SAMPLE PAPER - 4

Class 12 - Physics

Time Allowed: 3 hours **Maximum Marks: 70**

General Instructions:

1. There are 35 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
3. Section A contains eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.
4. There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

Section A

1. Metallic solids are always opaque because: **[1]**

a) incident light is readily absorbed by the free electron in a metal

b) solids reflect the incident light

c) incident light is scattered by solid molecules

d) energy band traps the incident light

2. Pieces of aluminium (Al) and germanium (Ge) are cooled from T_1 K to T_2 K. The resistance of: **[1]**

a) aluminium decreases and that of germanium increases.

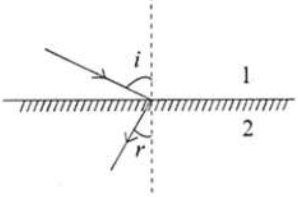
b) each of them increases.

c) aluminium increases and that of germanium decreases.

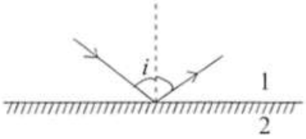
d) each of them decreases

3. There are certain materials developed in laboratories that have a negative refractive index. A ray incident from the air (medium 1) into such a medium (medium 2) shall follow a path given by: **[1]**

a)

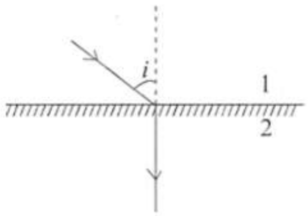


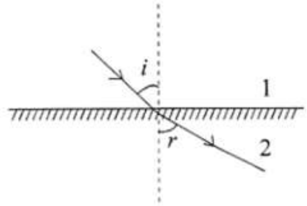
b)



c)

d)





4. In forward bias, the width of a potential barrier in a p-n junction diode **[1]**

a) remains constant

b) increases

c) decreases

d) first remains constant then decreases

5. Two spherical conductors of radii 2 cm and 6 cm are placed concentrically in air. The inner sphere is connected to earth while the other is given a charge of +9 statcoulomb. Then the charge in statcoulomb on the inner sphere is: **[1]**

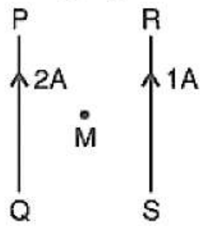
a) -6

b) +6

c) +3

d) -3

6. PQ and RS are long parallel conductors P separated by certain distance. M is the mid-point between them (see the figure). The net magnetic field at M is B. Now, the current 2 A is switched off. The field at M now becomes: **[1]**



a) $\frac{B}{2}$

b) B

c) 3B

d) 2B

7. Two coils are placed closed to each other. The mutual inductance of the pair of coils depends upon: **[1]**

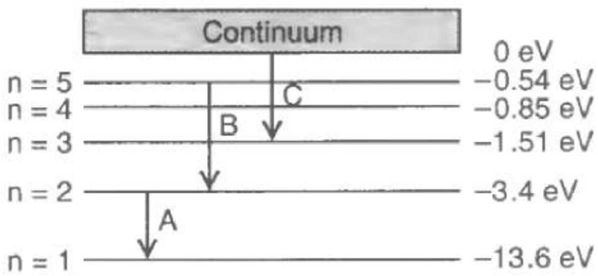
a) the currents in the two coils

b) the rates at which currents are changing in the two coils

c) relative position and orientation of the two coils

d) the material of the wires of the coils

8. Figure shows the energy levels of the hydrogen atom along with some transitions marked as A, B and C. The transitions A, B and C respectively represent: **[1]**



a) the first line of Lyman series, the third line of Balmer series and series limit line of Paschen series

b) the first line of Lyman series, second line of Balmer series and series limit line of Paschen series

c) the second line of Lyman series, the second line of Balmer series and second line of

d) the first line of Lyman series, second line of Balmer series and third line of Paschen

Paschen series | series

9. Two waves of light are $y_1 = 6\cos \omega t$, $y_2 = 10\sin(\omega + \phi)$. The ratio of intensity at maxima and minima formed by the superposition of these two waves: **[1]**

a) 1 : 6
b) 1 : 2
c) 16 : 1
d) 2 : 1

10. An electric dipole has a pair of equal and Opposite point charges q and - q separated by a distance 2x. The axis of the dipole is defined as: **[1]**

a) perpendicular to the line joining the two charges drawn at the centre and pointing downward direction
b) direction from negative charge to positive charge
c) direction from positive charge to negative charge
d) perpendicular to the line joining the two charges drawn at the centre and pointing upward direction

11. The depletion layer in the p-n junction region is caused by **[1]**

a) Drift of holes
b) Drift of electrons
c) Diffusion of carriers
d) Migration of impurity ions

12. The radius of curvature of the curved surface of a plano-convex lens is 20 cm. If the refractive index of the material of the lens be 1.5, it will **[1]**

a) act as a concave lens irrespective of side on which the object lies
b) act as a convex lens only for the objects that lie on its curved side
c) act as a concave lens for the objects that lie on its curved side
d) act as a convex lens irrespective of the side on which the object lies

13. Flashlight equipped with a new set of batteries, produces bright white light. As the batteries wear out: **[1]**

a) the light of intensity gets reduced with no change in its colour
b) light colour changes first to yellow and then red with no change in intensity
c) colour changes to red and also intensity gets reduced
d) it stops working suddenly while giving white light

14. Two charged spheres of same metal have radii a and b. They have been connected to a conducting wire. Find the ratio of the electric field Intensity upon the **[1]**

a) $\frac{a}{b}$
b) $\frac{b^2}{a}$
c) $\frac{b}{a}$
d) $\frac{b^2}{a^2}$

15. Interference occurs in which of the following waves? **[1]**

a) all of these
b) longitudinal
c) electromagnetic
d) transverse

16. **Assertion (A):** Nuclei having mass number about 60 are most stable. **[1]**

Reason (R): When two or more light nuclei are combined into a heavier nucleus, then the binding energy per nucleon will increase.

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 but R is true.

17. **Assertion (A):** The electromagnetic waves are transverse in nature. **[1]**
Reason (R): These waves propagate in straight lines.

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 but R is true.

18. **Assertion (A):** Susceptibility is defined as the ratio of the intensity of magnetisation I to magnetic intensity H. **[1]**
Reason (R): Greater the value of susceptibility, the smaller the value of the intensity of magnetisation I.

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 but R is true.

Section B

19. A semiconductor is known to have an electron concentration of 8×10^{13} per cm^3 and a hole concentration of 5×10^{12} per cm^3, **[2]**

i. Is the semiconductor n-type or p-type?
ii. What is the resistivity of the sample if the electron mobility is 23,000 cm^2 / Vs and hole mobility is 100 cm^2/ Vs?

20. The wavelength of H_α - line of the Balmer series is 6553 $\overset{\circ}{A}$ Calculate the value of Rydberg constant. **[2]**

21. Find the wavelength of electromagnetic waves of frequency 5×10^{19} Hz in free space. Give its two applications. **[2]**

OR

Show that the average value of radiant flux density **S** over a single period **T** is given by $S = \frac{1}{2c\mu_0}E_0^2$

22. In a centre trap full wave rectifier, the load resistance R_L = 1 kΩ. Each diode has a forward bias dynamic resistance of 10Ω. The voltage across half the secondary winding is 220 sin 314t. Find **[2]**

i. the peak value of current
ii. the dc value of current and
iii. the rms value of current

23. A hollow metal sphere is charged with 0.4 μC of charge and has a radius of 0.1 m. Find the potential **[2]**

i. at the surface
ii. inside the sphere
iii. at a distance of 0.6 m from the centre. The sphere is placed in air.

OR

Calculate the electric potential at the centre of a square of side $\sqrt{2}$ m, having charges 100 μC, - 50 μC, 20 μC, and -60 μC at the four corners of the square.

24. In Davisson and Germer experiment, state the observations which led to (i) show the wave nature of electrons, and (ii) confirm the de-Broglie relation. **[2]**

25. Calculate the binding energy per nucleon of ${}^{56}_{26}Fe$ nucleus. Given that **[2]**
mass of ${}^{56}_{26}Fe$ = 55.934939 amu

mass of a neutron = 1.008665 amu

mass of a proton = 1.007825 amu

Section C

26. The radius of the innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. What are the radii of the n = 2 and n = 3 orbits? **[3]**

27. Monochromatic light of wavelength λ is incident normally on a narrow slit of width 'a' to produce a diffraction pattern on the screen placed at a distance D from the slit With the help of a relevant diagram, deduce the conditions for maxima and minima on the screen. Use these conditions to show that the angular width of central maxima is twice the angular width of secondary maxima. **[3]**

28. The current through two inductors of self inductance 15 mH and 25 mH is increasing with time at the same rate. Draw graphs showing the variation of the **[3]**

    i. emf induced with the rate of change of current
    ii. energy stored in each inductor with the current flowing through it.

    Compare the energy stored in the coils, if the powers dissipated in the coils are same.

    OR

    i. A metallic rod of length l is moved perpendicular to its length with velocity v in a magnetic field B acting perpendicular to the plane in which rod moves. Derive the expression for the induced emf.
    ii. A wheel with 15 metallic spokes each 60 cm long, is rotated at 360 rev/min in a plane normal to the horizontal component of the earth's magnetic field. The angle of dip at that place is 60^{o}. If the emf induced between the rim of the wheel and the axle is 400 mV, calculate the horizontal component of the earth's magnetic field at the place. How will the induced emf change, if the number of spokes is increased?

29. i. It is necessary to use satellites for long distance TV transmissions. Why? **[3]**
    ii. If the earth did not have an atmosphere, would its average surface temperature be higher or lower than what it is now?
    iii. Some scientists have predicted that a global nuclear war on the earth would be followed by a severe 'nuclear winter' with a devastating effect on life on earth. What might be the basis of this prediction?

    OR

    Consider a plane wavefront of electromagnetic fields travelling with a speed c in the right (say +Z) direction, it is given that $\overrightarrow{E}$ and $\overrightarrow{B}$ are transverse to each other and uniform throughout the left of the wavefront and zero on the right of the wavefront.

    a. Use Faraday's law to show that E = cB.
    b. Use Ampere's law (with displacement current included) to show that $c = 1/\sqrt{\mu_0 \in_0}$

30. i. Draw diagrams to depict the behaviour of magnetic field lines near a bar of: **[3]**
        a. copper
        b. aluminium
        c. mercury, Cooled to a very low temperature (4.2 K)
    ii. The vertical component of the earth's magnetic field at a given place is $\sqrt{3}$ times its horizontal component. If total intensity of earth's magnetic field at the place is 0.4 G, find the values of:
        a. angle of dip
        b. the horizontal component of earth's magnetic field.

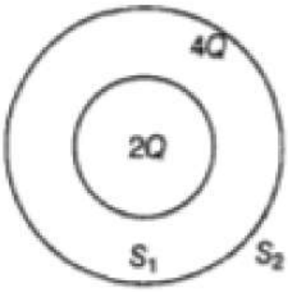
Section D

31. a. Deduce the expression for the torque acting on a dipole of dipole moment p in the presence of uniform electric field E. **[5]**

b. Consider two hollow concentric spheres S_1 and S_2 enclosing charges 2Q and 4Q respectively as shown in the figure.

i. Find out the ratio of the electric flux through them.

ii. How will the electric flux through the sphere S_1 changes, if a medium of dielectric constant $\in_r$ is introduced in the space inside S_1 in place of air? Deduce the necessary expression?



OR

i. Derive the expression for the electric field at a point on the equatorial line of an electric dipole,

ii. Depict the orientation of the dipole in

a. stable,

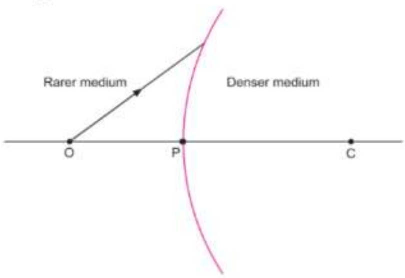
b. unstable equilibrium in a uniform electric field.

32. a. Draw a labelled ray diagram of an astronomical telescope to show the image formation of a distant object. Write the main considerations required in selecting the objective and eyepiece lenses in order to have large magnifying power and high resolution of the telescope. **[5]**

b. A compound microscope has an objective of focal length 1.25 cm and eyepiece of focal length 5 cm. A small object is kept at 2.5 cm from the objective. If the final image formed is at infinity, find the distance between the objective and the eyepiece.

OR

A spherical surface of radius of curvature R, separates a rarer and a denser medium as shown in the figure.

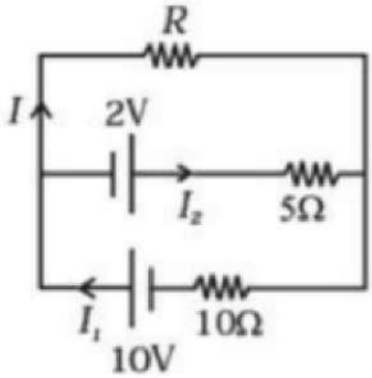


Complete the path of an incident ray of light, showing the formation of a real image. Hence derive the relation connecting object distance u, image distance v, radius of curvature R, and the refractive indices n_1 and n_2 of the two media.

Briefly explain, how the focal length of a convex lens changes, with an increase in wavelength of the incident light.

33. Two cells of voltage 10V and 2V and internal resistances 10Ω and 5Ω respectively, are connected in parallel with the positive end of 10V battery connected to negative pole of 2V battery (Fig). Find the effective voltage **[5]**

and effective resistance of the combination.



Section E

34. **Read the text carefully and answer the questions:** **[4]**

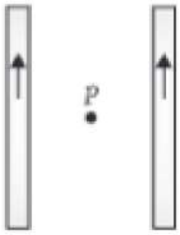
A magnetic field can be produced by moving, charges or electric currents. The basic equation governing the magnetic field due to a current distribution is the Biot-Savart law. Finding the magnetic field resulting from a current distribution involves the vector product, and is inherently a calculus problem when the distance from the current to the field point is continuously changing. According to this law, the magnetic field at a point due to a current element of length $d\vec{l}$ carrying current I, at a distance r from the element is dB = $\frac{\mu_0}{4\pi}\frac{I(d\vec{l}\times\vec{r})}{r^3}$.

Biot-Savart law has certain similarities as well as differences with Columb's law for electrostatic field e.g., there is an angle dependence in Biot-Savart law which is not present in the electrostatic case.

(i) What is the direction of magnetic field $d\vec{B}$ at a distance r due to a current element Idl when current I passes through a long conductor ?

(ii) What happens to the magnetic field due to a current carrying wire if the distance of the point from the current carrying wire is reduced to half?

(iii) Two long straight wires are set parallel to each other. Each carries a current i in the same direction and the separation between them is 2r. What will be the intensity of the magnetic field midway between them?



OR

A long straight wire carries a current along the z-axis. What will be the magnetic field along the Z axis.

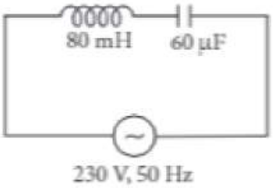
35. **Read the text carefully and answer the questions:** **[4]**

The power averaged over one full cycle of a.c. is known as average power. It is also known as true power.

$P_{av} = V_{rms} I_{rms} \cos\phi = \frac{V_0 I_0}{2}\cos\phi$

Root mean square or simply rms watts refer to continuous power. A circuit containing a 80 mH inductor and a

60 μ F capacitor in series is connected to a 230 V, 50 Hz supply. The resistance of the circuit is negligible.



(i) What will be the value of the current amplitude?

(ii) What will be the rms value of current?

(iii) What will be the average power transferred to the inductor?

OR

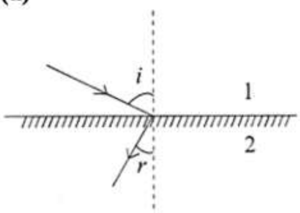
What will be the average power transferred to the capacitor?

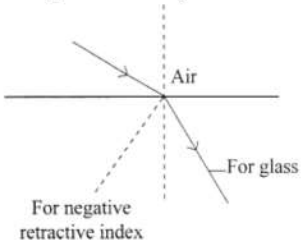
Solution

SAMPLE PAPER - 4

Class 12 - Physics

Section A

1. **(a)** incident light is readily absorbed by the free electron in a metal
Explanation: incident light is readily absorbed by the free electron in a metal
2. **(a)** aluminium decreases and that of germanium increases.
Explanation: aluminium decreases and that of germanium increases.
3. **(a)


Explanation:
The negative refractive index materials are those in which incident rays from Air (medium) to them refract or bezels differently or opposite and symmetric to normal to that of positive refractive index medium.


4. **(c)** decreases
Explanation: In forward biasing, the width of the potential barrier decreases.
5. **(d)** -3
Explanation: -3
6. **(b)** B
Explanation: $B_R = B_1 - B_2 = 2B - B = B$
7. **(c)** relative position and orientation of the two coils
Explanation: The mutual inductance of a pair of coils depends upon the relative position and orientation of the two coils.
8. **(a)** the first line of Lyman series, the third line of Balmer series and series limit line of Paschen series
Explanation: A corresponds to the first line of the Lyman series, B represents the third line of the Balmer series and C represents a series limit line of the Paschen series.
9. **(c)** 16 : 1
Explanation: add explanation here
10. **(b)** direction from negative charge to positive charge
Explanation: The torque acting on a dipole in a uniform external field $\vec{E}$ is $\vec{\tau} = \vec{P} \times \vec{E}$ or PE sin θ and its direction is perpendicular to E and also P (P = q2x, where 2x is the distance between the positive and negative charges).
11. **(c)** Diffusion of carriers
Explanation: Diffusion of carriers
12. **(d)** act as a convex lens irrespective of the side on which the object lies
Explanation:
The relation between focal length f, the refractive index of the given material μ, R_1 and R_2 is known as lens maker's formula and it is $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$
$R_1 = \infty, R_2 = -R$

$f=\frac{R}{(\mu-1)}$

Here, R = 20 cm, μ = 1.5. On substituting the values, we get

$f=\frac{R}{\mu-1}=\frac{20}{1.5-1}=40 \mathrm{cm}$

As f > 0 means converging nature. Therefore, the lens act as a convex lens irrespective of the side on which the object lies.

13. **(c)** colour changes to red and also intensity gets reduced

Explanation: As batteries wear out, temperature of filament of flash light attains lesser value, therefore intensity of radiation reduces. Also dominating wavelength $\left(\lambda_m\right)$ in spectrum, which is the red colour, increases.

14. **(c)** $\frac{b}{a}$

Explanation: Let a be the radius of a sphere A, Q_A be the charge on the sphere, and C_A be the capacitance of the sphere. Let b be the radius of a sphere B, Q_B be the charge on the sphere, and C_B be the capacitance of the sphere. Since the two spheres are connected with a wire, their potential (V) will become equal.

Let E_A be the electric field of sphere A and E_B be the electric field of sphere B. Therefore, their ratio,

$\frac{E_A}{E_B}=\frac{Q_A}{4 \pi \in_0 \times a_2} \times \frac{b^2 \times 4 \pi \epsilon_0}{Q_B}$

$\frac{E_A}{E_B}=\frac{Q_A}{Q_B} \times \frac{b^2}{a^2}$ ...(i)

However, $\frac{Q_A}{Q_B}=\frac{C_A V}{C_B V}$

And $\frac{C_A}{C_B}=\frac{a}{b}$ ...(ii)

Putting the value of (ii) in (i), we obtain

$\therefore \frac{E_A}{E_B}=\frac{a}{b} \frac{b^2}{a^2}=\frac{b}{a}$

Therefore, the ratio of electric fields at the surface is $\frac{a}{b}$.

A sharp and pointed end can be treated as a sphere of very small radius and a flat portion behaves as a sphere of much larger radius. Therefore, charge density on sharp and pointed ends of the conductor is much higher than on its flatter portions.

15. **(a)** all of these

Explanation: Interference occurs in all types of waves.

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

Explanation: Nuclei having mass number arouhd 60 have maximum binding energy per nucleon ($\simeq$8.7 MeV), so. they are most stable.

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

Explanation: The electromagnetic waves consist of sinusoidally time varying electric and magnetic fields acting at right angles to each other as well as at right angles to the direction of propagation of waves i.e., electromagnetic waves are transverse in nature.

18. **(c)** A is true but R is false.

Explanation: $\chi_m=\frac{I}{H}$

$\Rightarrow \chi_m \propto I$

Section B

19. Here $n_e = 8 \times 10^{13}$ cm^{-3}, n_h = 5 x 10^{12} cm^3, μ_e = 23,000 cm^2 V^{-1} s^{-1}, μ_h = 100 cm^2 V^{-1} s^{-1}

i. As $n_e > n_h$, the semiconductor must be n-type.

ii. Resistivity,

$\rho=\frac{1}{e\left(n_e \mu_e+n_h \mu_h\right)}$

$=\frac{1}{1.6 \times 10^{-19}\left(8 \times 10^{13} \times 23 \times 10^3+5 \times 10^{12} \times 10^2\right)} \Omega$ cm

$=\frac{1}{1.6 \times 10^{-19}\left(184 \times 10^{16}+5 \times 10^{14}\right)} \Omega$ cm

$=\frac{1}{1.6 \times 10^{-5} \times 18405} \Omega$ cm = 3.395 Ω cm

20. $\bar{v} = \frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$

For H_α line, n = 3 and λ = 6553 $\mathring{A}$, therefore,

$\frac{1}{6553 \times 10^{-10}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5}{36}R$

$\therefore \quad R = \frac{36 \times 10^{10}}{5 \times 6553} =$ 10980000 m^{-1}

21. Here it is given that, ν = 5 $\times$ 10^{19} Hz

Now, we know that the wavelength is given by:

$\lambda = \frac{c}{v} = \frac{3 \times 10^8}{5 \times 10^{19}} = 6 \times 10^{-12}$ m

This wavelength corresponds to either gamma rays or X-rays. These are used:

i. For causing certain nuclear reactions, and
ii. For treatment of cancer

OR

Radiant flux density

$\vec{S} = \frac{1}{\mu_0}(\vec{E} \times \vec{B}) = c^2\varepsilon_0(\vec{E} \times \vec{B}) \left[\because c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}\right]$

Let electromagnetic waves be propagating along x-axis. If electric field vector of electromagnetic wave be along y-axis, then magnetic field vector be along z-axis. Therefore,

E = E_0 cos (kx - ωt)

and B = B_0 cos (kx - ωt)

E $\times$ B = ($E_0 \times B_0$) $\cos^2$ (kx - ωt)

S = $c^2 \varepsilon_0$ (E $\times$ B)

= $c^2 \varepsilon_0$ ($E_0 \times B_0$) $\cos^2$ (kx - ωt)

Average value of the magnitude of radiant flux density over complete cycle is

$S_{av} = c^2 \varepsilon_0 |E_0 \times B_0| \frac{1}{T}\int_0^T \cos^2(kx - \omega t)$

$\Rightarrow S_{av} = c^2 \varepsilon_0 E_0 B_0 \times \frac{1}{T} \times \frac{T}{2}$

As $\left[\int_0^T \cos^2(kx - \omega t)dt = \frac{T}{2}\right]$

$\Rightarrow S_{av} = \frac{c^2}{2}\varepsilon_0 E_0\left(\frac{E_0}{c}\right)$ [As $c = \frac{E_0}{B_0}$]

$\Rightarrow S_{av} = \frac{c}{2}\varepsilon_0 E_0^2$

$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$ or $\varepsilon_0 = \frac{1}{c^2\mu_0}$ hence average value of radiant flux density **S** over a single period **T** is given by :-

$\Rightarrow S_{av} = \frac{E_0^2}{2\mu_0 c}$. Hence proved.

22. The voltage across half the secondary winding is V = 200 sin 314t

i. Peak value of voltage, V_0 = 220 V

$\therefore$ Peak value of current is

$I_0 = \frac{V_0}{r_d + R_L} = \frac{220}{10+1000}$ = 0.2178 A = 217.8 mA

ii. d.c. value of current,

$I_{dc} = \frac{2I_0}{\pi} = 2 \times 0.637 \times 217.8$ = 138.66 mA

iii. rms value of current is

$I_{rms} = \frac{I_0}{\sqrt{2}} = 0.707 \times 217.8$ = 154 mA

23. i. Potential at the surface,

$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r} = \frac{4 \times 10^{-7} \times 9 \times 10^9}{0.1}$

= 36000 V = 36 kV

ii. Potential inside a hollow conductor is the same as on its surface.

iii. When r = 0.6 m,

$V = \frac{9 \times 10^9 \times 4 \times 10^{-7}}{0.6}$ = 6000 V = 6 kV

OR

Diagonal of the square

$= \sqrt{(\sqrt{2})^2 + (\sqrt{2})^2} = 2\ \mathrm{m}$

Distance of each charge from the centre of the square is

r = Half diagonal = 1 m

$\therefore$ Potential at the centre of the square is

$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{r} + \frac{q_2}{r} + \frac{q_3}{r} + \frac{q_4}{r}\right]$

$V = 9 \times 10^9 \left[\frac{100\times10^{-6}}{1} - \frac{50\times10^{-6}}{1} + \frac{20\times10^{-6}}{1} - \frac{60\times10^{-6}}{1}\right]$

$= 9 \times 10^9 \times 10^{-6} \times 10 = 9 \times 10^4$ V.

24. i. Intensity of scattered electrons depends on the scattering angle ϕ and always shows a bump for $\phi = 50^\circ$.

ii. de-Broglie wavelength determined from the experiment agrees with the value determined from the relation, $\lambda = \frac{h}{p} = \frac{1227}{\sqrt{V}}$ nm.

25. Given: Mass of proton = 1.007825 amu

ass of neutron = 1.008665 amu

Mass of Fe = 55.934932 amu

Mass of 26 protons = 26 $\times$ 1.007825 amu = 26.20345

Number of neutrons = -56 - 26 - 30, Mass of neutron -30 $\times$ 1.008665 amu

= -30.25995

Total mass of 56 nucleaons = 56.4634

Mass defect of Fe^{56}_{23} = 55.934932 amu Mass of defect, Δm = 56.4634 - 55.934932 = 0.528468 amu

Total binding energy = Δm $\times$ 931.5 MeV

= 0.528468 $\times$ 931.5

= 492.267942 MeV

BE per nucleon = $\frac{492.267942}{56}$ = 8.790 MeV

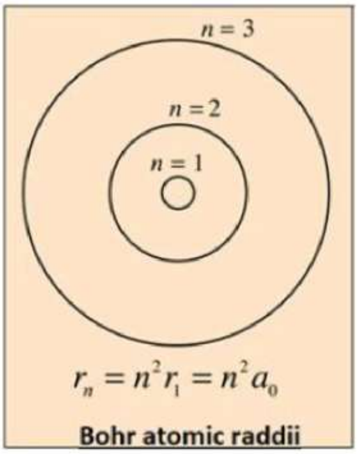
Section C

26. Given, the radius of the innermost orbit, $r_1 = 5.3 \times 10^{-11}$ m

Then, let r_2 be the radius of an orbit at n = 2.

Then, $r_2 = (n)^2 r_1$

As shown in the diagram:



$\Rightarrow r_2 = 2^2 \times 5.3 \times 10^{-11}$ m

$\Rightarrow r_2 = 2.12 \times 10^{-10}$ m

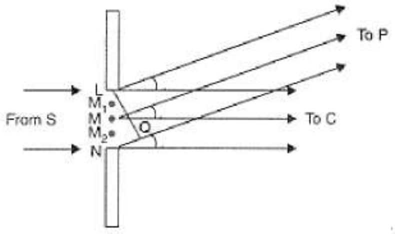
For n = 3, we can write the corresponding electron radius as:

$\Rightarrow r_3 = (n)^2\ r_1$

$\Rightarrow r_3 = 3^2 \times 5.3 \times 10^{-11}$ m

$\Rightarrow r_3 = 4.77 \times 10^{-10}$ m

Hence, the radii of an electron for n = 2 and n = 3 orbits are 2.12×10^{-10} m and 4.77×10^{-10} m

27.


According to the figure, the path difference is given by,

NP - LP = NQ

= a sin θ $\cong$ aθ

as θ <<< 1

$\therefore$ sin θ = θ

By dividing the slit into an appropriate number of parts, we find the point P for which

i. $\theta = \frac{n\lambda}{a}$ are points of minima.
ii. $\theta = \left(n + \frac{1}{2}\right)\frac{\lambda}{a}$ are points of maxima

The angular width of central maxima,

$\theta = \theta_1 - \theta_{-1} = \frac{\lambda}{a} - \left(-\frac{\lambda}{a}\right)$

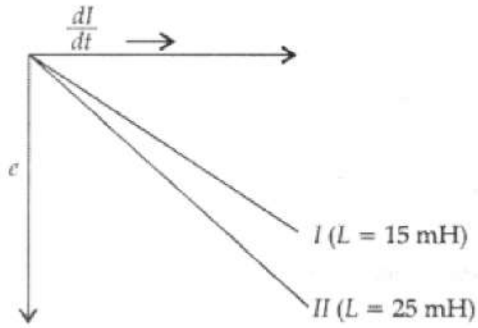
$\theta_2 = \frac{2\lambda}{a}$

The angular width of the secondary maxima = $\theta_2 - \theta_1$

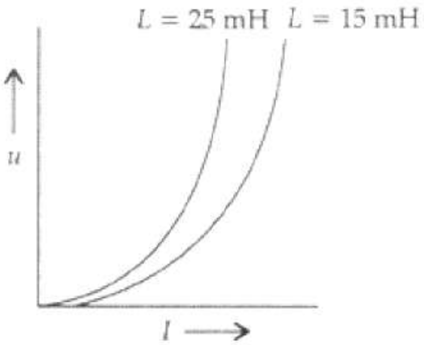
= $\frac{2\lambda}{a} - \frac{\lambda}{a} = \frac{\lambda}{a}$

= $\frac{1}{2}\times$ Angular width of central maxima

28. i.



ii.



$\frac{U_1}{U_2} = \frac{\frac{1}{2}L_1 i_1^2}{\frac{1}{2}L_2 i_2^2}$

But $\varepsilon_1 i_1 = \varepsilon_2 i_2$ ... (power dissipated is same)

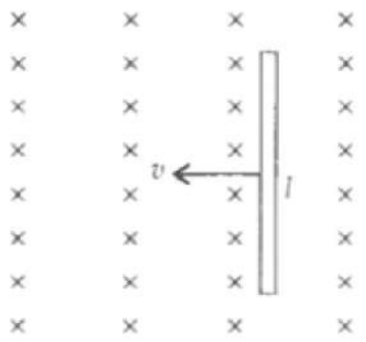
$\therefore \frac{i_1}{i_2} = \frac{\varepsilon_2}{\varepsilon_1} = \frac{L_2}{L_1}$ ... ($\because \frac{dI}{dt}$ is same and $\varepsilon = -L\frac{dI}{dt}$)

$\therefore \frac{U_1}{U_2} = \frac{L_1}{L_2}\left(\frac{L_2}{L_1}\right)^2$ thus the ratio of there energies is given by:-

$\frac{L_2}{L_1} = \frac{25}{15}$ = 1 .67

OR

i.



ϕ_B = Blx
$\varepsilon = \frac{-d\phi_B}{dt}$
$= -Bl\frac{dx}{dt}$
= Blv

ii. $\omega = 360 \times \frac{2\pi}{60} = 12\pi$ rad/s thus , emf induced is given by:-
$\varepsilon = \frac{1}{2}B_H l^2 \omega$
$\therefore 400 \times 10^{-3} = \frac{1}{2} \times B_H \times \left(60 \times 10^{-2}\right)^2 \times 12\pi$
$\therefore$thus the horizontal component of magnetic field $B_H = \frac{5}{27\pi} = 0.06$ T
No change in emf if no. of spokes is increased.

29. i. TV waves have frequency range 47 MHz-940 MHz. These frequencies are not reflected by the ionosphere. As space wave, they can cover a distance of 50-60 km only. Therefore, for long distance TV transmission, we make use of satellites which reflect the TV signal back towards the earth.
ii. If the earth did not have an atmosphere, then its average surface temperature will be lesser than what it is now because in that case, the greenhouse effect will be absent.
iii. The prediction is based on the assumption that the large dust clouds produced by global nuclear war would perhaps cover substantial part by the global nuclear war would perhaps cover a substantial part of the sky and solar radiations will not be able to reach the earth. It may cause a severe winter on the earth with a devastating effect on life on earth.

OR

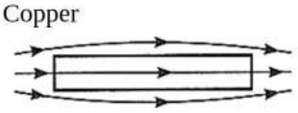
Let $\overrightarrow{E}$ be in the X-direction and $\overrightarrow{B}$ in the Y-direction.

a. Consinder the rectangular loop in the XZ plane with one side of length l parallel to $\overrightarrow{E}$. At the instant under consideration, the rectangle is partially on left and partially on the right of the wavefront.
Rate of change of magnetic flux = Blc
The line integral of $\overrightarrow{E} = \oint \overrightarrow{E} \cdot \overrightarrow{dl}$ = El
From Faraday's laws of electromagnetic induction
$\therefore$ E l = Blc or E = Bc ...(i)

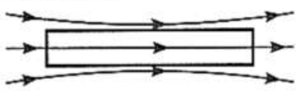
b. Consider a similar rectangle in the YZ plane.
Rate of change of electric flux = Elc
The line integral of $\overrightarrow{B}$ is B I
From Ampere's law,
or B l = $\mu_0 \in_0$ Elc or B = $\mu_0 \in_0$ Ec or B = $\mu_0 \in_0$ c (Bc) [from (i)]
or $c^2 = \frac{1}{\mu_0 \in_0}$ or $c = 1/\sqrt{\mu_0 \in_0}$

30. i. Copper is diamagnetic, aluminium paramagnetic and mercury is perfect diamagnetic at 4.2 K.

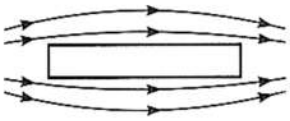
a. Copper



b. Aluminium



c. Mercury at 4.2 K



ii. $B_V = \sqrt{3}B_H$, B = 0.4 G

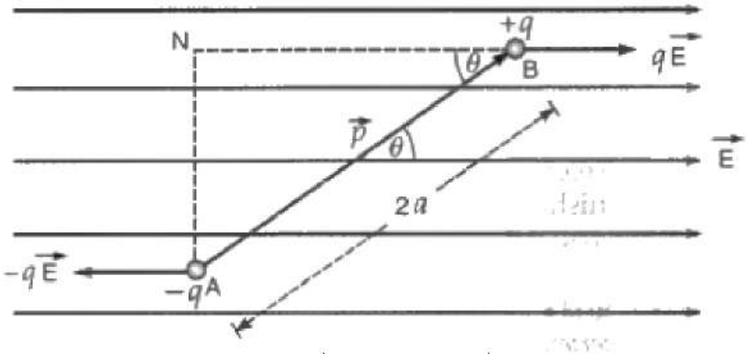
i. $\tan\delta = \frac{B_V}{B_H} = \sqrt{3}$

$\therefore$ Angle of dip, $\delta = 60^o$

ii. $B_H = B\cos\delta = 0.4\ G \times \cos 60^o = 0.4 \times 0.5 = 0.2$ G

Section D

31. a. Consider an electric dipole consisting of charges -q and +q and of length 2a placed in a uniform electric field $\vec{E}$ making an angle θ with the direction of the field as shown in Fig.



Force on charge -q at A = - q$\vec{E}$ (opposite to $\vec{E}$)

and force on charge +q at B = q$\vec{E}$ (along $\vec{E}$)

Thus, electric dipole is under the action of two equal and unlike parallel forces, which give rise to a torque on the dipole. The magnitude of the torque is given by

τ = either force $\times$ perpendicular distance between the two forces

= q E (AN) = q E (2a sin θ) = q (2a) E sin θ

or τ = p E sin θ

Here, p = q (2a) is electric dipole moment of the electric dipole.

The torque on the dipole tends to align it along the direction of the electric field.

Since electric dipole moment vector $\vec{p}$ is a vector from the charge -q to +q, the above equation may be expressed as

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

b. i. Charge enclosed by sphere S_1 = 2Q

Charge enclosed by sphere S_2 = 2Q + 4Q = 6Q

Now, using gauss law, electric flux enclosed by sphere S_1 and S_2 is given by

$\phi_1 = \frac{2Q}{\epsilon_0}$ and $\phi_2 = \frac{6Q}{\epsilon_0}$

Ratio of electric flux is,

$\frac{\phi_1}{\phi_2} = \frac{\frac{2Q}{\epsilon_o}}{\frac{6Q}{\epsilon_o}} = \frac{1}{3}$

ii. If a medium of dielectric constant '$\in_r$' is introduced in the space inside S_1 in place of air, electric flux becomes

$\phi_1' = \frac{\phi_1}{\epsilon_r}$

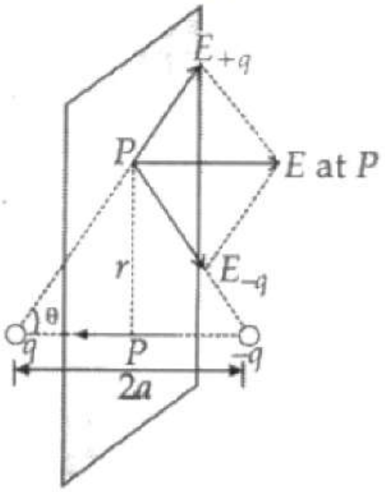
Therefore,

$\phi_1' < \phi_1$

That is, electric flux decreases.

OR

i. The derivation of expression of the electric field on the equatorial line of the electric dipole can be explained as follows:



Let the point 'P' be at a distance V from the midpoint of the dipole.

$|E_{+q}| = \frac{q}{4\pi\varepsilon_0 (r^2+a^2)}$

$|E_{-q}| = \frac{q}{4\pi\varepsilon_0 (r^2+a^2)}$

Both are equal and their directions are as shown in the figure, hence the net electric field

$\vec{E} = [-(E_{+q} + E_{-q})\cos\theta]\,\hat{p}$

$= -\frac{2qa}{4\pi\varepsilon_0 (r^2+a^2)^{3/2}}$

The electric field $=p/4\pi \in 0(r^2 + a^2)^(3/2)$

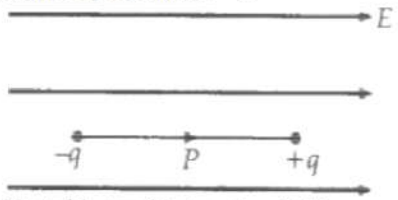
If the dipole is short then 2a<<<<r

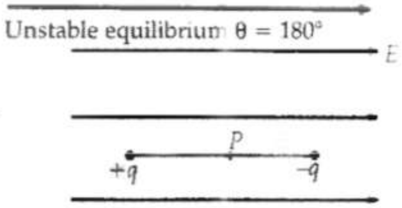
Hence electric field= $p/4\pi \in 0(r^3)$

where p is the dipole moment.

ii.

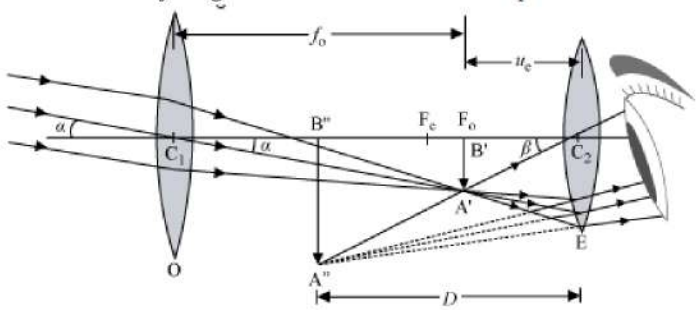
a. Stable equilibrium θ = 0





b.

32. a. Consider the ray diagram of Astronomical telescope.



When the final image is formed at the least distance of distinct vision,

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

Since α and β are small, we have:

$\therefore M = \frac{\tan\beta}{\tan\alpha}$ ...(i)

In $\Delta \mathrm{A'B'C_2}, \tan\beta = \frac{\mathrm{A'B'}}{\mathrm{C_2B'}}$

In $\Delta A'B'C_1, \tan\alpha = \frac{\mathrm{A'B'}}{\mathrm{C_1B'}}$

From equation (i), we get:

$M=\frac{\mathrm{A}'\mathrm{B}'}{\mathrm{C}_2\mathrm{B}'}\times\frac{\mathrm{C}_1\mathrm{B}'}{\mathrm{A}'\mathrm{B}'}$

$\Rightarrow M=\frac{C_1B'}{C_2B'}$

Here, $\mathrm{C}_1\mathrm{B}'=+f_0$

$\Rightarrow \mathrm{C}_2\mathrm{B}'=-u_\mathrm{e}$

$\Rightarrow M=\frac{f_0}{-u_\mathrm{e}}$ ...(ii)

Using the lens equation $\left(\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\right)$ for the eyepieces, we get,

$\frac{1}{-D}-\frac{1}{-u_\mathrm{e}}=\frac{1}{f_\mathrm{e}}$

$-\frac{1}{D}+\frac{1}{u_\mathrm{e}}=\frac{1}{f_\mathrm{e}}$

$\Rightarrow \frac{1}{u_e}=\frac{1}{f_e}+\frac{1}{D}$

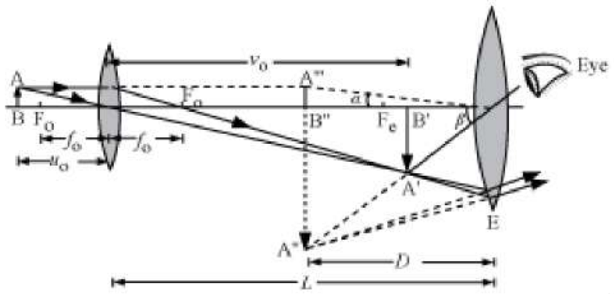
$\Rightarrow \frac{f_0}{u_e}=\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$

$\Rightarrow \frac{-f_0}{u_e}=\frac{-f_0}{f_e}\left(1+\frac{f_\mathrm{e}}{D}\right)$

or $M=-\frac{f_0}{f_\mathrm{e}}\left(1+\frac{f_\mathrm{e}}{D}\right)$

In order to have a large magnifying power and high resolution of the telescope, its objective lens should have a short length.

b.



Distance between the objective and the eyepiece, L = $v_0+|u_e|$

To find v_0, we have:

u_0 = -2.5 cm and f_0 = 1.25 cm

Now, $-\frac{1}{u_0}+\frac{1}{v_0}=\frac{1}{f_0}$

or v_0 = 2.5 cm

To find u_e, we have:

$v_e=\infty$ and f_e = 5 cm

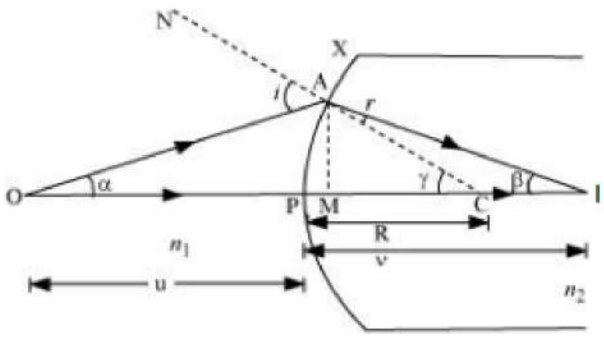
Calculating using the same formula as above, we get:

u_e = -5 cm

$\therefore$ L = 2.5 + 5 = 7.5 cm

OR

The complete path is shown in the figure.



Let a spherical refracting surface XY separate a rarer medium of refractive index n_1 from a denser medium of refractive index n_2.

Let P be the pole, C be the centre and R = PC be the radius of curvature of this surface.

Consider a point object O lying on the principal axis of the surface.

Let $\angle\mathrm{AOM}=\alpha, \angle\mathrm{AIM}=\beta, \angle\mathrm{ACM}=\gamma$

As external angle of a triangle is equal to sum of internal opposite angles, therefore, in ΔIAC, r + β = γ

r = γ - β ....(i)

Similarly, in ΔOAC , i = α + γ ...(ii)

According to Snell's law,

$\frac{n_2}{n_1}=\frac{\sin i}{\sin r}=\frac{i}{r}$ ...(ii) ($\because$ angles are small)

$\therefore$ $n_1 i = n_2 r$

Using (i) and (ii), we obtain

$n_1(\alpha+\gamma)=n_2(\gamma-\beta)$

As angles α, β and γ are small, and applying trigonometric functions, we obtain

$\therefore n_1\left(\frac{AM}{MO}+\frac{AM}{MC}\right)=n_2\left(\frac{AM}{MC}-\frac{AM}{MI}\right)$ ...(iii)

As aperture of the spherical surface is small, M is close to P. Therefore, MO $\approx$ PO, MI $\approx$ PI, MC $\approx$ PC

From (iii),

$n_1\left(\frac{1}{PO}+\frac{1}{PC}\right)=n_2\left(\frac{1}{PC}-\frac{1}{PI}\right)$

$\therefore \frac{n_1}{PO}+\frac{n_2}{PI}=\frac{n_2-n_1}{PC}$

Using new Cartesian sign conventions, we put

PO = -u, PI = +v, PC = R

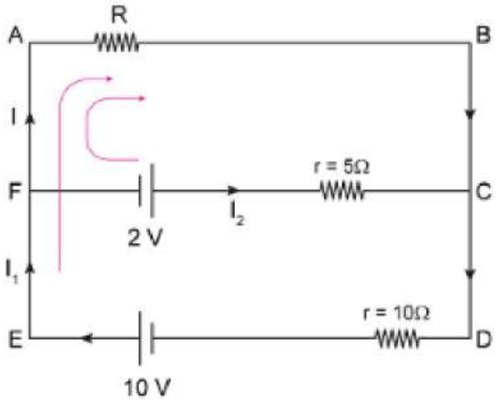
$\frac{n_1}{-u}+\frac{n_2}{v}=\frac{n_2-n_1}{R}$

This is the required relation.

Now, $f \propto \frac{1}{\mu-1}$ (from lens maker formula)

As a wavelength of incident light increases, μ decreases. Hence, the focal length f increases.

33. as we know,



$I_1 = I + I_2$ ....(1)

Apply Kirchhoff’s loop rule on loop ABDEA and loop FBACF

$10 = I R + 10 I_1$ ....(2)

$2 = 5 I_2 - IR$ ....(3)

$\Rightarrow$ $2 = 5(I_1 - I) -I R$ [using 1)] ....(4)

multiply (4) by 2, we get

$4 = 10 I_1 - 10 I - 2 IR$ ....(5)

Subtract (5) from (2), we get

$\Rightarrow$ 6=3 IR + 10 I

3 IR + 10 I = 6

I(3 R + 10) = 2 $\times$ 3

$\frac{I(3R+10)}{3}=2$

$2=I\left(R+\frac{10}{3}\right)$ ....(6)

Let the effective potential difference due to both batteries is V_{eq}. It will be be across

resistance R. So

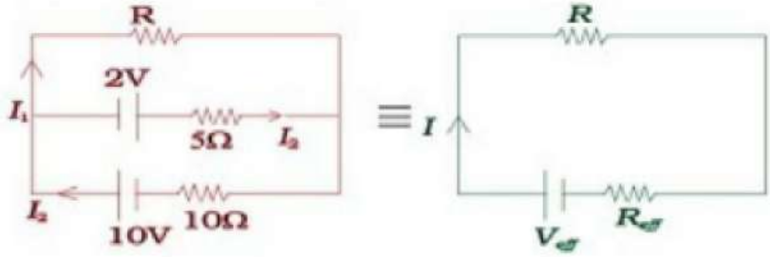
$V_{eq} = I(R + R_{eq})$ .... (7)

Where R_{eq} is the resistance of circuit except R

Comparing (6) and (7)

V_{eq} = 2 Volts and $R_{eq} = \frac{10}{3}\Omega$ = 3.333 ohm

the equivalent circuit for the figure is shown below:-



Section E

34. **Read the text carefully and answer the questions:**

A magnetic field can be produced by moving, charges or electric currents. The basic equation governing the magnetic field due to a current distribution is the Biot-Savart law. Finding the magnetic field resulting from a current distribution involves the vector product, and is inherently a calculus problem when the distance from the current to the field point is continuously changing. According to this law, the magnetic field at a point due to a current element of length $d\vec{l}$ carrying current I, at a distance r from the element is dB = $\frac{\mu_0}{4\pi}\frac{I(d\vec{l}\times\vec{r})}{r^3}$.

Biot-Savart law has certain similarities as well as differences with Columb's law for electrostatic field e.g., there is an angle dependence in Biot-Savart law which is not present in the electrostatic case.

(i) perpendicular to both $d\vec{l}$ and $\vec{r}$

According to Biot-Savart's law, the magnetic induction due to a current element is given by

$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\vec{r}}{r^3}$

this is perpendicular to both $\overrightarrow{dl}$ and $\vec{r}$

(ii) decreases as $\frac{1}{r^2}$, so it becomes 4 times.

From Biot-savart's law

dB = $\frac{\mu_0}{4\pi}\frac{Idl}{r^2}$ i.e., $dB \propto \frac{1}{r^2}$

(iii)It will become zero

B = $\frac{\mu_0}{2\pi}\cdot\frac{i}{r} - \frac{\mu_0}{2\pi}\cdot\frac{i}{r} = 0$

OR

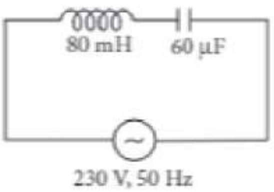
The magnetic fields along the current current carrying wire is zero.

35. **Read the text carefully and answer the questions:**

The power averaged over one full cycle of a.c. is known as average power. It is also known as true power.

$P_{av} = V_{rms} I_{rms}\cos\phi = \frac{V_0 I_0}{2}\cos\phi$

Root mean square or simply rms watts refer to continuous power. A circuit containing a 80 mH inductor and a 60 μ F capacitor in series is connected to a 230 V, 50 Hz supply. The resistance of the circuit is negligible.



(i) Inductance, L = 80 mH = 80 × 10^{-3} H

Capacitance, C = 60 μF = 60 × 10^{-6} F, V = 230 V

Frequency, ν = 50 Hz

$\omega = 2\pi\nu = 100\pi$ rad s^{-1}

Peak voltage, $V_0 = V\sqrt{2} = 230\sqrt{2}$ V

Maximum current is given by, $I_0 = \frac{V_0}{\left(\omega L - \frac{1}{\omega C}\right)}$

$I_0 = \frac{230\sqrt{2}}{\left(100\pi\times80\times10^{-3} - \frac{1}{100\pi\times60\times10^{-6}}\right)}$

$I_0 = \frac{230\sqrt{2}}{\left(8\pi - \frac{1000}{6\pi}\right)}$ = -11.63 A

Amplitude of maximum current, I_0 = 11.63 A

(ii) rms value of current, I = $\frac{I_0}{\sqrt{2}} = \frac{-11.63}{\sqrt{2}}$ = -8.23 A

Negative sign appears as $\omega L < \frac{1}{\omega C}$

(iii) Average power consumed by the inductor is zero because of phase difference of $\frac{\pi}{2}$ between voltage and current through inductor.

OR

Average power consumed by the capacitor is zero because of phase difference of $\frac{\pi}{2}$ between voltage and current through capacitor.