,

$p = q2l$ ...(*i*)

Force: The force on charge $+q$ is, $\vec{F}_1 = q\vec{E}$, along the direction of field $\vec{E}$.



The force on charge $-q$ is $\vec{F}_2 = q\vec{E}$, opposite to the direction of field $\vec{E}$.

Obviously forces $\vec{F}_1$ and $\vec{F}_2$ are equal in magnitude but opposite in direction; hence net force on electric dipole in uniform electric field is

$$F = F_1 - F_2 = qE - qE = 0 \text{ (zero)}$$

As net force on electric dipole is zero, so dipole does not undergo any translatory motion.

Torque: The forces $\vec{F}_1$ and $\vec{F}_2$ form a couple (or torque) which tends to rotate and align the dipole along the direction of electric field. This couple is called the torque and is denoted by τ.

$\therefore$ Torque, τ = magnitude of one force $\times$ perpendicular distance between lines of action of forces

$= qE\,(BN) = qE\,(2l \sin\theta) = (q2l)\,E\sin\theta$

$= pE\sin\theta$ [using (*i*)] ...(*ii*)

In vector form $\vec{\tau} = \vec{p} \times \vec{E}$ ..(*iii*)

(*c*) Here, $2l = 2 \text{ cm} = 2 \times 10^{-2}$ m

$\theta = 60°, E = 10^5 \text{ N/C}, \tau = 8\sqrt{3}$ Nm

Using $\tau = pE\sin\theta$

$\tau = 2\,qlE\sin\theta$

$$q = \frac{\tau}{2\,l\,E\sin\theta} = \frac{8\sqrt{3}\times 2}{2\times 10^{-2}\times 10^{5}\times\sqrt{3}} = 8\times 10^{-3}\text{C}$$

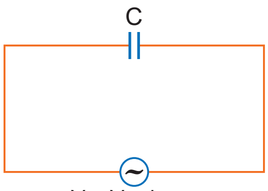
Potential energy $= -\,pE\cos\theta = -2qlE\cos\theta$

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

32. (*a*) **Capacitive reactance:** The opposition offered by a capacitor alone to the flow of alternating current through it is called the **capacitive reactance**. **5**

It is denoted by X_C. Its value is $X_C = \dfrac{1}{\omega C} = \dfrac{1}{2\pi f C}$

The graph of variation of capacitive reactance with frequency is shown in figure.



(*a*)

Circuit containing pure capacitance: Consider a capacitor of capacitance *C*; connected to an alternating voltage source as shown. As *ac* voltage changes in magnitude and direction periodically with a definite frequency; therefore the plates of capacitor get charged, discharged and charged in opposite direction, discharged continuously (Fig. *b*). Therefore the flow of alternating current in the circuit is maintained. The instantaneous voltage,

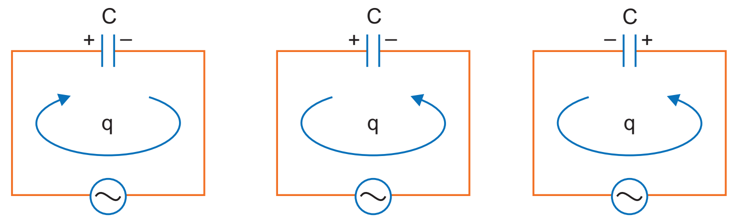
$$V = V_0 \sin \omega t \quad \text{...(i)}$$

Let *q* be the charge on capacitor and *i*, the current in the circuit at any instant, then instantaneous potential difference,

$$V = \frac{q}{C} \quad \text{...(ii)}$$

$\therefore$ From (*i*) and (*ii*) $\dfrac{q}{C} = V_0 \sin \omega t$

or $q = CV_0 \sin \omega t$



The instantaneous current,

$$i = \frac{dq}{dt} = \frac{d}{dt}(C V_0 \sin \omega t) = C V_0 \frac{d}{dt}(\sin \omega t) = C V_0\, \omega \cos \omega t$$

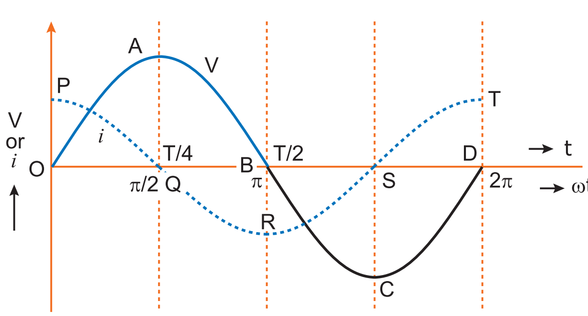
or $$i = \frac{V_0}{(1/\omega C)} \cos \omega t = \frac{V_0}{1/\omega C} \sin\left(\omega t + \frac{\pi}{2}\right)$$

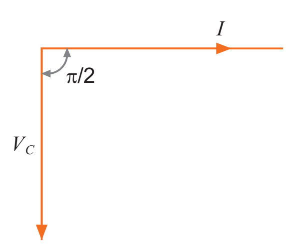
or $$i = i_0 \sin\left(\omega t + \frac{\pi}{2}\right) \quad \text{...(iii)}$$

where $i_0 = \dfrac{V_0}{(1/\omega C)}$ = peak value of *ac* ...(*iv*)

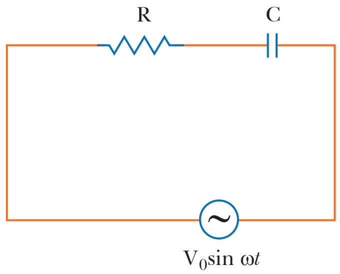
Also comparing (*i*) and (*iii*), we note that the current leads the applied emf by an angle $\dfrac{\pi}{2}$.

(*b*)





(*c*) Let a circuit contain a resistor of resistance R and a capacitor of capacitance C connected in series. The applied voltage is $V = V_0 \sin \omega t$. Suppose the voltage across resistor is V_R and that across capacitor is V_C. The voltage V_R and I are in the same phase while the voltage V_C lags behind the current by an angle $\frac{\pi}{2}$. Thus, V_R and V_C are mutually perpendicular to each other. The resultant of V_R and V_C is the applied voltage *i.e.*,



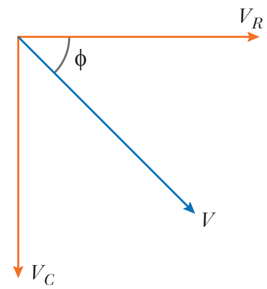
$$V = \sqrt{V_R^2 + V_C^2}$$

or $$V^2 = V_R^2 + V_C^2 = (I_0R)^2 + (I_0X_C)^2$$

$$V^2 = I_0^2(R^2 + X_C^2)$$

$$I_0 = \frac{V}{\sqrt{R^2 + X_C^2}}$$

Also, the phase angle ϕ between current and resultant voltage is given by



$$\tan \phi = \frac{V_C}{V_R} = \frac{I_0X_C}{I_0R} = \frac{X_C}{R} = \frac{\frac{1}{\omega C}}{R}$$

The current leads the voltage by an angle ϕ. So, the instantaneous current is given as

$$I = I_0 \sin(\omega t + \phi)$$

OR

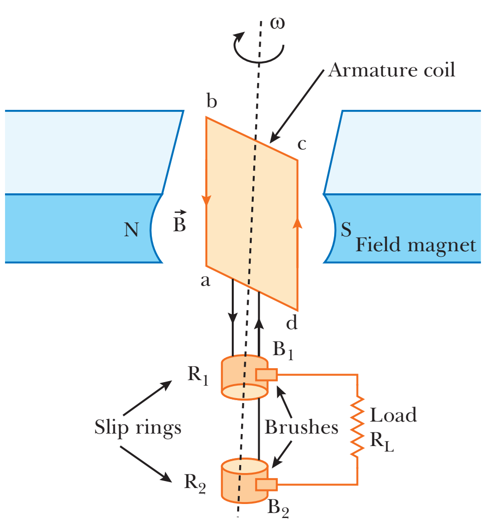
(*a*) **AC generator:** A dynamo or generator is a device which converts mechanical energy into electrical energy.

Principle: It works on the principle of electromagnetic induction. When a coil rotates continuously in a magnetic field, the effective area of the coil linked normally with the magnetic field lines, changes continuously with time. This variation of magnetic flux with time results in the production of an alternating emf in the coil.

Construction: It consists of the four main parts:

(*i*) **Field Magnet:** It produces the magnetic field. In the case of a low power dynamo, the magnetic field is generated by a permanent magnet, while in the case of large power dynamo, the magnetic field is produced by an electromagnet.

(*ii*) **Armature:** It consists of a large number of turns of insulated wire in the soft iron drum or ring. It can revolve round an axle between the two poles of the field magnet. The drum or ring serves the two purposes: (*a*) It serves as a support to coils and (*b*) It increases the magnetic field due to air core being replaced by an iron core.



(*iii*) **Slip Rings:** The slip rings R_1 and R_2 are the two metal rings to which the ends of armature coil are connected. These rings are fixed to the shaft which rotates the armature coil so that the rings also rotate along with the armature.

(*iv*) **Brushes:** These are two flexible metal plates or carbon rods (B_1 and B_2) which are fixed and constantly touch the revolving rings. The output current in external load R_L is taken through these brushes.

(*b*) **Working:** When the armature coil is rotated in the strong magnetic field, the magnetic flux linked with the coil changes and the current is induced in the coil, its direction being given by Fleming's right hand rule. Considering the armature to be in vertical position and as it rotates in clockwise direction, the wire *ab* moves downward and *cd* upward, so that the direction of induced current is shown in fig. In the external circuit, the current flows along $B_1R_LB_2$. The direction of current remains unchanged during the first half turn of armature. During the second half revolution, the wire *ab* moves upward and *cd* downward, so the direction of current is reversed and in external circuit it flows along $B_2\ R_LB_1$. Thus, the direction of induced emf and current changes in the external circuit after each half revolution.

Expression for induced emf: 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

$$\phi_B = BA\cos\theta = BA\cos\omega t$$

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 $NBA\omega = 2\pi\upsilon NBA$ is the maximum value of the emf, which occurs when $\sin\omega t = \pm 1$. If we denote $NBA\omega$ as ε_0, then

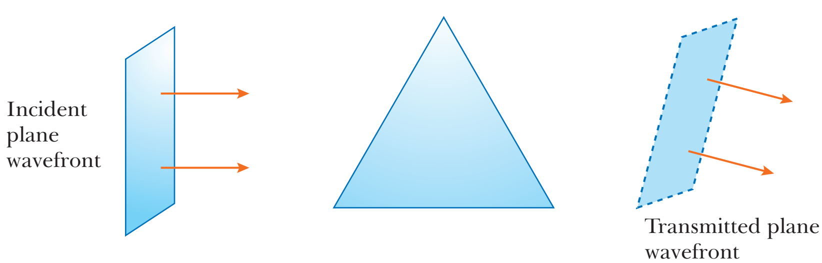
$$\varepsilon = \varepsilon_0\sin\omega t \qquad \Rightarrow \qquad \varepsilon = \varepsilon_0\sin 2\pi\nu t$$

where ν is the frequency of revolution of the generator's coil.

(*c*) The armature coil is placed in a strong uniform magnetic field and when this coil is rotated, the magnetic field linked with the coil changes that induces an emf. If the coil is not rotated, then the magnetic flux linked with the coil will not change and no emf will be induced.

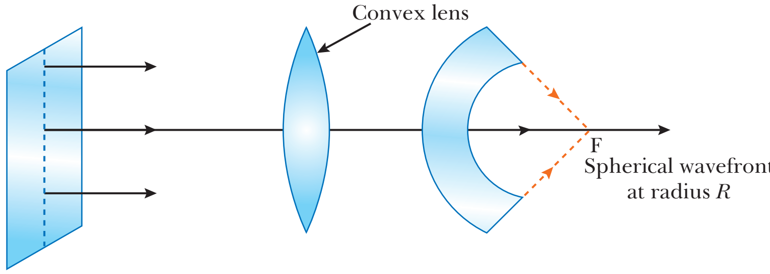
33. (*a*) A wavefront is defined as the locus of all the particles which are vibrating in the same phase. **5**

(*b*) (*i*)



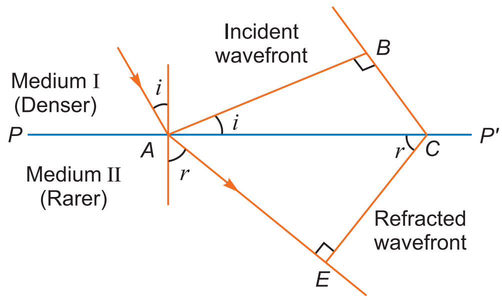
The wave front after refraction through prism is plane.

(*ii*)



The wave front emerging after refraction through convex lens is spherical and converges to focus *F*.

(c)



We assume a plane wavefront AB propagating in denser medium incident on the interface PP' at angle i as shown in Fig. Let t be the time taken by the wave front to travel a distance BC. If v_1 is the speed of the light in medium I.

So, $$BC = v_1 t$$

In order to find the shape of the refracted wavefront, we draw a sphere of radius $AE = v_2 t$, where v_2 is the speed of light in medium II (rarer medium). The tangent plane CE represents the refracted wavefront.

In ΔABC, $$\sin i = \frac{BC}{AC} = \frac{v_1 t}{AC}$$

and in ΔACE, $$\sin r = \frac{AE}{AC} = \frac{v_2 t}{AC}$$

$\therefore$ $$\frac{\sin i}{\sin r} = \frac{BC}{AE} = \frac{v_1 t}{v_2 t} = \frac{v_1}{v_2} \quad \ldots(i)$$

Let c be the speed of light in vacuum

So, $$n_1 = \frac{c}{v_1} \text{ and } n_2 = \frac{c}{v_2}$$

$$\frac{n_2}{n_1} = \frac{v_1}{v_2} \quad \ldots(ii)$$

From equations (i) and (ii), we have

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

$$n_1 \sin i = n_2 \sin r$$

It is known as Snell's law.

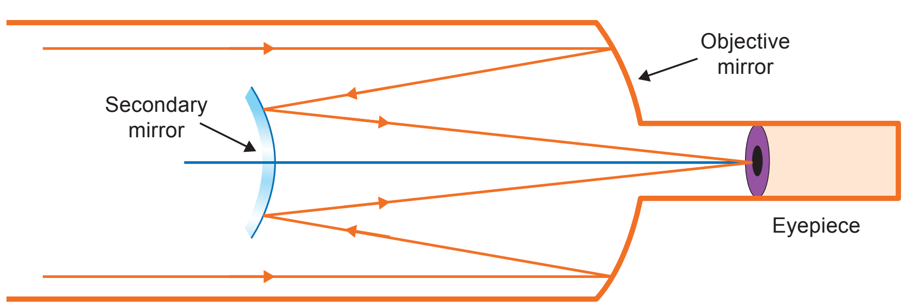
OR

(a) The main considerations taken into account while choosing the objective of astronomical telescope is:

(i) The aperture of objective lens is kept large so, that it may collect sufficient light to form a bright image of a distant object.

(ii) The focal length of objective is kept large so that the final image subtends a large angle at the eye and the object appears large.

(b)



If f_0 and f_e are the focal lengths of objective and eyepiece respectively, then magnifying power when the image is formed at the least distance of distinct vision,

$$m = \frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$$

Magnifying power when image is formed at infinity,

$$m = \frac{f_0}{f_e}$$

(*c*) The advantages of reflecting type telescope over refractive type telescope:

(*i*) No chromatic aberration, because mirror is used.

(*ii*) Easy mechanical support (less mechanical support is required, because mirror weighs much less than a lens of equivalent optical quality)

(*iii*) Large gathering power

(*iv*) Large magnifying power

(*v*) Large resolving power

(*vi*) Spherical aberration can be removed by using parabolic mirror