SAMPLE PAPER - 10

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

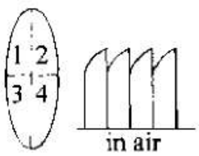
1. In n-type semiconductor majority carriers and minority carriers are respectively **[1]**

   a) germanium and silicon
   b) aluminum and boron
   c) holes and electrons
   d) electrons and holes

2. A 4 μF capacitor, a resistance of 2.5 MΩ is in series with 12 V battery. Find the time after which the potential difference across the capacitor is 3 times the potential difference across the resistor. [Given: ln(2) = 0.693] **[1]**

   a) 7s
   b) 13.86s
   c) 6.93s
   d) 14s

3. The given lens is broken into four parts rearranged as shown. If the initial focal length is f then after rearrangement the equivalent focal length is: **[1]**



   a) f
   b) $\frac{f}{4}$
   c) $\frac{f}{2}$
   d) 4f

4. Would there be any advantage to add n-type or p-type impurities to copper? **[1]**

   a) Yes
   b) May be
   c) Information is insufficient
   d) No

5. An electric dipole consisting of charges + q and - q separated by a distance L is in stable equilibrium in a uniform electric field $\vec{E}$. The electrostatic potential energy of the dipole is **[1]**

a) zero
b) - qLE
c) - 2 qEL
d) qLE

6. An ammeter has a resistance of G ohm and a range of I amp. The value of resistance used in parallel to convert it into an ammeter of range nI amp is: **[1]**

a) G/n
b) (n - 1)G
c) G/(n - 1)
d) nG

7. A 50 Hz alternating current of peak value 1 ampere flows through the primary coil of a transformer. If the mutual inductance between the primary and secondary be 1.5 H, then the mean value of the induced voltage is: **[1]**

a) 150 volt
b) 300 volt
c) 75 volt
d) 225 volt

8. When the wave of hydrogen atom comes from infinity into the first orbit, then the value of wave number is: **[1]**

a) $1097\ cm^{-1}$
b) $109700\ cm^{-1}$
c) $109\ cm^{-1}$
d) none of these

9. The maximum number of possible interference maxima when slit separation is equal to 4 times, the wavelength of light used in a double-slit experiment is: **[1]**

a) ∞
b) 4
c) 9
d) 8

10. Debye is the unit of: **[1]**

a) None of these
b) Electric dipole moment
c) Electric flux
d) Torque

11. A junction diode has a resistance of 25 Ω when forward biased and 25000 Ω when reverse biased. The current in the diode, for the arrangement shown will be: **[1]**

a) $\frac{1}{7}$A
b) $\frac{1}{180}$A
c) $\frac{1}{15}$A
d) $\frac{1}{25}$A

12. The refractive index of water is 1.33. The direction in which a man underwater should look to see the setting sun is: **[1]**

a) 90^o with the vertical
b) 49^o to the horizontal
c) along the horizontal
d) 49^o to the vertical

13. The number of photoelectrons emitted for the light of a frequency v (higher than the threshold frequency v_0) is proportional to: **[1]**

a) frequency of light (v)
b) $v - v_0$
c) intensity of light
d) threshold frequency (v_0)

14. A 40μF capacitor is connected to a 200 V, 50 Hz ac supply. The rms value of the current in the circuit is, nearly: **[1]**

a) 2.5 A
b) 1.7 A
c) 2.05 A
d) 25.1 A

15. A ray of light travelling in air has wavelength λ, frequency ν, velocity v and intensity I. If this ray enters into water, then these parameters are λ', ν', v' and I' respectively. Which of the following relation is correct? **[1]**

a) I = I'
b) $\lambda = \lambda'$
c) $\nu = \nu'$
d) $v = v'$

16. **Assertion (A):** The ionising power of β-particle is less compared to β-particles but their penetrating power is more. **[1]**

Reason (R): The mass of β-particle is less than the mass of α-particle.

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):** In Hertz experiment, the electric vector of radiation produced by the source gap is parallel to the two or detector gap. **[1]**

Reason (R): Production of sparks between the detector gap is maximum when it is placed perpendicular to the source gap.

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.

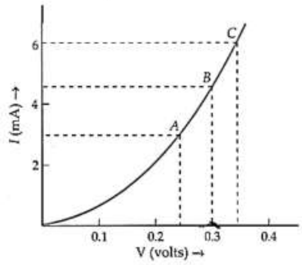
18. **Assertion (A):** Soft iron is used as the core of the transformer. **[1]**

Reason (R): Area of hysteresis loop for soft iron is small.

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. The figure shows the characteristic curve of a junction diode. Determine the d.c. and a.c. resistance of the diode, when it operates at 0.3 V. **[2]**



20. What is the distance of closest approach when a 5.0 MeV proton approaches a gold nucleus? **[2]**

21. A parallel plate capacitor with plate area A and plate separation d, is charged by a constant current I. Consider a plane surface of area A/2 parallel to the plates and situated symmetrically between the plates. Determine the displacement current through this area. **[2]**

OR

Arrange the following electromagnetic waves in the order of their increasing wavelength :

a. γ-rays

b. Microwaves

c. X-rays

d. Radio waves

How are infra-red waves produced? What role does infra-red radiation play in

i. maintaining the Earth's warmth and

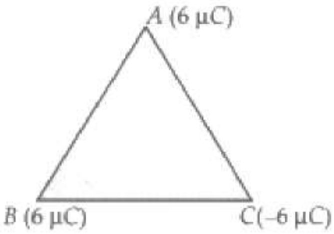
ii. physical therapy?

22. When the voltage drop across a p-n junction diode is increased from 0.70 V to 0.71 V, the change in the diode current is 10 mA. What is the dynamic resistance of the diode? **[2]**

23. A 12 pF capacitor is connected to a 50 V battery. How much electrostatic energy is stored in the capacitor? If another capacitor of 6 pF is connected in series with it with the same battery connected across the combination, find the charge stored and potential difference across each capacitor. **[2]**

OR

Find the amount of work done in arranging the three point charges, on the vertices of an equilateral triangle ABC, of side 10 cm, as shown in the figure.



24. The wavelength λ, of a photon and the de-Broglie wavelength of an electron have the same value. Show that energy of a photon is $\frac{2\lambda mc}{h}$ times the kinetic energy of electron, where m, c and h have their usual meaning. **[2]**

25. Complete the following nuclear reactions: **[2]**

i. a. ${}^{208}_{84}Po \rightarrow {}^{204}_{82}Pb + \ldots\ldots$

b. ${}^{32}_{15}P \rightarrow {}^{32}_{16}S + \ldots\ldots$

ii. Write the basic process involved in nuclei responsible for

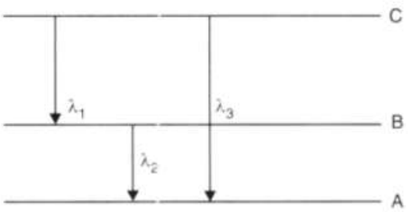
a. β^- and

b. β^+ decay

Section C

26. i. State Bohr's quantization condition for defining stationary orbits. How does de-Broglie hypothesis explain the stationary orbits? **[3]**

ii. Find the relation between the three wavelengths λ_1, λ_2 and λ_3 from the energy level diagram shown below:



27. In a single slit diffraction experiment, a slit of width d is illuminated by red light of wavelength 650 nm. For what value of d will **[3]**

i. the first minimum fall is at an angle of diffraction of 30°and

ii. the first maximum fall is at an angle of diffraction of 30°?

28. i. Define mutual inductance. **[3]**

ii. A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 0 to 20 A in 0.5 s, what is the change of flux linkage with the other coil?

OR

State Lenz's law. Give one example to illustrate this law. "The Lenz's law is a consequence of the principle of conservation of energy." Justify this statement.

29. 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? **[3]**

OR

Give reasons for the following:

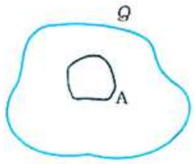
i. Long-distance radio broadcasts use short-waves bands.
ii. The small ozone layer on top of the stratosphere is crucial for human survival.
iii. Satellites are used for long-distance TV transmission.

30. If χ stands for the magnetic susceptibility of a given material, identify the class of materials for which **[3]**

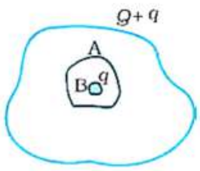
i. $-1 \leq x < 0$
ii. $0 < \chi < \varepsilon_r$, (ε stands for a small positive number).
   a. Write the range of relative magnetic permeability of these materials.
   b. Draw the pattern of the magnetic field lines when these materials are placed in an external magnetic field.

Section D

31. a. A conductor A with a cavity as shown in fig is given a charge Q. Show that the entire charge must appear on the outer surface of the conductor. **[5]**



b. Another conductor B with charge q is inserted into the cavity keeping B insulated from A. Show that the total charge on the outside surface of A is Q + q [fig].



c. A sensitive instrument is to be shielded from the strong electrostatic fields in its environment. Suggest a possible way.

OR

Four charges +q, +q, -q, -q are placed respectively at the four corners A, B, C and D of a square of side a. Calculate the electric field at the centre of the square.

32. i. Derive the mathematical relation between refractive indices μ_1 and μ_2 of two radii and radius of curvature R for refraction at a convex spherical surface. Consider the object to be a point source lying on the principal axis in rarer medium of refractive index $\mu_1$and a real image formed in the denser medium of refractive index μ_2. Hence, derive lens maker's formula. **[5]**

ii. Light from a point source in air falls on a convex spherical glass surface of refractive index 1.5 and radius of curvature 20 cm. The distance of light source from the glass surface is 100 cm. At what position is the image formed?

OR

i. Draw a labelled schematic ray diagram of the astronomical telescope in normal adjustment.

ii. Which two aberrations do objectives of refracting telescope suffer from? How are these overcome in reflecting telescope?

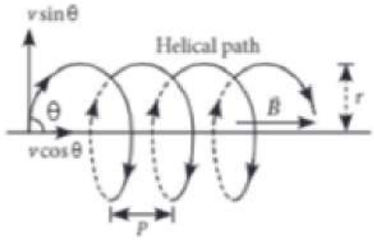
33. i. Derive an expression for drift velocity of free electrons. **[5]**

ii. How does drift velocity of electrons in a metallic conductor vary with increase in temperature? Explain.

Section E

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

The path of a charged particle in magnetic field depends upon angle between velocity and magnetic field. If velocity $\vec{v}$ is at angle θ to $\vec{B}$, component of velocity parallel to magnetic field (v cos θ) remains constant and component of velocity perpendicular to magnetic field (v sin θ) is responsible for circular motion, thus the charge particle moves in a helical path.



The plane of the circle is perpendicular to the magnetic field and the axis of the helix is parallel to the magnetic field. The charged particle moves along helical path touching the line parallel to the magnetic field passing through the starting point after each rotation.

Radius of circular path is r = $\frac{mv\sin\theta}{qB}$

Hence the resultant path of the charged particle will be a helix, with its axis along the direction of $\vec{B}$ as shown in figure.

(i) What will be the trajectory of a positively charged particle if it enters into a uniform magnetic field with uniform velocity at right angle to the magnetic field?

(ii) Two charged particles A and B having the same charge, mass and speed enter into a magnetic field in such a way that the initial path of A makes an angle of 30^o and that of B makes an angle of 90^o with the field. Find the ratio of radii of circular path covered by particles A and B?

(iii) An electron having momentum 2.4×10^{-23} kg m/s enters a region of uniform magnetic field of 0.15 T. The field vector makes an angle of 30^o with the initial velocity vector of the electron. What will be the radius of the helical path of the electron in the field ?

OR

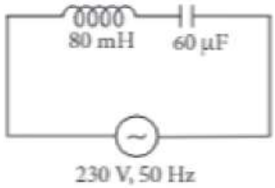
The magnetic field in a certain region of space is giver by B = $8.35 \times 10^{-2}\,\hat{i}$ T. A proton is shot into the field with velocity $\vec{v} = \left(2 \times 10^5\,\hat{i} + 4 \times 10^5\,\hat{j}\right)$ m/s. The proton follows a helical path in the field. What will be the distance moved by proton in the x-direction during the period of one revolution in the yz-plane? (Mass of proton = 1.67×10^{-27} kg)

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 - 10

Class 12 - Physics

Section A

1. **(d)** electrons and holes
   Explanation: N-type semiconductors have a larger electron concentration than hole concentration. The term n-type comes from the negative charge of the electron.
   In n-type semiconductors, electrons are the majority carriers and holes are the minority carriers.
   N-type semiconductors are created by doping an intrinsic semiconductor with donor impurities (or doping a p-type semiconductor as done in the making of CMOS chips). A common dopant for n-type silicon is phosphorus.

2. **(b)** 13.86s
   Explanation: At any instant of time t during the charging process, the transient current in the circuit
   $I=\frac{V_0}{R}e^{-t/RC}$
   ∴ Potential difference across resistor R
   $V_R=\left[\frac{V_0}{R}e^{-t/RC}\right]\times R$
   $= V_0e^{-t/RC}$ ...(i)
   ∴ Potential difference across C
   $V_c = V_0 - V_0e^{-t/RC} = V_0(1 - e^{-t/RC})$ ...(ii)
   ∵ $V_c = 3V_R$
   ∴ $V_0(1 - e^{-t/RC}) = 3V_0.e^{-t/RC}$
   $\Rightarrow 1 - e^{-t/RC} = 3e^{-t/RC} \Rightarrow 1 = 4e^{-t/RC}$
   Taking log on both sides
   $\log_e 1 = 2\log_e 2 + \left(-\frac{t}{RC}\right)$
   $\Rightarrow 0 = 2 \times 2.303 \log_{10} 2 - \frac{t}{RC}$
   $\Rightarrow t = [2 \times 2.303 \log_{10}2] \times 2.5 \times 10^6 \times 4 \times 10^{-6}$ or, t = 13.86 s

3. **(c)** $\frac{f}{2}$
   Explanation: Cutting a lens in transverse direction doubles their focal length i.e., 2f.
   Using the formula of equivalent focal length,
   $\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}+\frac{1}{f_3}+\frac{1}{f_4}$
   We get equivalent focal length as $\frac{f}{2}$

4. **(d)** No
   Explanation: No

5. **(b)** - qLE
   Explanation: When the dipole is in the direction of the field then net force is qE + (-qE) = 0 and its potential energy is minimum P= -pE
   Here, p is an electric dipole defined by the product of charge and distance between them: p = qL
   thus P= -qLE

6. **(c)** G/(n - 1)
   Explanation: S = $\frac{I_g}{I-I_g}\times$ G = $\frac{I}{(nI-I)}\times$ G = $\frac{G}{(n-1)}$

7. **(b)** 300 volt
   Explanation: Time period of AC, T = $\frac{1}{n}=\frac{1}{50}$ second
   Time interval At for current to decrease from the peak value of one ampere to zero amperes = T/4.
   $\Delta t=\frac{T}{4}=\left(\frac{1}{50}\right)\left(\frac{1}{4}\right)=\frac{1}{200}$sec
   Change in current, $\Delta t = I_f - I_i = 0 - 1 = -1$ amp

Mean induced emf, e = $-M\left(\frac{\Delta I}{\Delta t}\right)$
= (-1)(1.5)$\left[\frac{-1}{1/200}\right]$
= 300 volt

8. **(b)** 109700 cm^{-1}
Explanation: Wavelength $\bar{v}=\frac{1}{\lambda}=R\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$, $n_2=\infty$ and $n_1=1$
$\Rightarrow \bar{v}$ = R = 1.097 × 10^7 m^{-1} = 109700 cm^{-1}

9. **(b)** 4
Explanation: $\Delta x=n\lambda$
or $d\sin\theta=n\lambda$ [For maximum intensity]
For maximum number o f possible interference maxima,
$\sin\theta$ = 1
∴ d = nλ or 4λ = nλ or n = 4

10. **(b)** Electric dipole moment
Explanation: SI units for electric dipole moment are Coulombmeter (Cm), however, the most common unit is the Debye (D).

11. **(a)** $\frac{1}{7}$A
Explanation: The junction diode is forward biased. Therefore, the effective resistance = 25 + 10 = 35 Ω
∴ Current in diode,
$I=\frac{5\text{V}}{35\Omega}=\frac{1}{7}\text{A}$

12. **(d)** 49^o to the vertical
Explanation: 49^o to the vertical

13. **(c)** intensity of light
Explanation: The number of photoelectrons decide the photocurrent. Assuming that the number of electrons emitted depends on the number of photons incident, the number of photoelectrons depend on the intensity of light.

14. **(a)** 2.5 A
Explanation: RMS value of applied voltage = 200 V
The impedance of a capacitor is given by:
$X_C=\frac{1}{2\pi fC}$
Hence, rms current through it is:
$I_{rms}=\frac{\mathbf{V}}{\mathbf{X_C}}$
I_{rms} = 200 × 2 × π × 50 × 40 × 10^{-6}
I_{rms} = 2.51 A

15. **(c)** $\nu=\nu'$
Explanation: When light travels from air into water, only its frequency remains unchanged.

16. **(b)** Both A and R are true but R is not the correct explanation of A.
Explanation: β-particles, being emitted with very high speed compared to α-particles, pass for very little time near the atoms of the medium. So the probability of the atoms being ionised is comparatively less. But due to this reason, their loss of energy is very slow and they can penetrate the medium through a sufficient depth.

17. **(c)** A is true but R is false.
Explanation: Hertz experimentally observed that the production of spark between the detector gap is maximum when it is placed parallel to source gap. This means that the electric vector of radiation produced by the source gap is parallel to the two gaps i.e., in the direction perpendicular to the direction of propogation of the radiation.

18. **(a)** Both A and R are true and R is the correct explanation of A.
Explanation: Hysteresis loss in the core of the transformer is directly proportional to the hysteresis loop area of the core material. Since soft iron has narrow hysteresis loop area, that is why the soft iron core is used in the transformer.

Section B

19. The d.c. resistance is just equal to the voltage divided by current.

$\therefore r_{dc} = \frac{V_B}{I_B} = \frac{0.3\text{ V}}{4.5\times10^{-3} A}$ = 66.67 Ω

Consider two points A and C around the point of operation B. Then,

$r_{ac} = \frac{\Delta V}{\Delta I} = \frac{V_C - V_A}{I_C - I_A} = \frac{0.35-0.25}{(6-3)\times10^{-3}}$ = 33.33 Ω

20. At the distance r_0 of closest approach,

K.E. of a proton = P.E. of proton and the gold nucleus

$K = \frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Ze\cdot e}{r_0}$ [q_1 = Ze, q_2 = e]

$= r_0 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Ze^2}{K}$

But K = 5.0 MeV = 5.0 × 1.6 × 10^{-13} J

For gold, Z = 79

$\therefore r_0 = \frac{9\times10^9\times79\times(1.6\times10^{-19})^2}{5.0\times1.6\times10^{-13}}$

= 2.28 × 10^{-14}m = 2.3 × 10^{-14} m

21. Let charge on capacitor plates at any instant t be q. Then electric field between the capacitor plates will be

$E = \frac{\sigma}{\varepsilon_0} = \frac{q}{\varepsilon_0 A}$

Flux through the area A/2 will be

$\phi_E = E\cdot\frac{A}{2} = \frac{q}{\varepsilon_0 A}\cdot\frac{A}{2} = \frac{q}{2\varepsilon_0}$

∴ The displacement current is

$I_D = \varepsilon_0\frac{d\phi_E}{dt} = \varepsilon_0\cdot\frac{I}{2\varepsilon_0}\cdot\frac{dq}{dt} = \frac{I}{2}$

OR

In the order of increasing wavelength, the e.m. waves are

γ-rays, < X-rays < Microwaves < Radiowaves

Infrared rays are produced by hot bodies or by vibrations of atoms and molecules.

i. Infrared rays maintain earth's warmth through green house effect.
ii. Infrared lamps are used in physical therapy because of the heat produced by infrared rays.

22. For a p-n junction diode, the dynamic resistance is given by:

r = $\frac{\Delta V}{\Delta I}$

Given that:

ΔV = 0.71 - 0.70 = 0.01 V = 10^{-2} V

ΔI = 10^{-3} × 10A = 10^{-2} A

∴ r = $\frac{10^{-2}}{10^{-2}}$ = 1Ω

23. Energy stored in the capacitor of capacitance 12 pF = $\frac{1}{2}C_1V^2$

$= \frac{1}{2}\times12\times10^{-12}\times(50)^2\text{J} = 6\times25\times10^{-10}\text{J} = 15\times10^{-9}\text{J}$

With another capacitor of capacitance 6 pF in series with the first one, we get equivalent capacitance,

C = $\frac{C_1\times C_2}{C_1+C_2} = \frac{6\times12}{6+12}\text{pF} = \frac{12\times6}{18}$ = 4 pF

Charge stored in each capacitor is same and given by

Q = CV = 4 × 10^{-12}× 50 C = 2×10^{-10}C

Each of the two capacitors will get same charge and equal to Q = 2 ×10^{-10}C

Potential on capacitors with capacitance 12pF is $= \frac{Q}{C_1} = \frac{2\times10^{-10}}{12\times10^{-12}}\text{V} = 16.67\text{V}$

Potential on capacitor with capacitance 6 pF is $= \frac{2\times10^{-10}}{6\times10^{-12}}\text{V} = 33.33\text{V}$

OR

Given q_A =6× 10^{-6} C = q_B

qC = -6× 10^{-6}C

r = 10 cm = 0.1 m

W = $W_{AB} + W_{BC} + W_{AC}$ (in general form W= $q_1q_{2/4}\pi\in_0$r)

$W = \frac{1}{4\pi\varepsilon_0 r}$ [$q_Aq_B + q_Bq_C + q_Cq_A$]

$W = 9\times10^9\times\frac{1}{0.1}$ [36-36-36] × 10^{-12}

W = 9 × 10^9 × (-36) × 10^{-11}

W = -3.24 J

24. The de-Broglie wavelength of the electron is $\lambda = \frac{h}{mv}$

K.E of electron,

$E_e = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{h}{m\lambda}\right)^2 = \frac{h^2}{2m\lambda^2}$ ....(i)

We know that energy of photon is $E_p = \frac{hc}{\lambda}$ ....(ii)

On dividing Eq. (i) by Eq. (ii), we get,

$\frac{E_e}{E_p} = \frac{h^2}{2m\lambda^2} \times \frac{\lambda}{hc} \Rightarrow E_p = \frac{2\lambda mc}{h}E_e$

25. i. Radioactive emissions include emission of alpha, beta and gamma rays along with other subatomic particles.

a. ${}^{208}_{84}Po \rightarrow {}^{204}_{82}Pb + {}^{4}_{2}He$

208 = 204 + A ⇒ A = 208 - 204 = 4

84 = 82 + Z; Z = 84 - 82 = 2

b. ${}^{32}_{15}P \rightarrow {}^{32}_{16}S + {}_{-1}e^0 + \bar{v}$

32 = 32 + A, A = 32 - 32 = 0 : 15 = 16 + Z, z = 15 - 16 = -1; A = 0, z = -1 ⇒ ${}_{-1}e^0$

ii. In both processes, the conversion of a neutron to proton and proton to neutron inside the nucleus takes places as follows

${}^{A}_{Z}X \rightarrow \beta^- + {}^{A}_{Z+1}Y + \bar{v}(\beta^- - decay)$

${}^{A}_{Z}X \rightarrow \beta^+ + {}^{A}_{Z-1}Y + v(\beta^+ - decay)$

Section C

26. i. Only those orbits are stable for which the angular momentum, of revolving electron, is an integral multiple of h/2π. $L = \frac{nh}{2\pi}$

i.e., angular momentum of orbiting electron is quantized.

According to de-Broglie hypothesis

Linear momentum

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

And for a circular orbit, L = r_np where 'r_n' is the radius of n^{th} orbit

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

Also, L $= \frac{nh}{2\pi}$

$\therefore \frac{r_n h}{\lambda} = \frac{nh}{2\pi}$

$\Rightarrow \quad 2\pi r_n = n\lambda$

∴ Circumference of permitted orbits are integral multiples of the wave-length λ

ii. $E_C - E_B = \frac{hc}{\lambda_1}$ ...(i)

$E_B - E_A = \frac{\hbar c}{\lambda_2}$ ...(ii)

$E_C - E_A = \frac{hc}{\lambda_3}$ ...(iii)

Adding (i) & (ii)

$E_C - E_A = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$ ...(iv)

Using equation (iii) and (iv)

$\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$

$\Rightarrow \quad \frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$

27. i. In single slit diffraction pattern, first minimum occurs at $d\sin\theta = \lambda$ [θ and λ are diffraction angle and wavelength of the light used]

∴ Slit width, $d = \frac{\lambda}{\sin\theta}$ ....(a)

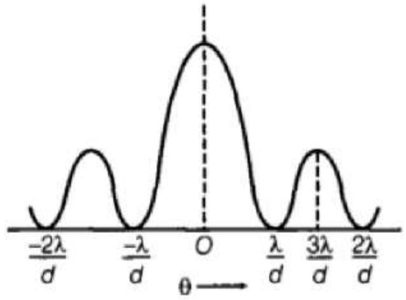
Given, $\lambda = 650 \times 10^{-9}\text{m}\, and\, \theta = 30^\circ$

Now from equation (a) we get slit width, $d = \frac{650\times10^{-9}}{\sin 30^\circ} = \frac{650}{(1/2)} \times 10^{-9}$

$= 1300 \times 10^{-9}$ m

$\therefore d = 1.3 \times 10^{-6}\text{m} = 1.3\ \mu m$

ii. In single slit diffraction pattern, maximum and minima occurs as per the below diagram -



Now for first maximum,

$d \sin\theta = \frac{3\lambda}{2}\left[using,\ d\sin\theta = (2n+1)\frac{\lambda}{2}\right]$

where, n = 1(for first maximum)

$\Rightarrow \quad d = \frac{3\lambda}{2\sin\theta}$

where, $\theta = 30^{\circ}, \lambda = 650 \times 10^{-9}\text{m}$

$\therefore d = \frac{3\lambda}{2\sin\theta}$

$= \frac{3\times650\times10^{-9}}{2\times\sin30^{\circ}}$

$= 1950 \times 10^{-9}\text{m}$

$\therefore d = 1.95 \times 10^{-6}\text{m} = 1.95\ \mu m$

28. i. Mutual inductance is numerically equal to the induced emf in the secondary coil when the current in the primary coil changes by unity. Or **Mutual Inductance** is the interaction of one coils magnetic field on another coil as it induces a voltage in the adjacent coil.

ii. Mutual inductance of a pair of coils, μ = 1.5 H

Initial current, I_1 = 0 A

Final current I_2 = 20 A

Change in current will be: $\Delta I = l_2 - l_1$

20 - 0 = 20 A

and we know,

$\Delta\phi = M\Delta I$,

where, $\Delta\phi$ is change in magnetic flux

$\Delta\phi = 1.5 \times 20 = 30$ Wb

Hence, change in the flux linkage will be 30 Wb.

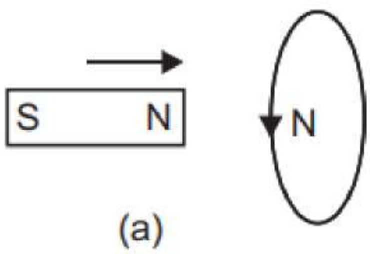
OR

According to Lenz's law, the direction of the induced current (caused by induced emf) is always such as to oppose the change causing it.

$\varepsilon = -k\frac{d\phi}{dt}$

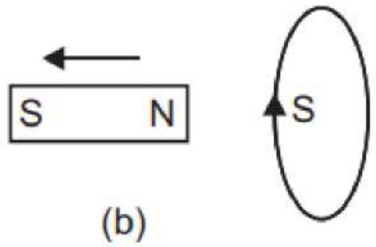
where k is a positive constant. The negative sign expresses Lenz's law. It means that the induced emf is such that, if the circuit is closed, the induced current opposes the change in flux.

Example: When the north pole of a coil is brought near a closed coil, the direction of current induced in the coil is such as to oppose the approach of north pole. For this the nearer face of coil behaves as north pole. This necessitates an anticlockwise current in the coil, when seen from the magnet side [fig. (a)]



(a)

Similarly when north pole of the magnet is moved away from the coil, the direction of current in the coil will be such as to attract the magnet. For this the nearer face of coil behaves as south pole. This necessitates a clockwise current in the coil, when seen from the magnet side (fig. b).



(b)

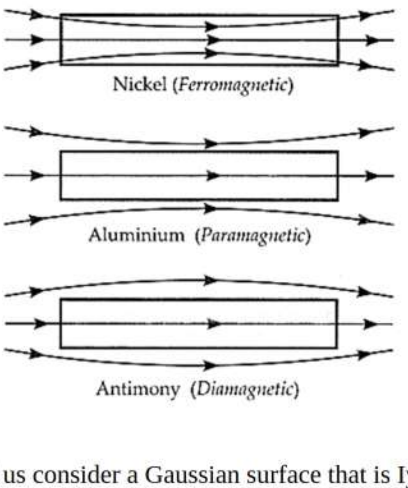
Thus, in each case whenever there is a relative motion between a coil and the magnet, a force begins to act which opposes the relative motion. Therefore to maintain the relative motion, a mechanical work must be done. This work appears in the form of electric energy of coil. Thus Lenz's law is based on conservation of energy.

29. 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.

OR

i. Shortwave radio waves are reflected back by the ionosphere in the atmosphere, that is why long-distance radio broadcasts use short-wave radio wave bands.
ii. The ozone layer absorbs harmful ultraviolet radiations coming from the sun and other sources thus preventing us from its harmful effects. That is why it is crucial for human survival.
iii. The electromagnetic waves, used for long-distance TV transmission, are not reflected by the ionosphere. Therefore, to reflect back the TV signals to the desired locations on the earth, satellites are used.

30. i. If $-1 \leq \chi < 0$, the material is diamagnetic. The range of relative magnetic permeability is $0 \leq \mu_r < 1$.
ii. If $0 < \chi < \varepsilon_r$, the material is paramagnetic.
a. The range of relative magnetic permeability is $1 < \mu_r, < 1 + \varepsilon$.
b. For pattern of the field lines,



Section D

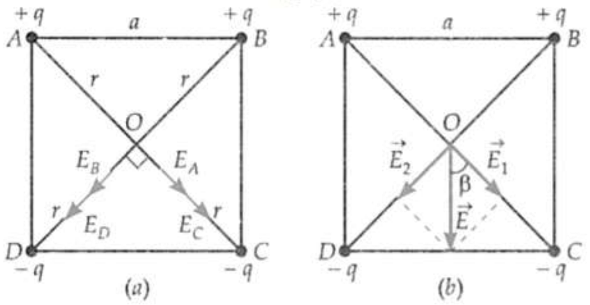
31. a. Let us consider a Gaussian surface that is Iying wholly within a conductor and enclosing the cavity. The electric field intensity E inside the charged conductor is zero. Let q is the charge inside the conductor and $\in_o$ is the permittivity of free space.
According to Gauss's law,
Flux, $\phi = \overrightarrow{E}.\overrightarrow{ds} = \frac{q}{\epsilon_0}$
Here, E = 0
$\frac{q}{\epsilon^0} = 0$
$\therefore \epsilon_o \neq 0$
$\therefore$ q = 0
Therefore, the charge inside the conductor is zero.
The entire charge Q appears on the outer surface of the conductor.
b. The outer surface of conductor A has a charge of amount Q. Another conductor B having charge +q is kept inside conductor A and it is insulated from A. Hence, a charge of the amount -q will be induced in the inner surface of conductor A and +q is

induced on the outer surface of conductor A. Therefore, the total charge on the outer surface of conductor A is Q+q.

c. A sensitive instrument can be shielded from the strong electrostatic field in its environment by enclosing it fully inside a metallic surface. A closed metallic body acts as an electrostatic shield.

OR

Let E_A, E_B, E_C and E_D be the electric fields at the centre O of the square due to the charges at A, B, C and D respectively. Their directions are as shown in fig. (a).



Since all the charges are of equal magnitude and at the same distance r from the centre O, so

$E_A = E_B = E_C = E_D = k \cdot \frac{q}{r^2} = \frac{q}{\left(\frac{a}{\sqrt{2}}\right)^2} = 2\frac{kq}{a^2}$ $[\because r^2 + r^2 = a^2]$

Because E_A and E_C act in the same direction, so their resultant is

$E_1 = E_A + E_C = \frac{2kq}{a^2} + \frac{2kq}{a^2} = \frac{4kq}{a^2}$

Similarly, the resultant of E_B and E_D is

$E_2 = E_B + E_D = \frac{4kq}{a^2}$

Now, the resultant of E_1 and E_2 will be

$E = \sqrt{E_1^2 + E_2^2} = \sqrt{\left(\frac{4kq}{a^2}\right)^2 + \left(\frac{4kq}{a^2}\right)^2}$

$= 4\sqrt{2}k\frac{q}{a^2}$,

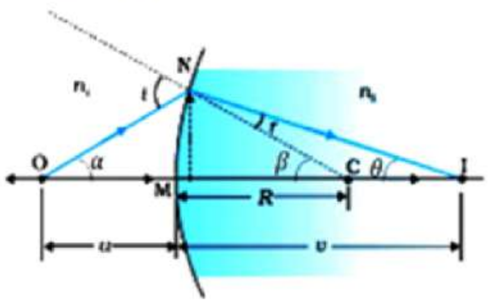
directed parallel to AD or EC, as shown in Fig. (b).

$\cos\beta = \frac{E_1}{E} = \frac{1}{\sqrt{2}}$

$\therefore \beta = 45^o$

i.e., the resultant field is inclined at an angle of 45^o with AC.

32. i. The figure shows the geometry of the formation of a real image I of an object O and the principal axis of a spherical surface with centre of curvature C and radius of curvature R.



Assumptions:

a. The aperture of the surface is small compared to other distance involved.

b. NM is taken to be nearly equal to the length of the perpendicular from the point N on the principal axis.

Now, $\tan\angle NOM = \frac{MN}{OM}$

$\tan\angle NCM = \frac{MN}{MC}$

$\tan\angle NIM = \frac{MN}{MI}$

For $\triangle NOC$, i is the exterior angle.

Assuming the incident ray is very close to the principal axis, all the angles are very small. Hence, for small angles,

tan x = x = sin x

Therefore,

i = ∠NOM + ∠NCM

i = $\frac{MN}{OM}$ + $\frac{MN}{MC}$ .....(i)

Similarly,

r = ∠NCM - ∠NIM

r = $\frac{MN}{MC}$ - $\frac{MN}{MI}$ ....(ii)

Using Snell's law,

$\mu_1\ sin\ i = \mu_2\ sin\ r$

For small angles,

$\mu_1 i = \mu_2 r$

Putting the values of i and r from eqns. from (i) and (ii), we have

$\mu_1\left(\frac{MN}{OM}+\frac{MN}{MC}\right) = \mu_2\left(\frac{MN}{MC}-\frac{MN}{MI}\right)$

$\frac{\mu_1}{OM}$ + $\frac{\mu_2}{MI}$ = $\frac{\mu_2-\mu_1}{MC}$ ....(iii)

Now, OM = -u, MI = +v, MC = +R

Putting these values in equation (iii), we have

$\frac{\mu_2}{v}$ - $\frac{\mu_1}{u}$ = $\frac{\mu_2-\mu_1}{R}$

ii. According to the question,

$\mu_1 = 1$, $\mu_2 = 1.5$, R = 20 cm, u = -100 cm

$\frac{\mu_2}{v}$ - $\frac{\mu_1}{u}$ = $\frac{\mu_2-\mu_1}{R}$

$\Rightarrow \frac{1.5}{v} + \frac{1}{100} = \frac{1.5-1}{20}$

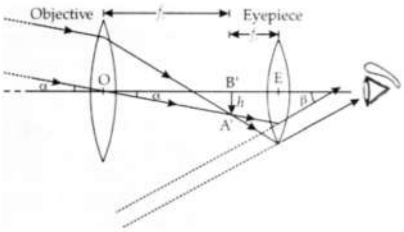
$\Rightarrow \frac{1.5}{v} = \frac{0.5}{20} - \frac{1}{100}$

$\Rightarrow$ v = 100 cm

Therefore, the image is formed at a distance of 100 cm in the denser medium.

OR

i. Ray diagram of the astronomical telescope as shown in the figure:



ii. The two aberrations that objectives of refracting telescope suffer from are given below;

a. **Spherical aberrations:** Because of the surface geometry of the lens, sharp point image of star is difficult to obtain on a point.
b. **In reflecting telescope**, we use a parabolic mirror to remove this aberration.
c. **Chromatic aberrations:** Different colors of light have a different refractive index with respect to glass. Hence different colors would focus at different points. Hence the image of the white object would appear as different color point images. This is known as chromatic aberrations.
d. **In reflecting telescope**, image is formed with reflected rays hence this aberration is removed.

33. i. When a conductor is subjected to an electric field E, each electron experiences a force:

F = - eE, and free electron acquires an

acceleration, a = F/m = -eE/m ... (i)

where, m = mass of electron, e = electronic charge and E = electric field.

Free electron starts accelerating and gains velocity and collide with atoms and molecules of the conductor. The average time difference between two consecutive collisions is known as relaxation time of electron and can be calculated as -

$\bar{\tau} = \frac{\tau_1+\tau_2+\ldots+\tau_n}{n}$ ...(ii)

where, $\tau_1,\ \tau_2 \ldots .\ \tau_n$ are the average time difference(relaxation time) between 1st, 2nd, ...nth collisions.

∴ $v_1, v_2, \ldots v_n$, are velocities gained by electron in 1st, 2nd, ..., nth collisions with initial thermal velocities $u_1, u_2, \ldots, u_n$, respectively.

$\therefore \quad v_1 = u_1 + a\tau_1$

Similarly,

$v_2 = u_2 + a\tau_2$

$\vdots \quad \vdots \quad \vdots$

$v_n = u_n + a\tau_2$

The drift speed v_d may be defined as

$v_d = \frac{v_1+v_2+\ldots+v_n}{n}$

$v_d = \frac{(u_1+u_2+\ldots+u_n)+a(\tau_1+\tau_2+\ldots+\tau_n)}{n}$

$v_d = \frac{(u_1+u_2+\ldots+u_n)}{n} + \frac{a(\tau_1+\tau_2+\ldots+\tau_n)}{n}$

$v_d = 0 + a\tau$ [$\because$ Average thermal velocity in n collisions = 0]

$v_d = -(eE/m)\tau$ [from Eq. (i)]

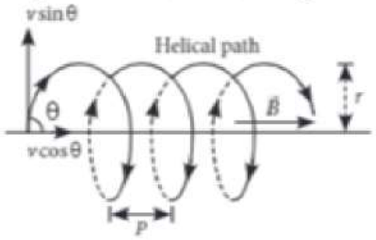
This is the required expression of drift speed of free electrons which shows it is directly proportional to relaxation time.

ii. As the temperature of a conductor is increased, the thermal agitation increases and the collisions become more frequent. The average time τ between the successive collisions decreases and hence the drift speed decreases. Thus, the conductivity decreases and the resistivity of the conductor increases.

Section E

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

The path of a charged particle in magnetic field depends upon angle between velocity and magnetic field. If velocity $\vec{v}$ is at angle θ to $\vec{B}$, component of velocity parallel to magnetic field (v cos θ) remains constant and component of velocity perpendicular to magnetic field (v sin θ) is responsible for circular motion, thus the charge particle moves in a helical path.



The plane of the circle is perpendicular to the magnetic field and the axis of the helix is parallel to the magnetic field. The charged particle moves along helical path touching the line parallel to the magnetic field passing through the starting point after each rotation.

Radius of circular path is r = $\frac{mv\sin\theta}{qB}$

Hence the resultant path of the charged particle will be a helix, with its axis along the direction of $\vec{B}$ as shown in figure.

(i) The path of charged particle will be circular.

(ii) Using, $qvB\sin\theta = \frac{mv^2}{r}$

$r \propto \frac{1}{\sin\theta}$ for the same values of m, v, q and B

$\therefore \frac{r_A}{r_B} = \frac{\sin 90^\circ}{\sin 30^\circ}$ = 2

(iii)The radius of the helical path of the electron in the uniform magnetic field is

r = $\frac{mv_\perp}{eB} = \frac{mv\sin\theta}{eB} = \frac{(2.4\times10^{-23}\text{ kg m/s})\times\sin 30^\circ}{(1.6\times10^{-19}\text{C})\times0.15\text{ T}}$

= 5×10^{-4} m = 0.5×10^{-3} m = 0.5 mm

OR

Here, $\vec{B} = 8.35 \times 10^{-2}\hat{i}$ T

$\vec{v} = 2 \times 10^5\hat{i} + 4 \times 10^5\hat{j}$ m/s

m = 1.67×10^{-27} kg

Pitch of the helix (i.e., the linear distance moved along the magnetic field in one rotation) is given by Pitch of the helix = $\frac{2\pi mv_1}{qB}$

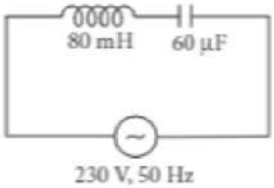
= $\frac{2\times3.14\times1.67\times10^{-27}\times2\times10^5}{1.6\times10^{-19}\times8.35\times10^{-2}}$ = 0.157 m

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.

$P_{av} = V_{rms} I_{rms}\cos\phi = \frac{V_0I_0}{2}\cos\phi$

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, $I_0 = \frac{V_0}{\left(\omega L - \frac{1}{\omega C}\right)}$

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

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