Class: XII

SESSION : 2022-2023

SUBJECT: PHYSICS (THEORY)

SAMPLE QUESTION PAPER - 1

with SOLUTION

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

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. Thermo emf set up in thermocouple varies as $E = aT - \frac{1}{2}bT^2$, where a, b are constant and T is temperature in Kelvin. If a = $16.3\mu V/^\circ C$ and $b = 0.042\mu V/(^\circ C)^2$, then inversion temperature is: **[1]**

   a) 776°C b) 388°C

   c) 490°C d) 279°C

2. What is the packing fraction of a bcc lattice? **[1]**

   a) $\frac{\pi\sqrt{3}}{4}$ b) $\frac{\pi\sqrt{3}}{8}$

   c) $\frac{2\pi\sqrt{3}}{8}$ d) $\frac{\pi\sqrt{2}}{8}$

3. In an astronomical telescope in normal adjustment, a straight black line of length L is drawn on the objective lens. The eyepiece forms a real image of this line. The length of the image is l. The magnification of telescope is: **[1]**

   a) $\frac{L+l}{L-l}$ b) $\frac{L}{l}$ - 1

   c) $\frac{L}{l}$ d) $\frac{L}{l} + 1$

4. Four charges each equal to q are placed at the corners of a square is: **[1]**

   a) $\frac{1}{\pi\varepsilon_0}\frac{2q}{l}$ b) $\frac{1}{4\pi\varepsilon_0}\frac{4q}{\sqrt{2}l}$

   c) $\frac{1}{\pi\varepsilon_0}\frac{\sqrt{2}q}{l}$ d) $\frac{1}{4\pi\varepsilon_0}\frac{4q}{l}$

5. The cause of the potential barrier in a p-n diode is **[1]**

a) depletion of positive charges near the junction

b) the concentration of positive and negative charges near the junction

c) concentration of positive charges near the junction

d) depletion of negative charges near the junction

6. When current changes from +2A to -2A in 0.05 sec, an emf of 8V is induced in a coil. The coefficient of self inductance of the coil is: **[1]**

a) 0.8 H

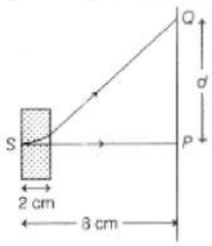
b) 0.1 H

c) 0.2 H

d) 0.4 H

7. An electron moving along the X-axis with an initial energy of 100 eV, enters a region of magnetic field $\vec{B} = (1.5 \times 10^{-3}\text{T})\ \hat{k}$ at S (see figure). The field extends between x = 0 and x = 2 cm. The electron is detected at the point Q on a screen placed 8 cm away from the point S. The distance d between P and Q (on the screen) is **[1]**

(Take, electron's charge = 1.6×10^{-19} C, mass of electron = 9.1×10^{-31} kg)



a) 12.87 cm

b) 11.65 cm

c) None of these

d) 1.22 cm

8. The shape of the wavefront of the portion of the wavefront of light from a distant star intercepted by the earth is **[1]**

a) plane

b) spherical

c) conical

d) hyperboloid

9. The minimum energy in electron volt required to strip ten times ionised sodium atom (i.e., Z = 11) of its last electron is: **[1]**

a) 13.6×11 eV

b) $\frac{13.6}{11}$ eV

c) $13.6 \times (11)^2$ eV

d) 13.6 eV

10. The electrical conductivity of an intrinsic semiconductor at 0 K is: **[1]**

a) less than that of an insulator

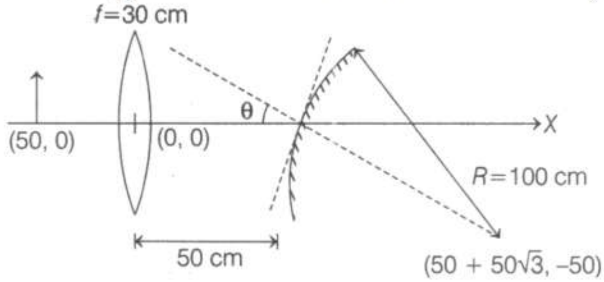
b) more than that of an insulator

c) is equal to zero

d) is equal to infinity

11. A small object is placed 50 cm to the left of a thin convex lens of focal length 30 **[1]**

cm. A convex spherical mirror of radius of curvature 100 cm is placed to the right of the lens at a distance of 50 cm. The mirror is tilted such that the axis of the mirror is at an angle $\theta = 30°$ to the axis of the lens, as shown in the figure.



If the origin of the coordinate system is taken to be at the centre of the lens, the coordinates (in cm) of the point (x, y) at which the image is formed are

a) (0, 0)

b) $(50-25\sqrt{3}, 25)$

c) $(25, 25\sqrt{3})$

d) $(125/3, 25/\sqrt{3})$

12. Law stating that force is directly proportional to the product of charges and inversely proportional to the square of the separation between them is called: **[1]**

a) Newton's law

b) Coulomb's law

c) Gauss's law

d) Ohm's law

13. The de Broglie wavelength of an electron is the same as that of a 50 keV X-ray photon. The ratio of the energy of the photon to the kinetic energy of the electron is: (the energy equivalent of electron mass is 0.5 MeV) **[1]**

a) 1 : 20

b) 1 : 50

c) 20 : 1

d) 50 : 1

14. In a certain region of space with volume 0.2 m^3, the electric potential is found to be 5 V throughout. The magnitude of the electric field in this region is: **[1]**

a) zero

b) 1 N/C

c) 5 N/C

d) 0.5 N/C

15. When light suffers reflection at the interface between water and glass, the change of phase in the reflected wave is: **[1]**

a) Zero

b) $\frac{\pi}{2}$

c) π

d) 2π

16. **Assertion (A):** The electrical conductivity of earth's atmosphere increases with altitude. **[1]**
Reason (R): The high energy particles (i.e., γ-rays and cosmic rays) coming from outer space and entering earth's atmosphere causes ionisation of the atoms of the gases present there and the ionising power of these radiation decreases rapidly as they approach to earth.

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):** Heavy water is used as moderator in nuclear reactor. **[1]**
Reason (R): Water cools down the fast neutron

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):** Iron behaves as magnet. **[1]**
Reason (R): In magnet, the molecular magnets are aligned in same direction.

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. n-type semiconductor has large number of electrons but still it is electrically neutral. Explain. **[2]**

20. Obtain Bohr's quantisation condition for angular momentum of electron orbiting in nth orbit in hydrogen atom on the basis of the wave picture of an electron using de Broglie hypothesis. **[2]**

21. Give two examples each of **[2]**

i. elemental

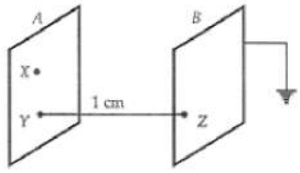
ii. compound inorganic and

iii. compound organic semiconductors

22. A charge q is moved from a point A above a dipole of dipole moment p to a point B below the dipole in an equatorial plane without acceleration. Find the work done in this process. **[2]**

OR

Two identical plane metallic surfaces A and B are kept parallel to each other in air, separated by a distance of 1 cm, as shown in Fig.



Surface A is given a positive potential of 10 V, and the outer surface of B is earthed.

i. What is the magnitude and direction of the uniform electric field between points Y and Z?

ii. What is the work done in moving a charge of $20\mu C$ from point X to point Y?

23. Give one use of each of the following: **[2]**

i. microwaves
ii. infrared waves
iii. ultraviolet radiation
iv. gamma rays

OR

Write any four characteristics of electromagnetic waves. Give two uses of (i) radio waves (ii) Microwaves.

24. i. The mass of a particle moving with velocity 5×10^6 m/s has de-Broglie wavelength associated with it to be 0.135 nm. Calculate its mass. **[2]**
ii. In which region of the electromagnetic spectrum does this wavelength lie?

25. Calculate the disintegration energy Q for the fission of ${}^{98}_{42}Mo$ into two equal fragments, ${}^{49}_{21}$Sc. If Q turns out to be positive, explain why this process does not occur spontaneously. Given that: **[2]**

$m\binom{98}{42}Mo$ = 97.90541 amu

$m\binom{49}{21}\text{Sc}$ = 48.95002 amu

m_n = 1.00867 amu.

Section C

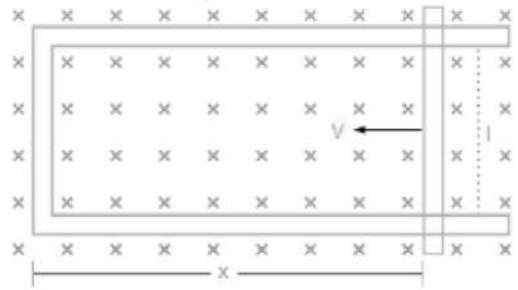
26. Monochromatic light of wavelength 589 nm is incident from air on a water surface. What are the wavelength, frequency and speed of (a) reflected, and (b) refracted light? Refractive index of water is 1.33. **[3]**

27. The first four spectral lines in the Lyman series of an H-atom are λ = 1218 $\overset{\circ}{A}$, 1028 $\overset{\circ}{A}$, 974.3 $\overset{\circ}{A}$ and 951.4$\overset{\circ}{A}$. If instead of Hydrogen, we consider Deuterium, calculate the shift in the wavelength of these lines. **[3]**

28. A horizontal straight wire 10 m long extending from east to west is falling with a speed of 5.0 ms^{-1}, at right angles to the horizontal component of the earth's magnetic field, 0.30×10^{-4} Wb m^{-2}. **[3]**
a. What is the instantaneous value of the emf induced in the wire?
b. What is the direction of the emf?
c. Which end of the wire is at the higher electrical potential?

OR

i. A rod of length l is moved horizontally with a uniform velocity v in a direction perpendicular to its length through a region in which a uniform magnetic field is acting vertically downward. Derive the expression for the emf induced across the ends of the rod.



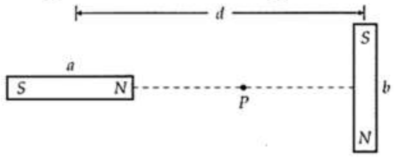
ii. How does one understand this motional emf by invoking the Lorentz force acting on the free charge carriers of the conductor? Explain.

29. Name the type of EM waves having a wavelength range 10^{-7} m to 10^{-9} m. How are these waves generated? Write their two uses. **[3]**

OR

When an ideal capacitor is charged by a DC battery, no current flows. However, when an AC source is used, the current flows continuously. How does one explain this, based on the concept of displacement current?

30. Two identical short magnets a and b of magnetic moments m each are placed at a distance d with their axes perpendicular to each other, as shown in figure. Find the magnetic field at a point P midway between the two dipoles. **[3]**



Section D

31. i. An object is placed in front of a concave mirror. It is observed that a virtual image is formed. Draw the ray diagram to show the image formation and hence derive the mirror equation $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$. **[5]**

ii. An object is placed 30 cm in front of a plano-convex lens with its spherical surface of radius of curvature 20 cm. If the refractive index of the material of the lens is 1.5, find the position and nature of the image formed.

OR

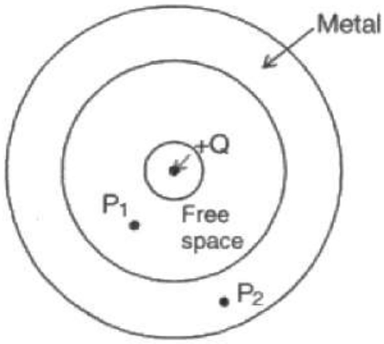
i. Draw a ray diagram for the formation of the image of a point object by a thin double convex lens having radii of curvatures R_1 and R_2 and hence, derive lens maker's formula.

ii. Define power of a lens and give its SI unit. If a convex lens of length 50 cm is placed in contact coaxially with a concave lens of focal length 20 cm, what is the power of the combination?

32. a. Define electric flux. Write its SI unit. **[5]**

b. A small metal sphere carrying charge +Q is located at the centre of a spherical cavity inside a large uncharged metallic spherical shell as shown in the figure.

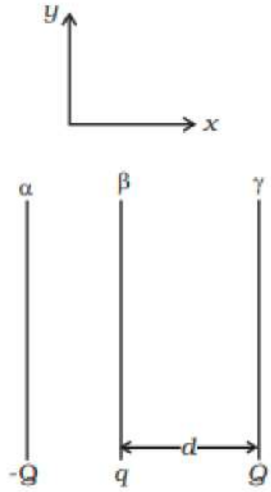
Use Gauss's law to find the expressions for the electric field at points P_1 and P_2.



c. Draw the pattern of electric field lines in this arrangement.

OR

Two fixed, identical conducting plates (α & β), each of surface area S are charged to $-Q$ and q, respectively, where $Q > q > 0$. A third identical plate (γ), free to move is located on the other side of the plate with charge q at a distance d (Fig). The third plate is released and collides with the plate β. Assume the collision is elastic and the time of collision is sufficient to redistribute charge amongst β & γ



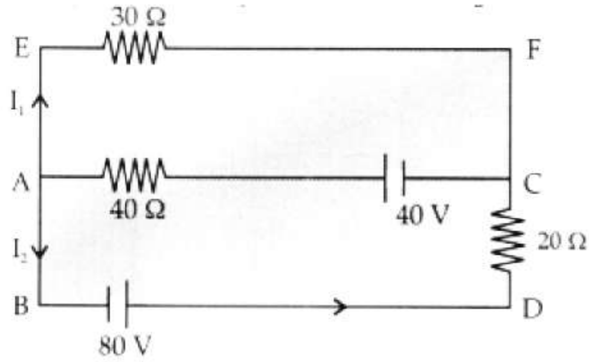
a. Find the electric field acting on the plate γ before collision.

b. Find the charges on β and γ after the collision.

c. Find the velocity of the plate γ after the collision and at a distance d from the plate β.

33. i. Use Kirchhoff's rules, calculate the current in the arm AC of the given circuit. **[5]**

ii. On what principle does the metre bridgework? Why are the metal strips used in the bridge?



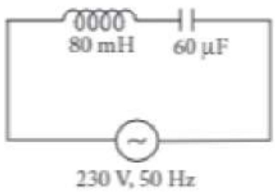
Section E

34. **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?

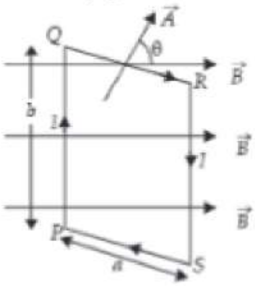
(iii) What will be the average power transferred to the inductor?

OR

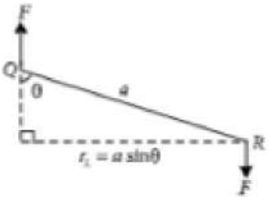
What will be the average power transferred to the capacitor?

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

When a rectangular loop PQRS of sides a and b carrying current I is placed in uniform magnetic field $\vec{B}$, such that area vector $\vec{A}$ makes an angle θ with the direction of the magnetic field, then forces on the arms QR and SP of loop are equal, opposite and collinear, thereby perfectly cancel each other, whereas forces on the arms PQ and RS of loop are equal and opposite but not collinear, so they give rise to torque on the loop.



Force on side PQ or RS of loop is F = IbB sin 90^o = IbB and perpendicular distance between two non-collinear forces is $r_1 = a \sin\theta$



So, torque on the loop, $\tau = IAB\sin\theta$

In vector form torque, $\vec{\tau} = \vec{M} \times \vec{B}$

where $\vec{M} = NI\vec{A}$ is called magnetic dipole moment of current loop and is directed in direction of area vector $\vec{A}$ i.e., normal to the plane of loop.

(i) A circular loop of area 1 cm^2, carrying a current of 10 A is placed in a magnetic field of 0.1 T perpendicular to the plane of the loop. Calculate the torque acting on the loop due to the magnetic field.

(ii) Write the relation between magnetic moment and angular velocity of the coil.

(iii) A current loop is lying in a magnetic field, what are conditions for it to be in stable and unstable equilibrium?

OR

How does the magnetic moment of a current I carrying circular coil of radius r and number of turns N varies with radius of the coil?

SOLUTION

Section A

1. **(b)** 388°C

   Explanation: Inversion temperature,

   $$T_i = \frac{a}{b}$$

   $$\Rightarrow T_i = \frac{16.3}{0.042}$$

   $T_i = 388^{o}C$

2. **(b)** $\frac{\pi\sqrt{3}}{8}$

   Explanation: Packing fraction for a bcc lattice,

   $$= \frac{2 \times \frac{4}{3}\pi r^3}{a^3} = \frac{2 \times \frac{4}{3}\pi\left(\frac{\sqrt{3}a}{4}\right)^3}{a^3} = \frac{\pi\sqrt{3}}{8}$$

3. **(c)** $\frac{L}{l}$

   Explanation: Let f_o and f_e be the focal length of objective and eye-piece. For normal adjustment distance from objective to eye-piece = $f_o + f_e$.
   Treating the line on the objective as object and the eye-piece as lens.
   $u = -(f_o - f_e)$ and $f = f_e$

   $$\frac{1}{v} - \frac{1}{\left(f_o + f_e\right)} = \frac{1}{f_e}$$

   $$\therefore \quad v = \frac{\left(f_o + f_e\right)f_e}{f_o}$$

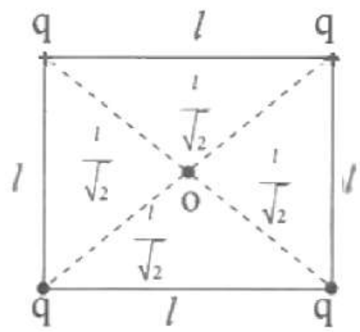
   Magnification = $\frac{v}{u} = \frac{f_e}{f_o} = \frac{l}{L}$

   Hence, $\frac{v}{u} = \frac{f_e}{f_o} = \frac{l}{L}$ = Magnification of telescope m normal adjustment.

4. **(c)** $\frac{1}{\pi\varepsilon_0}\frac{\sqrt{2}q}{l}$

   Explanation:
   As we know that,

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



Electric potential due to each charge at the centre of the square is $\frac{1}{4\pi\varepsilon_0}\frac{\sqrt{2}q}{l}$

Hence total potential is,

$$= 4 \times \frac{1}{4\pi\varepsilon_0}\frac{\sqrt{2}q}{l}$$

$$= \frac{1}{\pi\varepsilon_0}\frac{\sqrt{2}q}{l}$$

5. **(b)** the concentration of positive and negative charges near the junction
Explanation: The cause of a potential barrier in a p-n junction is the concentration of positive and negative charges near the junction.
6. **(b)** 0.1 H

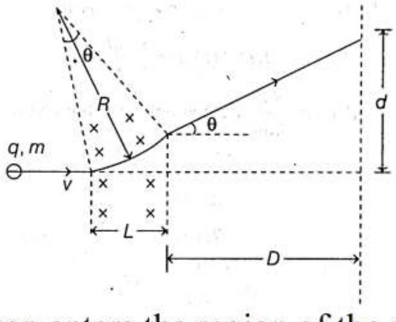
Explanation: $L = -\frac{e}{\frac{\Delta i}{\Delta t}}$

$$\frac{\Delta i}{\Delta t} = -\frac{4}{0.05} = -80$$

e = 8 volt

$$L = -\frac{8}{-80} = 0.1H$$

7. **(c)** None of these

Explanation: 

When an electron enters the region of the magnetic field, itexperiences a Lorentz force which rotates electron in a
a circular path of radius R. So, Lorentz force acts like a centripetal force and we have

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

where, m = mass of electron, q = charge of electron, v = speed of electron, R = radius of path, and B = magnetic field intensity.
The radius of the path of an electron,

$R = \frac{mv}{Bq}$

Now, from the geometry of given arrangement, comparing values of $\tan\theta$, we have

$\tan\theta = \frac{L}{R} = \frac{d}{D} \Rightarrow d = \frac{LD}{R} = \frac{BqLD}{mv}$

$\Rightarrow d = \frac{BqLD}{\sqrt{2mk}}$ [$\because mv = \sqrt{2mk}$]

where, k = kinetic energy of electron

Here, B = 1.5×10^{-3} T,

q = 1.6×10^{-19} C, L = 2×10^{-2} m, D= 6×10^{-2} m,

m = 9.1×10^{-31} kg, k = $100 \times 1.6 \times 10^{-19}$J

So, $d = \frac{\left(1.5\times10^{-3}\times1.6\times10^{-19}\times2\times10^{-2}\times6\times10^{-2}\right)}{\sqrt{\left(2\times9.1\times10^{-31}\times100\times1.6\times10^{-19}\right)}}$

$= \frac{28.8\times10^{-26}}{\sqrt{29.12\times10^{-48}}} = \frac{28.8\times10^{-26}}{5.39\times10^{-24}} = 5.34 \times 10^{-2}$ m

= 5.34 cm

No option is matching.

8. **(a)** plane

Explanation: Stars are very far away from earth. Near the star the shape is spherical but by the time its light reaches earth, the portion of the wavefront is plane due to increase in radius.

9. **(c)** $13.6 \times (11)^2$ eV

Explanation: For hydrogen-like ions

$E_n = -\frac{13.6}{n^2}(Z^2)$ eV

When n = 1, $E_1 = -13.6 (Z^2)$ eV

When n = ∞, $E_\infty = 0$

Ionisation energy for the last electron

$= E_\infty - E_1$

$= 0 - [-(13.6)(11)^2]$

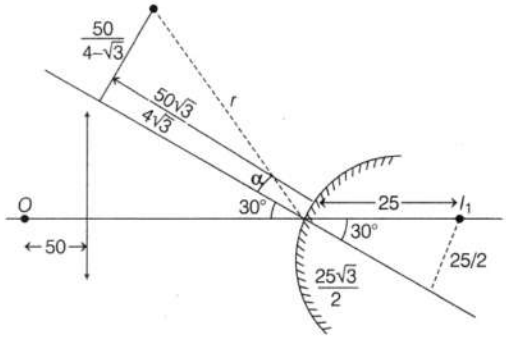
$= 13.6 \times (11)^2$ eV

10. **(c)** is equal to zero

Explanation: At 0 K, intrinsic semiconductor behaves like an insulator. Therefore, the electrical conductivity of an intrinsic semiconductor at 0 K is equal to that of an insulator.

11. **(c)** $(25, 25\sqrt{3})$

Explanation:



For lens

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \Rightarrow v=\frac{uf}{u+f}$$

$$\Rightarrow v=\frac{(-50)(30)}{-50+30}=75$$

For Mirror

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \Rightarrow v=\frac{uf}{u-f}$$

$$\Rightarrow v=\frac{\left(\frac{25\sqrt{3}}{2}\right)(50)}{\frac{25\sqrt{3}}{2}-50}=\frac{-50\sqrt{3}}{4-\sqrt{3}}$$

$$\Rightarrow m=-\frac{v}{u}=\frac{h_2}{h_1} \Rightarrow h_2=-\left(\frac{\frac{-50\sqrt{3}}{4-\sqrt{3}}}{\frac{25\sqrt{3}}{2}}\right)\cdot\frac{25}{2}$$

$$\Rightarrow h_2=\frac{+50}{4-\sqrt{3}}$$

The x-coordinate of the images

$= 50 - v\cos 30 + h_2 \cos 60 \approx 25$

They-coordinate of the images

$= v\sin 30 + h_2 \sin 60 \approx 25\sqrt{3}$

12. **(b)** Coulomb's law

Explanation: Coulomb's law states that, the magnitude of the electrostatic force of attraction or repulsion between two point charges is directly proportional to the product of the magnitudes of charges and inversely proportional to the square of the distances between them. The force acts always along the line joining the two charges.

13. **(c)** 20 : 1

Explanation: de-Broglie wavelength, $\lambda_e=\frac{h}{\sqrt{2mk}}$

where subscript e referes to electron.

The kinetic energy of the electron,

$$K_{\text{electron}} = \frac{h^2}{2m \cdot \lambda_e^2} \text{ ...(i)}$$

Where h = Plonck's contant λ = wavelength

The photon energy $E_{\text{photon}} = \frac{ch}{\lambda}$ ...(ii)

From Eqs. (ii) nd (i), we get

$$\frac{E_{\text{photon}}}{K_{\text{electron}}} = \frac{ch/\lambda}{h^2/2m \cdot \lambda^2} = \frac{hc \cdot \lambda^2 2m}{h^2 \cdot \lambda} = \frac{2m\lambda c}{h} \quad \left[\lambda = \frac{hc}{v}\right]$$

$$= \frac{2m}{h/\lambda c} = \frac{2 \times 5 \times 10^5}{50 \times 10^3} = 20 = 20:1$$

14. **(a)** zero

Explanation: Using the expression:

$$E = -\frac{dV}{dr}$$

Since the potential 'V' is constant, the change in potential dV is zero for any displacement dr.

Hence the electric field will be zero in the region.

15. **(c)** π

Explanation: Phase reversal occurs i.e. phase change = π takes place on reflection, because glass is much denser than water.

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

Explanation: Both A and R are true and R is the correct explanation of A.

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

Explanation: A is true but R is false.

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

Explanation: In an ordinary piece of iron, the molecular magnets are randomly oriented and form closed chains. Since the molecular magnets cancel the effect of each other, thus ordinary iron piece does not behave as a magnet.

Section B

19. An n-type semiconductor is obtained by doping the impurity atoms of valence five in a pure Si or Ge crystal. Four out of five valence electrons of impurity atom form covalent bonds by sharing electrons with four neighbouring Si or Ge atoms and the fifth electron is loosely bound to impurity atom which acts as a free electron. Hence for each free electron, there is a stationary positively charged impurity ion in the crystal and so the crystal as a whole remains electrically neutral.

20. Let λ be the deBroglie wavelength associated with electron orbiting (with speed v) in the with n^{th} orbit (of radius r) in hydrogen atom.

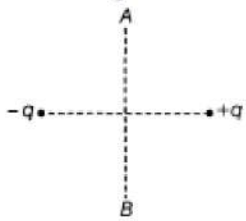
$$\therefore \lambda = \frac{h}{mv}$$

Now, $2\pi r = n\lambda = \frac{nh}{mv}$

Or $mvr = \frac{nh}{mv}$

$\therefore\ L = mvr = \frac{nh}{2\pi}$

21. i. Elemental semiconductors: Si and Ge.
  ii. Compound Inorganic: CdS, GaAs, etc.
  iii. Compound Organic polymers: Polypyrrole, polyaniline, etc.

22. 

We know work done in moving a charge from one point to another is given by the relation,
$W = Q\Delta V$
where W is the work done in the process, Q is the charge, ΔV is the potential difference or change in potential in going from one point to another.
We know electric dipole moment of a dipole is given by,
$p = q.d$
where, q is magnitude of either of charge and d is separation between them
Now plane passing through the midpoint joining the two charges is called an equatorial plane, the equatorial plane is an equipotential surface, i.e. potential is same everywhere or it is constant when the charge moves from A to B, there is no change in potential as both points lie on the same equatorial plane so potential difference or change in potential is
$\Delta V = 0\ V$
Now the magnitude of charge is
$Q = q\ C$
So the work done is
$W = q \times 0 = 0\ J$
i.e. work done in the process is 0 J

OR

i. $E = -\frac{dV}{dr} = -\frac{10\ V}{1\ cm}$

$= -\frac{10\ V}{10^{-2}\ m} = -1000 Vm^{-1}$

The magnitude of the uniform electric field between X and Y = 1000 Vm^{-1}
The direction of the electric field is from plate A to plate B.

ii. Zero. This is because points X and Y are at the same potential.

23. i. Microwaves are used in radar, long-range communication systems and in houses as microwave ovens.
  ii. Infrared waves are used for the treatment of muscular pains, aches, etc. and in remote control of television sets.
  iii. Ultraviolet rays are used for sterilising surgical instruments, operation theatres, and wards in hospitals, etc.
  iv. Gamma rays are used for treatment of cancer.

OR

Characteristics of electromagnetic waves:
  i. Electromagnetic waves are produced by accelerating or oscillating charges.

ii. E.M. waves do not require any material medium for their propagation.

iii. E.M. waves travel in free space with a velocity, $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ which is equal to the velocity of light ($c = 3 \times 10^8$ m/s).

iv. E.M. waves are transverse in nature.

Uses of Radio waves:

i. They are used in radio and TV communication systems.

ii. Cellular phones use radio waves to transmit voice communication in the ultrahigh frequency (UHF) band.

Uses of Microwaves:

i. Microwaves are used in Radar systems for aircraft navigation.

ii. Microwave ovens are used for cooking purposes.

24. i. We know that,

$$\lambda = \frac{h}{mv} \Rightarrow m = \frac{h}{\lambda v}$$

Here, $\lambda = 0.135 \times 10^{-9}$ m, $v = 5 \times 10^6 m/s$

Thus, $m = \frac{6.63 \times 10^{-34}}{0.135 \times 10^{-9} \times 5 \times 10^6} = 9.82 \times 10^{-31} kg$

ii. This wavelength 0.135 nm falls in the region of X-ray of electromagnetic spectrum.

25. The fission of $^{98}_{42}$Mo can be represented as

$$^{98}_{42}\text{Mo} + {}^{1}_{0}n \rightarrow 2\,^{49}_{21}\text{Sc} + Q$$

The disintegration energy in the fission of $^{98}_{42}$Mo is given by

$$Q = \left[m\left(^{98}_{42}\text{Mo}\right) + m_n - 2m\left(^{49}_{21}\text{Sc}\right)\right]c^2$$

$= [97.90541 + 1.00867 - 2 \times 48.95002]$ amu $\times\ c^2$

$= [98.91408 - 97.90004]$ amu $\times \frac{931.5\text{MeV}}{\text{amu}}$

$= 1.01404 \times 931.5 = 944.6$ MeV

Section C

26. Given, $\lambda = 589nm$

$c = 3 \times 10^8 m/s, \mu = 1.33$

a. For reflected light,

Wavelength $\lambda = 589nm = 589 \times 10^{-9} m$

$$v = \frac{c}{\lambda} = \frac{3 \times 10^8}{589 \times 10^{-9}}$$

$= 5.09 \times 10^{14} Hz$

Hence, the speed, frequency, and wavelength of the reflected light are 3×10^8 m/s, 5.09×10^{14} Hz, and 589 nm respectively.

b. Frequency of light does not depend on the property of the medium in which it is travelling. Hence, the frequency of the refracted ray in water will be equal to the frequency of the incident or reflected light in air.

$$v = \frac{c}{\mu}$$

$$v = \frac{3 \times 10^8}{1.33} = 2.26 \times 10^8 \text{m/s}$$

Wavelength of light in water is given by the relation,

$$\lambda = \frac{c}{v}$$

$$= \frac{2.26 \times 10^8}{5.09 \times 10^{14}}$$

$$= 444.007 \times 10^{-9} \text{m} = 444.01\ nm$$

Hence the speed, frequency and wavelength of refracted light are 2.26 $\times$ 10^8 m/s, 5.09 $\times$ 10^{14} Hz and 444.01 nm respectively.

27. The reduced mass of H atom (mass defect) μ_n then

$$\frac{1}{\mu_H} = \frac{1}{m_e} + \frac{1}{M} \text{ (M is mass of H atom)}$$

$$\frac{1}{\mu_H} = \frac{M + m_e}{M \cdot m_e} = \frac{M\left[1 + \frac{m_e}{M}\right]}{M \cdot m_e} \left(\because M >>> m_e\right)$$

$$\therefore \mu_M = m_e\left[1 + \frac{m_e}{M}\right]^{-1} = m_e\left[1 - \frac{m_e}{M}\right]$$

For Deuterium M = 2M

The reduced mass of Deuterium-μ_D

$$\mu_D = m_e\left[1 - \frac{m_e}{M}\right]\left[1 + \frac{m_e}{M}\right]$$

m is the reduced mass of the electron and proton in H atom.

So hv = En_i - En_f

$$v = \frac{me^4}{8\varepsilon_0^2 h^2}\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right] = \frac{c}{\lambda}$$

$$\frac{1}{\lambda} \propto \mu \Rightarrow \lambda \propto \frac{1}{\mu}$$

For hydrogen and deuterium = $\frac{\lambda_H}{\lambda_D}$

So $\frac{\lambda_H}{\lambda_D} = \frac{\mu_H}{\mu_D} = \frac{m_e\left[1 - \frac{m_e}{M}\right]}{m_e\left[1 - \frac{m_e}{M}\right]\left[1 + \frac{m_e}{2M}\right]}$

$\lambda_D = \left[1 + \frac{m_e}{2M}\right]^{-1} \lambda_h = \left(1 - \frac{m_e}{2M}\right)\lambda_H$

$\lambda_D = \lambda_H(0.99973)$

$\lambda_{DI} = \overset{\circ}{A} = 1214\ \overset{\circ}{A}$

$\lambda_{D2} = 0.9973 \times 1028 = 1025\ \overset{\circ}{A}$

$\lambda_{D3} = 0.9973 \times 974 = 971\ \overset{\circ}{A}$

$\lambda_{D4} = 0.9973 \times 954 = 951\overset{\circ}{A}$

28. Length of the wire, l = 10 m
Falling speed of the wire, v = 5.0 m/s
Magnetic field strength, $B = 0.3 \times 10^{-4}$ wb m^{-2}
a. the instantaneous value of Emf induced in the wire,
e = Blv
$= 0.3 \times 10^{-4} \times 5 \times 10$
$= 1.5 \times 10^{-3}$ V
b. Using Fleming's right-hand rule, it can be inferred that the direction of the induced emf is from West to East.
c. The eastern end of the wire is at a higher potential.

OR

i. Suppose a rod of length 'l' moves with velocity v inward in the region having uniform magnetic field B.
Initial magnetic flux enclosed in the rectangular space is $\phi = |B|lx$
As the rod moves with velocity $-v = \frac{dx}{dt}$
Using Lenz's law,
$$\varepsilon = -\frac{d\phi}{dt} = -\frac{d}{dt}(Blx) = Bl\left(-\frac{dx}{dt}\right)$$
$\therefore \quad \varepsilon = Blv$
ii. Suppose any arbitrary charge 'q' in the conductor of length 'l' moving inward in the field as shown in figure, the change q also moves with velocity v in the magnetic field B.
The Lorentz force on the charge 'q' is F = qvB and its direction is downwards.
So, work done in moving the charge 'q' along the conductor of length l

W = F.l

W = qvBl

Since emf is the work done per unit charge

$$\therefore \quad \varepsilon = \frac{W}{q} = Blv$$

This equation gives emf induced across the rod.

29. EM waves: ultraviolet

Sun is an important source of UV rays. Some special lamps and very hot bodies also produce UV rays.

Uses:

i. In LASIK eye surgery.

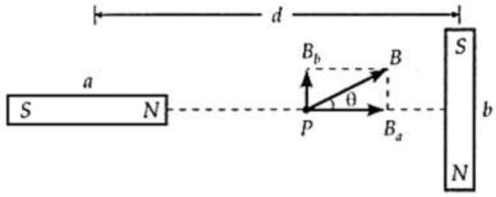
ii. UV lamps are used to kill germs in water purifiers. Also, UV radiation is widely used in industrial processes and in medical and dental practices for a variety of purposes, such as killing bacteria.

OR

In case of connection of the capacitor with DC, circuit charge flows momentarily till the capacitor gets fully charged. The ideal capacitor offers infinite resistance for dc.

On the other hand, when the AC source is connected to a capacitor, a conduction current continuously flows through the connecting wire to charge the capacitor. This leads to the accumulation of the charges at the two plates. Due to this, a varying electric field of increasing nature is produced between the plates. This, in turn, produces a displacement current in between the plates. To maintain this continuity, this conduction current will be equal to the displacement current flowing, i.e. Conduction current = Displacement current and displacement current, $I_D = \varepsilon_0\left(d\phi_E/dt\right)$, where $\frac{d\phi_E}{dt}$ is rate of change of electrostatic flux with respect to time.

30. As shown in figure, the point P lies on the axial line of magnet a and on the equatorial line of magnet b.



$$\therefore \quad B_a = B_{axial} = \frac{\mu_0}{4\pi} \cdot \frac{2m}{(d/2)^3} \text{ (along the axis of a)}$$

$$B_b = B_{equa} = \frac{\mu_0}{4\pi} \cdot \frac{m}{(d/2)^3} \text{ (parallel to the axis of b)}$$

The resultant field at P is

$$B = \sqrt{B_a^2 + B_b^2} = \frac{\mu_0 m}{4\pi(d/2)^3} \cdot \sqrt{1^2 + 2^2}$$

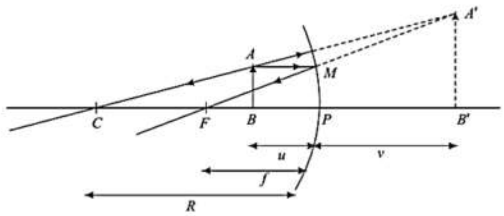
$$= \frac{2\sqrt{5}\mu_0 m}{\pi d^3}$$

If field B makes angle θ with B_a, then

$$\tan\theta = \frac{B_b}{B_a} = \frac{1}{2} = 0.5 \text{ or } \theta = 26.57^{o}$$

Section D

31. i.



Here, $\Delta ABC \sim \Delta A'B'C$,

$$\frac{AB}{A'B'} = \frac{CB}{CB'} = \frac{CP-BP}{CP+PB'} = \frac{-2f+u}{-2f+v} \quad ...(i)$$

Also, $\Delta MPF \sim \Delta A'B'F$, therefore,

$$\frac{MP}{A'B'} = \frac{FP}{FB'} = \frac{FP}{FP+PB'}$$

$$\therefore \frac{AB}{A'B'} = \frac{-f}{-f+v} \quad [\because MP = AB] \; ...(ii)$$

From equation (i) and (ii), we get

$$\frac{-2f+u}{-2f+v} = \frac{-f}{-f+v}$$

$\Rightarrow$ -fv - fu + uv = 0

uv = fv + fu

Dividing both sides by uvf, we get,

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$, this is the required result.

ii. By using the Lens-maker formula, we get

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

$$\frac{1}{f} = (1.5 - 1)\left[\frac{1}{20} - \frac{1}{\infty}\right]$$

$$\frac{1}{f} = \frac{0.5}{20} = \frac{1}{40}$$

$\Rightarrow$ f = 40 cm

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

$$\frac{1}{40} = \frac{1}{v} - \frac{1}{(-30)}$$

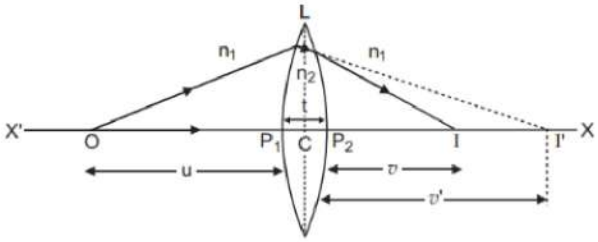
$$v = \frac{-40 \times 30}{10}$$

v = -120 cm

Image is virtual, and enlarged in front of lens 120 cm away.

OR

i. Consider the figure. Suppose L is a thin lens. The thickness of lens is t, which is very small. O is a point object on the principal axis of the lens. The distance of O from pole P_1 is u. The first refracting surface forms the image of O at I' at a distance v' from P_1.



From the refraction formula at spherical surface:

$$\frac{n_2}{v'} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} \text{ ....(i)}$$

The image I' acts as a virtual object for second surface and after refraction at second surface, the final image is formed at I. The distance of I from pole P_2 of second surface is v. The distance of virtual object (I') from pole P_2 is (v' - t).

For refraction at second surface, the ray is going from second medium (refractive index n_2) to first medium (refractive index n_1), therefore from refraction formula at spherical surface

$$\frac{n_1}{v} - \frac{n_2}{(v' - t)} = \frac{n_1 - n_2}{R_2} \text{ .....(ii)}$$

For a thin lens, t is negligible as compared to v', therefore from (ii),

$$\frac{n_1}{v} - \frac{n_2}{(v')} = -\frac{n_2 - n_1}{R_2} \text{ .....(iii)}$$

Adding equations (i) and (iii), we get

$$\frac{n_1}{v} - \frac{n_1}{u} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\text{or } \frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \text{ .....(iv)}$$

If the object O is at infinity, the image will be formed at second focus i.e. if u = ∞, v = f_2 = f

Therefore from equation (iv)

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

$$\text{i.e. } \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \text{ ....(v)}$$

This is the formula of refraction for a thin lens. This formula is called Lens-Maker's Formula.

ii. **Power of a Lens:** The power of a lens is its ability to deviate the rays towards its principal axis. It is defined as the reciprocal of focal length in metres.

Power of a lens, $P = \frac{1}{f(\text{ in metres })}$ diopters $= \frac{100}{f(\text{ in cm})}$ diopters

The SI unit for power of a lens is dioptre (D).

Power of convex lens, $P_1 = \frac{1}{F_1} D = \frac{1}{0 \cdot 50} = 2$ D

Power of concave lens, $P_2 = \frac{1}{F_2} D = \frac{1}{-0 \cdot 20} = -5$ D

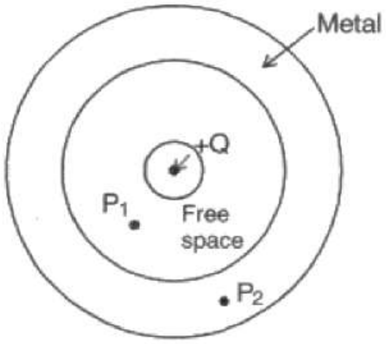
∴ Power of combination of lenses in contact

$P = P_1 + P_2 = 2 - 5 = -3$ D

32. a. It is defined as the total number of electric field lines crossing a given area normal to its surface. It can be practically obtained by taking the dot product of the electric field vector and area vector. Its SI unit is Nm^2C^{-1}.

b. For point P_1, using Gauss law, we have

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q}{\varepsilon_0}$$

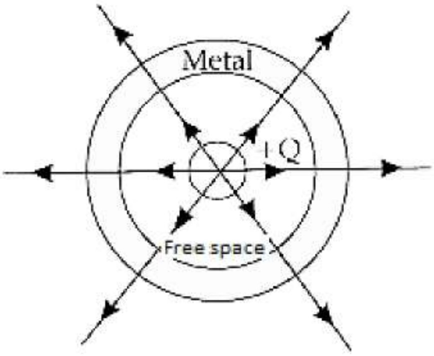


Since E and dA are in the same direction, therefore, we have,

$$E = \frac{Q}{\varepsilon_0 A}$$

Point P_2 lies inside the metal, therefore Gaussian surface drawn at P_2 does not include a charge because charge always resides on the outer surface of the sphere, hence the electric field at P_2 is zero.

c. The electric field lines are shown in the following figure:



OR

a. Net electric field at plate γ before collision is vector sum of electric field at plate γ due to plate $\alpha$and β. Considering the right direction to be positive

The electric field at γ due to the plate α is $-\dfrac{Q}{S\left(2\epsilon_o\right)}$ [i.e., towards left]

The electric field at γ due to the plate β is $\dfrac{Q}{S\left(2\epsilon_o\right)}$ [i.e., towards right]

The net electric field = $\dfrac{q-Q}{S\left(2\in_o\right)}$[Here, Q>q, so the direction will be towards left

b. During the collision plates β and γ are together so they must be at one potential. Charge on β is q_1 and on γ is q_2 . Consider a point O, in between the plates. The electric field here must be zero.

Electric field at O due to $\alpha = \dfrac{-Q}{S\left(2\varepsilon_0\right)}$, to the left

Electric field at O due to $\beta = \dfrac{q_1}{S\left(2\varepsilon_0\right)}$, to the right

Electric field at O due $\gamma = \dfrac{q_2}{S\left(2\varepsilon_0\right)}$ to the left

As the electric field at O is zero, therefore

$$\frac{Q+q}{S\left(2\varepsilon_0\right)}=\frac{q_1}{S\left(2\varepsilon_0\right)}$$

$\therefore$ Q + q_2 - q_2, (i)

There is no loss of charge on collision, therefore

Q + q = q_1 + q_2 (ii)

On solving (i) and (ii), we get

$q_1 = (Q + \frac{q}{2})$ = charge on plates β

$q_2 = (\frac{q}{2})$ = charge on plate γ

c. Let the velocity be v at the distance d after the collision. If m is the mass of the plate γ, then the gain in K.E. over the round trip must be equal to the work done by the electric field. After the collision, the electric field at γ is

$$E_2=\frac{-Q}{2\varepsilon_0 S}+\frac{(Q+q/2)}{2\varepsilon_0 S}=\frac{q/2}{2\varepsilon_0 S}$$

$$F_2=E_2 q/2=\frac{(q/2)^2}{2\varepsilon_0 S}$$

Total work done $=\left(F_1+F_2\right)d=\left[\frac{(Q-q)Q}{2\varepsilon_0 S}+\frac{(q/2)^2}{2\varepsilon_0 S}\right]d=\frac{(Q-q/2)^2 d}{2\varepsilon_0 S}$

Using work energy theorem, we have

$$\frac{1}{2}mw^2=\frac{(Q-q/2)^2 d}{2\varepsilon_0 S}$$

Further solving, we have

$$v=(Q-\frac{q}{2})\left(\frac{d}{m\varepsilon_0 S}\right)^{1/2}$$

33. i. Applying kirchoff's junction rule at A node,

$I_3 = I_1 + I_2$ ...(i)

Applying kirchoff's second rule in loop EFCA,

$-30I_1 + 40 - 40I_3 = 0$

$3I_1 + 4I_3 = 4$ ...(ii)

In loop EFDB,

$-30I_1 + 20I_2 - 80 = 0$

$-3I_1 + 2I_2 = 8$ ...(iii)

from equation (i) put the value of I_3 in equation (ii),

$3I_1 + 4(I_1 + I_2) = 4$

$7I_1 + 4I_2 = 4$ ...(iv) (by multiplying the equation 3rd by 2 and subtract 3rd and 4th equation) we get,

$13I_1 = -12$

$I_1 = -\frac{12}{13}$ A

Put I_1 in equation (iv),

$7 \times -\frac{12}{13} + 4I_2 = 4$

$4I_2 = 4 + \frac{84}{13}$

$I_2 = \frac{34}{13}$ A

from equation (i),

$I_3 = -\frac{12}{13} + \frac{34}{13}$

Thus the current through the arm AC is given by, $I_3 = \frac{22}{13}$ A

ii. Metre bridge works on the principle of the Wheat stone bridge. A meter bridge is used in finding the unknown resistance of a conductor as that of in wheatstone bridge.The thick metal strips are used to minimise the resistance of connection wires because the connection resistance have not been accounted in the formula. (resistance is inversely proportional to cross-section area, so thick wire has low resistance, moreover, the resistivity of copper is small compared to manganin.

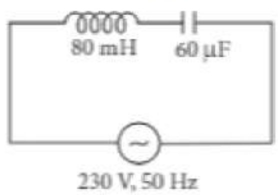
Section E

34. **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, $L = 80 \text{ mH} = 80 \times 10^{-3}$ H

Capacitance, $C = 60\ \mu\text{F} = 60 \times 10^{-6}$ F, V = 230 V

Frequency, $v = 50$ Hz

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

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

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

$$I_0 = \frac{230\sqrt{2}}{\left(100\pi \times 80 \times 10^{-3} - \dfrac{1}{100\pi \times 60 \times 10^{-6}}\right)}$$

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

Amplitude of maximum current, $I_0 = 11.63$ A

(ii)

rms value of current, $I = \dfrac{I_0}{\sqrt{2}} = \dfrac{-11.63}{\sqrt{2}} = -8.23$ A

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

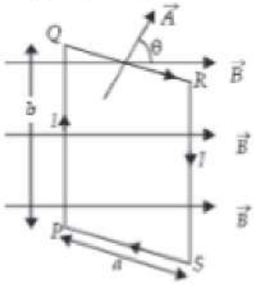
(iii)

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

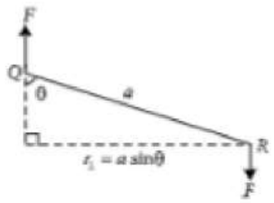
OR

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

35. **Read the text carefully and answer the questions:**
When a rectangular loop PQRS of sides a and b carrying current I is placed in uniform magnetic field $\vec{B}$, such that area vector $\vec{A}$ makes an angle θ with the direction of the magnetic field, then forces on the arms QR and SP of loop are equal, opposite and collinear, thereby perfectly cancel each other, whereas forces on the arms PQ and RS of loop are equal and opposite but not collinear, so they give rise to torque on the loop.



Force on side PQ or RS of loop is F = IbB sin 90^{o} = IbB and perpendicular distance between two non-collinear forces is $r_1 = a \sin\theta$



So, torque on the loop, $\tau = IAB\sin\theta$

In vector form torque, $\vec{\tau} = \vec{M} \times \vec{B}$

where $\vec{M} = NI\vec{A}$ is called magnetic dipole moment of current loop and is directed in direction of area vector $\vec{A}$ i.e., normal to the plane of loop.

(i) zero
Torque on a current carrying loop in magnetic field, $\tau = IBA\sin\theta$
Here, I = 10A, B = 0.1 T, A = 1 $cm^2 = 10^{-4}$ m^2, $\theta = 0^{o}$
$\therefore \tau = 10 \times 0.1 \times 10^{-4}\sin 0^{\circ} = 0$

(ii) $M \propto \omega$
Magnetic moment, $M = IA = I\left(\pi r^2\right) = \frac{q}{T} \times \pi r^2$

As $\omega = \frac{2\pi}{T}$ $\therefore M = \frac{q\omega r^2}{2}$ or $M \propto \omega$

(iii) It can be in equilibrium in two orientations, one stable while the other is unstable
When a current loop is placed in a magnetic field it experiences a torque. It is given by
$\vec{\tau} = \vec{M} \times \vec{B}$
where $\vec{M}$ is the magnetic moment of the loop and $\vec{B}$ is the magnetic field.
or $\tau = MB\sin\theta$ where θ is angle between M and B

When $\vec{M}$ and $\vec{B}$ are parallel (i.e. $\theta = 0^{o}$) the equilibrium is stable and when they are antiparallel (i.e. $\theta = \pi$) the equilibrium is unstable.

OR

Magnetic moment, $M = NIA = NI \pi r^2$ i.e., $M \propto r^2$