Class: XII

SESSION : 2022-2023

SUBJECT: PHYSICS (THEORY)

SAMPLE QUESTION PAPER - 3

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. **Assertion (A):** A piece of copper and a similar piece of stone are dropped simultaneously from a height near the earth's surface. Both will touch the ground at the same time. **[1]**
Reason (R): There is no effect of the earth's magnetic field on the motion of falling bodies.

a) Both A and R are true and R is the correct explanation of A
b) Both A and R are true but R is NOT the correct explanation of A
c) A is true but R is false
d) A is false and R is also false

2. A ray of light making an angle 10^o with tlhe horizontal is incident on a plane mirror making an angle θ with the horizontal. What should be the value of θ so that the reflected ray goes vertically upwards? **[1]**

a) 30^o
b) 45^o
c) 40^o
d) 20^o

3. Five balls, numbered 1 to 5 are suspended using separate threads. Pairs (1, 2), (2, 4) and (4, 1) show electrostatic attraction, while pairs (2, 3) and (4, 5) show repulsion. Therefore, ball 1 must be: **[1]**

a) made of metal
b) neutral
c) positively charge
d) negatively charged

4. To obtain a p-type germanium semiconductor, it must be doped with: **[1]**

a) arsenic
b) phosphorus

c) antimony

d) indium

5. On increasing the number of electrons striking the anode of an X-ray tube, which one of the following parameters of the resulting X-rays would increase? **[1]**

a) Wavelength

b) Frequency

c) Intensity

d) Penetration power

6. A point source of electromagnetic radiation has an average power output of 800 W. The maximum value of electric field at a distance of 4.0 m from the source is: **[1]**

a) 64.7 V/m

b) 56.72 V/m

c) 54.77 V/m

d) 57.8 V/m

7. A photon of energy 12.09 eV is completely absorbed by a hydrogen atom initially in the ground state. The quantum number of the excited state is: **[1]**

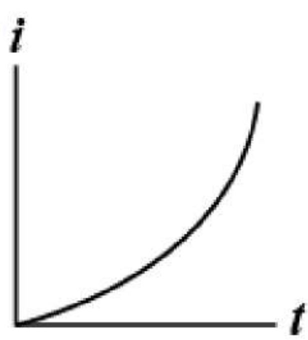
a) 3

b) 4

c) 2

d) 5

8. When a battery is connected across a series combination of self inductance L and resistance R, the variation in the current i with time t is best represented by: **[1]**

a)


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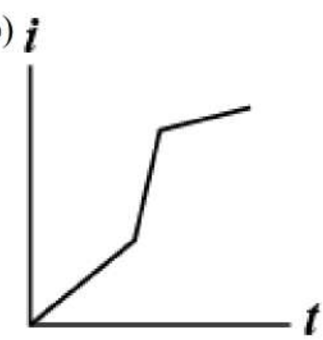

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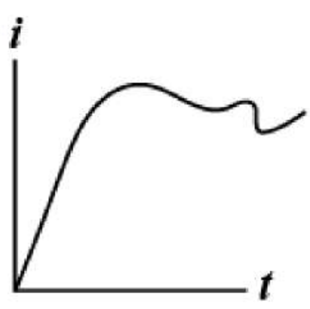

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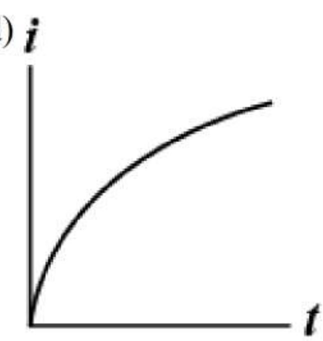


9. Gauss's law is valid for **[1]**

a) any open surface

b) only irregular open surfaces

c) only regular closed surfaces

d) any closed surface

10. The depletion layer of a p-n junction: **[1]**

a) is depleted of ions

b) is of constant width irrespective of the bias

c) has a width that increases with an increase in forward bias

d) acts like an insulating zone under reverse bias

11. A linear aperture whose width is 0.02 cm is placed immediately in front of a lens of focal length 60 cm. The aperture is illuminated normally by a parallel beam of wavelength 5×10^{-5} cm. The distance of the first dark band of the diffraction pattern from the centre of the screen is: [1]

a) 0.25 cm

b) 0.15 cm

c) 0.10 cm

d) 0.20 cm

12. A 2 mW laser operates at a wavelength of 500 nm. The number of photons that will be emitted per second is [1]
[Given, Planck's constant $h = 6.6 \times 10^{-34}$ Js, speed of light $c = 3.0 \times 10^8$ m/s]

a) 2×10^{16}

b) 1.5×10^{16}

c) 1×10^{16}

d) 5×10^{15}

13. If $\vec{E}$ and $\vec{B}$ are the electric and magnetic field vectors of electromagnetic waves, then the direction of propagation of the electromagnetic wave is along the direction of: [1]

a) $\vec{E}$

b) $\vec{E} \times \vec{B}$

c) None of these

d) $\vec{B}$

14. When air is replaced by a dielectric medium of dielectric constant K, the maximum force of attraction between two charges separated by a distance: [1]

a) decreases K^2 times

b) decreases K times

c) increases K times

d) remains unchanged

15. In a primary coil 5 A current is flowing on 220 volts. In the secondary coil, 2200 V voltage produces. Then the ratio of the number of turns in the secondary coil and the primary coil will be: [1]

a) 11 : 1

b) 10 : 1

c) 1 : 1

d) 1 : 10

16. **Assertion (A):** Unlike electric forces and gravitational forces, nuclear force has limited range. [1]
Reason (R): Nuclear force do not obey inverse square law.

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):** Kirchoff's junction rule follows from conservation of charge. **[1]**
Reason (R): Kirchoff's loop rule follows from conservation of momentum.

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. Amorphous solids show: **[1]**

a) equal strengths of all interatomic bonds

b) sharp melting points

c) different freezing and melting points

d) homogeneous composition

Section B

19. Two particles A and B of de-Broglie wavelength λ_1 and λ_2 combine to form a particle C. The process conserves momentum. Find the de-Broglie wavelength of the particle C (the motion is one dimensional). **[2]**

20. a. Two stable isotopes of lithium ${}^{6}_{3}Li$ and ${}^{7}_{3}Li$ have respective abundances of 7.5% and 92.5%. These isotopes have masses 6.01512 u and 7.01600 u, respectively. Find the atomic mass of lithium. **[2]**

b. Boron has two stable isotopes, ${}^{10}_{5}B$ and ${}^{11}_{5}B$. Their respective masses are 10.01294 u and 11.00931 u, and the atomic mass of boron is 10.811 u. Find the abundances of ${}^{10}_{5}B$ and ${}^{11}_{5}B$.

21. An n-type semiconductor has excess of free electrons while a p-type semiconductor has a deficiency of these. But when a p-n junction is formed, all the electrons do not flow from the n-region to the p-region. Why? **[2]**

22. The susceptibility of a magnetic material is 0.9853. Identify the type of magnetic material. Draw the modification of the field pattern on keeping a piece of this material in a uniform magnetic field. **[2]**

OR

Give two points to distinguish between a paramagnetic and diamagnetic substance.

23. The ratios of number density of free electron to holes, $\left(\frac{n_e}{n_h}\right)$, for two different materials A and B, are equal to one and less than one respectively. Name the type of semiconductors to which A and B belong. Draw energy level diagram for A and B. **[2]**

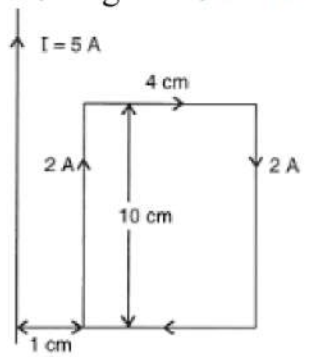
24. An alpha particle is projected vertically upward with a speed of 3×10^4 km s^{-1} in a region where a magnetic field of magnitude 1.0 T exists in the direction south to north. Find the magnetic force that acts on the particle. **[2]**

OR

A rectangular loop of wire of size 4 cm $\times$ 10 cm carries a steady current of 2 A. A straight long wire carrying 5 A current is kept near the loop as shown. If the loop and the wire are coplanar, find:

i. the torque acting on the loop and

ii. the magnitude and direction of the force on the loop due to the current-carrying wire.



25. A slit of width 0.025 mm is placed in front of a lens of focal length 50 cm. The slit is illuminated with light of wavelength 5900 $\mathring{A}$ Calculate the distance between the centre and first dark band of diffraction pattern obtained on a screen placed at the focal plane of the lens. **[2]**

Section C

26. Three point charges +q each are kept at the Vertices of an equilateral triangle of side l. Determine the magnitude and sign of the charge to be kept at its centroid so that the charges at the vertices remain in equilibrium. **[3]**

27. A bar magnet of magnetic moment 6 J/T is aligned at 60° with a uniform external magnetic field of 0.44 T. Calculate **[3]**

a. the work done in turning the magnet to align its magnetic moment

i. normal to the magnetic field

ii. opposite to the magnetic field

b. the torque on the magnet in the final orientation in case (ii).

28. Identify the type of waves which are produced by the following way and write one application for each: **[3]**

i. Radioactive decay of the nucleus.

ii. Rapid acceleration and decelerations of electrons in aerials.

iii. Bombarding a metal target by high energy electrons.

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.

29. In a Young's double-slit experiment, red light of wavelength 6000 $\mathring{A}$ is used and the nth bright fringe is obtained at a point P on the screen. Keeping the same setting, the source is replaced by the green light of 5000 $\mathring{A}$ and now (n + 1)th bright fringe is obtained at the point P. Calculate the value of n. **[3]**

OR

What is the effect on the interference fringes in Young's double-slit experiment due to each of the following operations? Justify your answers.

i. The screen is moved away from the plane of the slits.

ii. The separation between slits is increased.

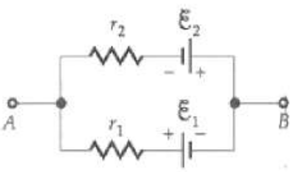
iii. The source slit is moved closer to the plane of double slit.

30. i. Name the machine which uses crossed electric and magnetic fields to accelerate the ions to high energies. With the help of a diagram, explain the resonance condition. **[3]**

ii. What will happen to the motion of the charged particle if the frequency of the alternating voltage is doubled?

Section D

31. Find the emf (ε_0) and internal resistance (r_0) of a battery which is equivalent to a parallel combination of two batteries of emfs ε_1 and ε_2 and internal resistances r_1 and r_2 respectively, with polarities as shown in the figure. **[5]**



OR

A dry cell of emf 1.5 V and internal resistance 0.10 Ω is connected across a resistor in series with a very low resistance ammeter. When the circuit is switched on, the ammeter reading settles to a steady value of 2.0 A What is the steady:

i. rate of chemical energy consumption of the cell,

ii. rate of energy dissipation inside the cell,

iii. rate of energy dissipation inside the resistor,

iv. power output of the source?

32. Determine the 'effective focal length' of the combination of the two lenses having focal lengths 30 cm and -20cm if they are placed 8.0 cm apart with their principal axes coincident. Does the answer depend on which side of the combination a beam of parallel light is incident? Is the notion of effective focal length of this system useful at all? **[5]**

OR

i. Draw a ray diagram showing the image formation by a compound microscope. Obtain the expression for total magnification when the image is formed at infinity.

ii. How does the resolving power of a compound microscope get affected, when

1. focal length of the objective is decreased.
2. the wavelength of light is increased ? Give reasons to justify your answer.

33. i. In the Rutherford scattering experiment, draw the trajectory traced by α-particles **[5]**

in the Coulomb field of the target nucleus and explain how this led to estimate the size of the nucleus.

ii. Describe briefly how the wave nature of moving electrons was established experimentally.

iii. Estimate the ratio of de-Broglie wavelengths associated with deuterons and a-particles when they are accelerated from rest^ through the same accelerating potential V.

OR

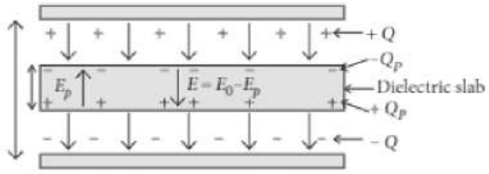
In the study of Geiger-Marsden experiment on scattering of a-particles by a thin foil of gold, draw the trajectory of α-particles in the coulomb field of target nucleus. Explain briefly how one gets the information on the size of the nucleus from this study.

From the relation $R = R_0 A^{\frac{1}{3}}$, where, R_0 is constant and A is the mass number of the nucleus, show that nuclear matter density is independent of A.

Section E

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

A dielectric slab is a substance which does not allow the flow of charges through it but permits them to exert electrostatic forces on one another. When a dielectric slab is placed between the plates, the field E_0 polarises the dielectric. This induces charge $-Q_p$ on the upper surface and $+Q_p$ on the lower surface of the dielectric. These induced charges set up a field E_p inside the dielectric in the opposite direction of $\vec{E}_0$ as shown.



(i) In a parallel plate capacitor, the capacitance increases from 4 μF to 80 μF, on introducing a dielectric medium between the plates. What is the dielectric constant of the medium?

(ii) A parallel plate capacitor with air between the plates has a capacitance of 8 pF. The separation between the plates is now reduced half and the space between them is filled with a medium of dielectric constant 5. Calculate the value of capacitance of the capacitor in second case.

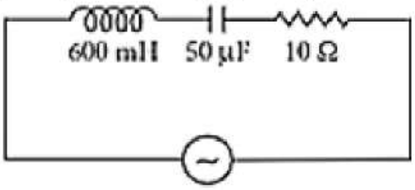
(iii) What happens to the charge and the electric field between the plates of capacitor on introducing the dielectric between the plates of capacitor?

OR

A parallel plate capacitor of capacitance 1 pF has separation between the plates is d. When the distance of separation becomes 2d and wax of dielectric constant x is inserted in it the capacitance becomes 2pF. What is the value of x?

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

In an a.c. circuit, values of voltage and current change every instant. Therefore, the power of an a.c. circuit at any instant is the product of instantaneous voltage (E) and instantaneous current (I). The average power supplied to a pure resistance R over a complete cycle of a.c. is P = $E_v I_\gamma$. When the circuit is inductive, the average power per cycle is $E_v I_v \cos\phi$



In an a.c. circuit, 600 mH inductor and a 50 μF capacitor are connected in series with 10 Ω resistance. The a.c. supply to the circuit is 230 V, 60 Hz.

(i) What will be the value of average power transferred per cycle to the resistance?

(ii) What will be the value of the average power transferred per cycle to the capacitor?

(iii) What will be the total power transferred per cycle by all three circuit elements?

OR

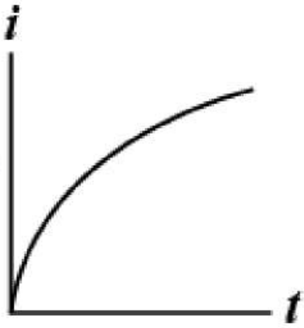
What will be the electrical energy spent in running the circuit for one hour?

SOLUTION

Section A

1. **(d)** A is false and R is also false
   Explanation: A is false and R is also false
2. **(c)** 40^{o}
   Explanation: Angle between incident and reflected ray = 80^{o}
   Angle of incidence = Angle of reflected ray = 40^{o}
   Angle of reflected ray with mirror = 90 - 40 = 50
   So, angle with horizontal = 90 - 50 = 40^{o}
3. **(b)** neutral
   Explanation: It should be neutral because 2, and 4 show attraction means have opposite charge 2 to show attraction with 1 means 1 and 4 should have the same charge but as they are showing attraction too then. 1 should be electrically neutral. Besides, it can be seen that ball 2 is positively charged then ball 4 is negatively charged because 2 and 4 show attraction. Now, ball if ball 2 is (+ve) charged then ball 3 is also (+ve) charged because 2 and 3 also show repulsion and similarly ball 5 is (−ve) charged because ball 4 and 5 show repulsion and we left with ball 1 and it never be (+ve) by charged because ball 2 and 1 show attraction it means ball 1 is negatively charging but it is also not possible because ball 1 and 4 also show attraction and in the end, we know that ball 1 is nor be positively or neither be negatively charged. It means be ball 1 has no charge so it must be neutral.
4. **(d)** indium
   Explanation: indium
5. **(c)** Intensity
   Explanation: Greater is the number of electrons striking the anode, larger will be the number of X-ray photons emitted. So, intensity of X-rays would increase.
6. **(c)** 54.77 V/m
   Explanation: The intensity of the electromagnetic wave is,
   $I=\frac{P_{\text{av}}}{2\pi r^2}=\frac{E_0^2}{\mu_0 C}$
   or $E_0=\sqrt{\frac{\mu_0 C P_{\text{av}}}{2\pi r^2}}$
   $=\sqrt{\frac{(4\pi\times10^{-7})(3\times10^{8})\times800}{2\pi\times(4)^2}}$
   = 54.77 V/m
7. **(a)** 3
   Explanation: Energy difference in hydrogen atom = 13.6 - $\frac{13.6}{n^2}$ = 12.09
   $\Rightarrow n^2 \approx 9$
   $\Rightarrow n = 3$

8. **(d)**



Explanation: add explanation here

9. **(d)** any closed surface

Explanation: Gauss's law is valid for any closed surface.

10. **(d)** acts like an insulating zone under reverse bias

Explanation: acts like an insulating zone under reverse bias

11. **(b)** 0.15 cm

Explanation: Position of 1st minima,

$y = \frac{D\lambda}{a} = \frac{5\times10^{-8}\times0.6}{0.02\times10^{-2}} = 0.15$ cm

12. **(d)** 5×10^{15}

Explanation: Power of laser is given as P = $\frac{\text{Energy}}{\text{Time}}$

$= \frac{\text{Number of photons emitted} \times \text{Energy of one photon}}{\text{Time}}$

$\Rightarrow \quad P = \frac{NE}{t} = \left(\frac{N}{t}\right) \cdot E$

So, number of photons emitted per second

$= \frac{N}{t} = \frac{P}{E}$

$= \frac{P}{hc/\lambda} = \frac{P\lambda}{hc}$ $[\because E = h\nu = \frac{hc}{\lambda}]$

Here, $h = 6.6 \times 10^{-34}$ J-s, $\lambda = 500$ nm $= 500 \times 10^{-9}$ m

$c = 3 \times 10^{8}$ ms^{-1}

$P = 2$ mW $= 2 \times 10^{-3}$ W

$\therefore \quad \frac{N}{t} = \frac{2\times10^{-3}\times500\times10^{-9}}{6.6\times10^{-34}\times3\times10^{8}}$

$= 5.56 \times 10^{15}$

$\approx 5 \times 10^{15}$ photons per second

13. **(b)** $\vec{E} \times \vec{B}$

Explanation: We know that;

The direction of propagation of the electromagnetic wave is perpendicular to the plane of oscillation of electric and magnetic field of the EM wave.

Thus,

If, $\vec{E}$ and $\vec{B}$ are electric and magnetic field vectors of the EM wave, the direction of its propagation will be given by $\vec{E} \times \vec{B}$

As in an EM wave, the vectors $\vec{E}$ and $\vec{B}$ are perpendicular to each other, the direction of the wave propagation will be perpendicular to the plane containing the electric and magnetic field vectors.

14. **(b)** decreases K times

Explanation: when air is replaced by dielectric medium, **electrostatic force** decreases by K times

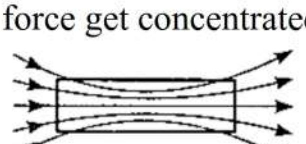
15. **(b)** 10 : 1

Explanation: 10 : 1

16. **(b)** Both A and R are true but R is not the correct explanation of A.
Explanation: Both A and R are true but R is not the correct explanation of A.
17. **(c)** A is true but R is false.
Explanation: A is true but R is false.
18. **(c)** different freezing and melting points
Explanation: different freezing and melting points

Section B

19. Since the motion is one dimensional, therefore,
   i. If the particles move in the same direction, momentum is given by ;-
   $|\overrightarrow{p_C}| = |\overrightarrow{p_A}| + |\overrightarrow{p_B}|$
   $\frac{h}{\lambda_C} = \frac{h}{\lambda_1} + \frac{h}{\lambda_2}$
   or $\lambda_C = \frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$
   ii. If the particles move in the opposite direction, momentum is given by :-
   $|\overrightarrow{p_C}| = |\overrightarrow{p_A}| - |\overrightarrow{p_B}|$
   $\frac{h}{\lambda_C} = \frac{h}{\lambda_1} - \frac{h}{\lambda_2}$
   or $\lambda_C = \frac{\lambda_1\lambda_2}{\lambda_1-\lambda_2}$
20. a. The atomic mass of the two isotopes are respectively given as 6.01512 u and 7.01600 u with have respective abundances of 7.5% and 92.5%.
   Hence the mass of Lithium can be given as,
   $M_{Li} = \frac{\text{Mass of 1 st isotope} \times \text{it ' s abundance} + \text{mass of 2 nd isotope} \times \text{it ' s abundance}}{\sum \text{of both the isotope ' s abundances}}$
   $= \frac{6.01512 \times 7.5 + 7.01600 \times 92.5}{100} = 6.9409$ u
   The mass of Lithium is given by = 6.9409 u
   b. The atomic mass of the two isotopes of Boron ($^{10}_{5}B$ and $^{11}_{5}B$) are given as 10.01294 u and 11.00931 u
   Let their abundances be respectively, x and (100 - x) percent.
   then,
   $10.811 = \frac{10.01294 \times x + 11.0931 \times (100 - x)}{100}$
   So, x = 19.89% and (100 - x) = 80.11%
   Hence the abundance of $^{10}_{5}B$ is 19.89% and that of $^{11}_{5}B$ is 80.11%
21. Though the p-type and n-type semiconductors have excess free electrons and holes respectively, yet they have an equal number of fixed positive donor ions and negative acceptor ions respectively. When a p-n junction is formed, electrons diffuse from n-region to p-region while holes diffuse from p-region to n-region. As a result, the n-region near the junction becomes increasingly positive and the p-region becomes increasingly negative. This sets up a potential barrier across the junction which opposes the further diffusion of electrons and holes across the junction. That is why all the electrons do not flow from n-region to p-region.
22. As the susceptibility has a small positive value, so the given material is paramagnetic in nature. When a piece of this material is placed in a uniform magnetic field, the lines of force get concentrated inside it as shown in the figure.

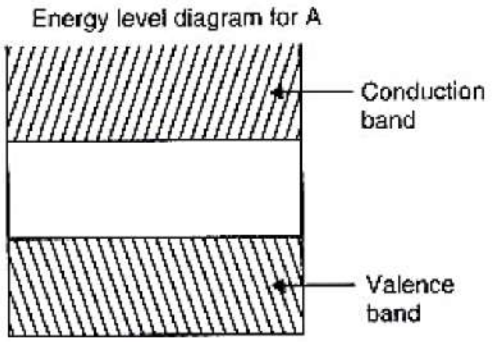


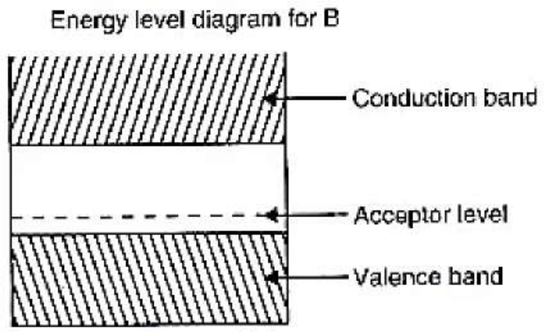
OR

Paramagnetic Substance	Diamagnetic Substance

Paramagnetic Substance	Diamagnetic Substance
A paramagnetic substance is feebly attracted by magnet.	A diamagnetic substance is feebly repelled by a magnet.
For a paramagnetic substance, the intensity of magnetization (I = M/V = magnetic moment/volume) has a small positive value. i.e. I = +ve Example - Aluminium, Chromium etc	For a diamagnetic substance, the intensity of magnetization has a small negative value. i.e. I = - ve Example - Antimony, Bismuth etc

23. A is intrinsic semiconductor and B is p-type semiconductor.

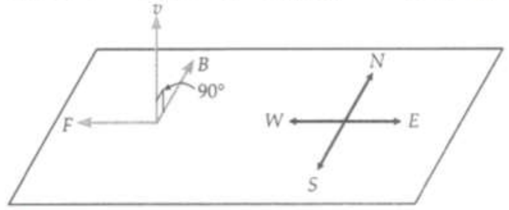




24. Charge on α-particle,

$q = +2e = 2 \times 1.6 \times 10^{-19}$ C

Here $v = 3 \times 10^4$ km $s^{-1} = 3 \times 10^7$ ms^{-1}, B = 1.0 T, $\theta = 90^o$.



Magnetic force on the α-particle is

$F = qvB \text{ Sin } \theta$

$= 2 \times 1.6 \times 10^{-19} \times 3 \times 10^7 \times 1.0 \times \sin 90^o$

$= 9.6 \times 10^{-12}$ N

According to Fleming's left-hand rule, the magnetic force on the α-particle acts towards the west.

OR

i. Torque on the loop

$\tau = MB\sin\theta$

As M and B are parallel to each other so θ=0

Therefore, $\tau = 0$

ii. Force acting on the loop is given by $|F| = \frac{\mu_0 I_1 I_2}{2\pi} l \left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

$= 2 \times 10^{-7} \times 2 \times 2 \times 10^{-1} \left(\frac{1}{10^{-2}} - \frac{1}{5 \times 10^{-2}}\right)$ N

$= \frac{8 \times 10^{-8}}{10^{-2}} \left(1 - \frac{1}{5}\right)$ N

$= 8 \times 10^{-6} \left(\frac{4}{5}\right)$ N

$= 6.4 \times 10^{-6}$N

Direction: Towards conductor/Attractive.

25. Here $\lambda = 5900\ \mathring{A} = 59 \times 10^{-8}$m, f = 50 cm = 0.50m, a = 0.025 mm = 2.5×10^{-5}m

For first dark band, $\sin\theta = \frac{\lambda}{a}$

As the diffraction pattern is obtained in the focal plane of the lens, therefore

$\tan\theta = \frac{x}{f}$

where x is the distance between the centre and the first dark band.

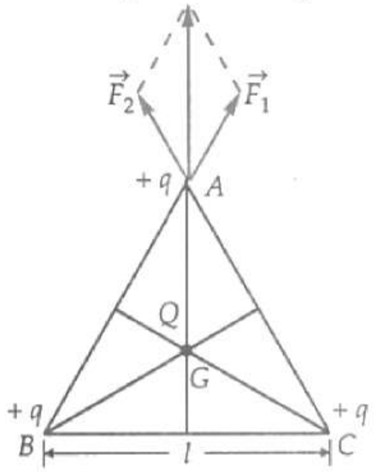
For small θ, $\tan\theta \simeq \sin\theta$ or $\frac{x}{f} = \frac{\lambda}{a}$

$\therefore x = \frac{\lambda}{a} \times f = \frac{59 \times 10^{-8} \times 0.50}{2.5 \times 10^{-5}}$

$= 11.8 \times 10^{-3}$m = 11.8 mm

Section C

26. At any vertex, the charge will be in equilibrium if the net electric force due to the remaining three charges is zero.



Let Q be the charge required to be kept at the centroid G. Then,

$\overrightarrow{F_1}$ = Force at A due to the charge at B

$= \frac{1}{4\pi\varepsilon_0} \frac{q^2}{l^2}$, along $\overrightarrow{BA}$

$\overrightarrow{F_2}$ == Force at A due to charge at C = $\frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{l^2}$, along $\overrightarrow{CA}$

$\vec{F}_1 + \vec{F}_2$ = 2F$_1$ cos 30^o, along $\overrightarrow{GA} = \sqrt{3} \cdot \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{l^2}$, along $\overrightarrow{GA}$

Force at A due to charge at G

$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{Qq}{AG^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Qq}{\left(\frac{l}{\sqrt{3}}\right)^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{3Qq}{l^2}$

This must be equal and opposite to $\left(\vec{F}_1 + \vec{F}_2\right)$

$\therefore 3Qq = -\sqrt{3}q^2$ or $Q = -\frac{q}{\sqrt{3}}$

27. a. When a dipole is rotated from 1 position to other position 2 in a uniform magnetic field, Workdone, W = mB(cos θ_1 - cos θ_2)

(i) Here $\theta_1 = 60^o, \theta_2 = 90^o$

$\therefore$ Workdone, W = mB(cos 60^o - cos 90^o)

$= mB(\frac{1}{2} - 0) = \frac{1}{2}mB$

$= \frac{1}{2} \times 6 \times 0.44 = 1.32$ J

(ii) Here $\theta_1 = 60^o, \theta_2 = 180^o$

$\therefore$ Workdone, W = mB(cos 60^o - cos 180^o)

$= mB[\frac{1}{2} - (-1)] = \frac{3}{2}mB$

$= \frac{3}{2} \times 6 \times 0.44 = 3.96$ J

b. Torque, $\tau = |\vec{m} \times \overline{B}|$ = mB sinθ

For $\theta = 180^o$, we have

Torque, $\tau = 6 \times 0.44 \sin 180^o = 0$

28.

S.No.	Type of wave	Applications
(i)	Gamma rays	Treatment of tumors
(ii)	Radio waves	Radio and television Communication system
(iii)	X-rays	Study of crystals , **X-ray** therapy to destroy diseased cells.

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.

29. Let x be the distance of point P from the centre of the screen.

When red light ($\lambda = 6000 \overset{\circ}{A}$) is used, nth bright fringe is obtained at point P

$\therefore \quad x = \frac{nD\lambda}{d} = \frac{nD \times 6000 \times 10^{-10}}{d}$

When green light ($\lambda' = 5000 \overset{\circ}{A}$) is used, (n + 1)th bright fringe is obtained at the same point P

$\therefore \quad x = \frac{(n+1)D\lambda'}{d} = \frac{(n+1)D \times 5000 \times 10^{-10}}{d}$

Equating the two values of x, we get

$\frac{nD \times 6000 \times 10^{-10}}{d} = \frac{(n+1)D \times 5000 \times 10^{-10}}{d}$

or 6n = 5(n + 1)

or n = 5

OR

i. D is Distance between screen to slits, d is distance between the slits, λ is wavelength

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

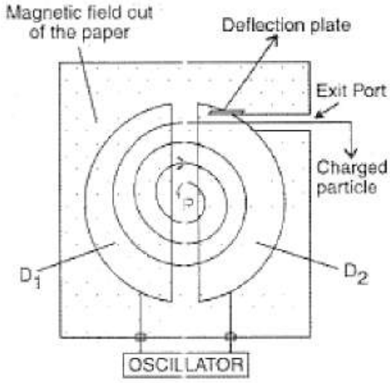
Since $\beta \propto D$, the fringe width will increase, as screen is moved away.

ii. $\beta \propto \frac{1}{d}$, therefore fringe width will decrease as the separation between slits is increased.

iii. Let s be the width of the source slit and S its distance from plane of two slit. For interference fringes to be distinctly seen, the condition

$\frac{s}{S} < \frac{\lambda}{d}$
should be satisfied, otherwise, the interference patterns produced will overlap.

30. i. cyclotron: it accelerates charged particles or ions.



Construction: The cyclotron is made up of two hollow semi-circular discs like metal containers, D_1 and D_2 called dees.

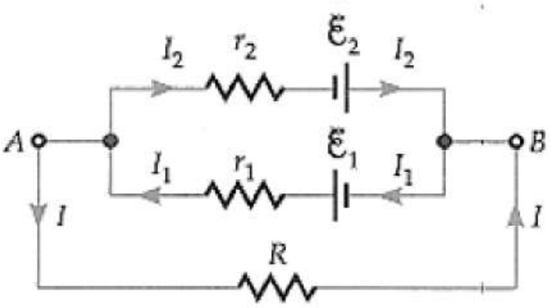
It uses crossed electric and magnetic fields. The electric field is provided by an oscillator of adjustable frequency.

Working: In a cyclotron, the frequency of the applied alternating field is adjusted to be equal to the frequency of revolution of the charged particles in the magnetic field. This ensures that the particles get accelerated every time, they cross the space between the two dees. The radius of their path increases with an increase in energy and they are finally made to leave the system via an exit slit.

ii. The particle will accelerate and deaccelerate alternately. However, the radius of the path remains unchanged.

Section D

31. Suppose we connect a resistance R between points A and B. Then the circuit will be of the form as shown in the figure.



Applying Kirchhoff's first law at junction A,

$I = I_1 - I_2$ ...(i)

Applying Kirchhoff's second law,

$\varepsilon_1 = I_1r_1 + IR$

or $IR = \varepsilon_1 - I_1r_1$ ...(ii)

and $\varepsilon_2 = Ir_2 - IR$

or $IR = -\varepsilon_2 + I_2r_2$ ...(iii)

From (i) and (iii),

$IR = -\varepsilon_2 + (I_1 - I)I_2$

or $I(R + r_2) = -\varepsilon_2 + I_1r_2$

Multiplying (ii) by r_2 and (iv) by r_1, and on adding, we get

$IRr_2 + I(R + r_2)r_1 = \varepsilon_1 r_2 - \varepsilon_2 r_1$

or $I = \frac{\varepsilon_1 r_2 - \varepsilon_2 r_1}{R(r_1 + r_2) + r_1 r_2}$

$= \frac{(\varepsilon_1 r_2 - \varepsilon_2 r_1)/(r_1+r_2)}{R + \frac{r_1 r_2}{r_1+r_2}} = \frac{\varepsilon_0}{R+r_0}$

Clearly,

$\varepsilon_0 = \frac{\varepsilon_1 r_2 - \varepsilon_2 r_1}{r_1 + r_2}$ = emf of the battery required and $r_0 = \frac{r_1 r_2}{r_1 + r_2}$

= internal resistance of the battery required.

OR

Here ε = 1.5 V, r = 0.10 Ω, I = 2.0 A

i. Rate of chemical energy consumption of the cell
 $= \varepsilon I = 1.5\ V \times 2.0\ A = 3.0\ W$

ii. Rate of energy dissipation inside the cell
 $= I^2 r = (2)^2 \times 0.10\ W = 0.40\ W.$

iii. Rate of energy dissipation inside the resistor
 $= \varepsilon I - I^2 r = 3.0 - 0.40 = 2.6\ W.$

iv. Power output of the source
 = Power input to the external circuit
 $= \varepsilon I - I^2 r = 2.6\ W$

32. Here, f_1 = 30 cm, f_2 = -20 cm, d = 8.0 cm

Let a parallel beam be incident on the convex lens first. If second lens were absent, then

$\therefore u_1 = \infty$ and f_1 = 30 cm

As $\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$

$\therefore \frac{1}{v_1} - \frac{1}{\infty} = \frac{1}{30}$

or v_1 = 30 cm

This image would now act as virtual object for second lens.

$\therefore u_2 = +(30 - 8) = +22$ cm

f_2 = -20 cm

Since, $\frac{1}{v_2} = \frac{1}{f_2} + \frac{1}{u_2}$

$\therefore \frac{1}{v_2} = \frac{1}{-20} + \frac{1}{22}$

$= \frac{-11+10}{220} = \frac{-1}{220}$

v_2 = -220 cm

$\therefore$ Parallel incident beam would appear to diverge from a point 220 - 4 = 216 cm from the centre of the two lens system.

Assume that a parallel beam of light from the left is incident first on the concave lens.

$\therefore u_1 = -\infty$, f_1 = -20 cm

As $\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$

$\therefore \frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{u_1} = \frac{1}{-20} + \frac{1}{-\infty} = -\frac{1}{20}$

v_1 = -20cm

This image acts as a real object for the second lens

$u_2 = -(20 + 8) = -28$cm, f_2 = 30 cm

Since, $\frac{1}{v_2} - \frac{1}{u_2} = \frac{1}{f_2}$

$\therefore \frac{1}{v_2} = \frac{1}{f_2} + \frac{1}{u_2} = \frac{1}{30} - \frac{1}{28} = \frac{14-15}{420}$

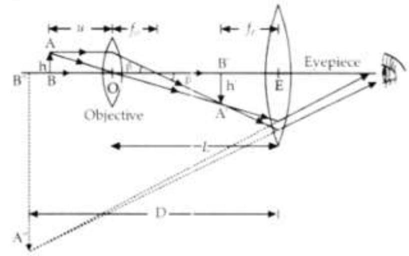
v_2 = -420 cm

The parallel beam appears to diverge from a point 420 - 4 = 416 cm, on the left of the centre of the two lens system.

We finally conclude that the answer depends on the side of the lens system where the parallel beam is incident. Therefore, the notion of effective focal length does not seem to be meaningful here.

OR

i. The ray diagram, showing image formation by a compound microscope, is given below ;-



ii. Linear Magnification due to objective lens is given by $= \frac{\tan\beta}{\tan\alpha}$

$\tan\beta = \frac{h'}{L} = \frac{h}{f_o}$

$\frac{h'}{h} = \frac{L}{f_0}$

(where the distance between the second focal point of the objective and the first focal point of the eyepiece is called the tube length of the compound microscope and is denoted by L) The eyepiece will act as a simple microscope, hence we may use the formula of magnification by a simple microscope for normal adjustment.

$m_e = \frac{D}{f_e}$

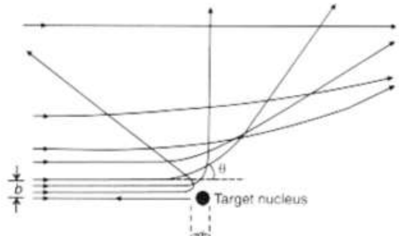
Total magnification, $m = m_o \times m_e$

$= \frac{L}{f_o} \times \frac{D}{f_e} d_{\min}$

a. From the equation, it is clear that resolving power increases when the focal length of the objective is decreased. This is because the minimum separation, d_{min} decreases when f is decreased.

b. Resolving power decreases when the wavelength of light is increased. This is because the minimum separation, d_{min} increases when λ is increased.

33. i. The trajectory, traced by the α-particles in the Coulomb field of target nucleus, has the form shown below.



The size of the nucleus was estimated by observing the distance (d) of closest approach, of the α-particles. This distance is given by :

$d = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2eZe}{K}$

where, K = kinetic energy of the a-particles when they are far away from the target nuclei.

ii. The wave nature of moving electrons was established through the Davisson-Germer experiment.

In this experiment, it was observed that a beam of electrons, when scattered by a nickel target, showed 'maxima' in certain directions.

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

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

$\lambda = \frac{h}{\sqrt{2mqV}}$

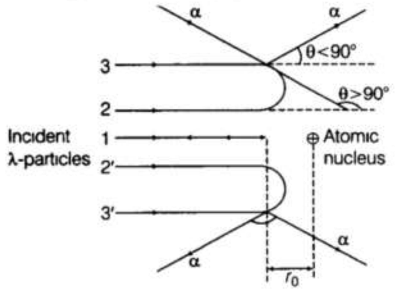
Hence $\frac{\lambda_d}{\lambda_\alpha} = \sqrt{\frac{m_a q_\alpha}{m_d q_d}}$

(accelerated potential is same for both particles)

$\frac{\lambda_d}{\lambda_\alpha} = \sqrt{\frac{4\times2}{2\times1}} = 2$

OR

Trajectory of an α-particles in the Coulomb field of the target nucleus is given below as



From this experiment, the following is observed.

i. Most of the α-particles pass straight through the gold foil. It means that they do not suffer any collision with gold atoms.

ii. About one α-particle in every 8000 α-particles deflects by more than 90°. As most of the α-particles go undeflected and only a few get deflected, this shows that most of the space in an atom is empty and at the centre of the atom, there is a heavy mass, which is most commonly known as nucleus. Thus, with the help of these observations regarding the deflection of a-particles, the size of the nucleus was predicted.

If m is the average mass of the nucleon and R is the nuclear radius, then mass of nucleus = mA, where A is the mass number of the element.

The volume of the nucleus, $V = 4/3\pi R^3$

$\Rightarrow \quad V = \frac{4}{3}\pi\left(R_0 A^{1/3}\right)^3 \Rightarrow V = \frac{4}{3}\pi R_0^3 A$

Density of nuclear matter

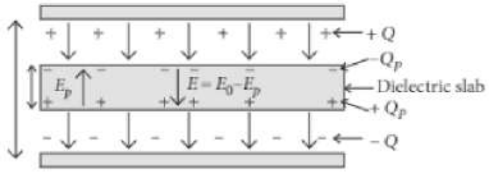
$\rho = \frac{mA}{V} \Rightarrow \rho = \frac{mA}{4/3\pi R_0^3 \cdot A} \Rightarrow \rho = \frac{3m}{4\pi R_0^3}$

This shows that the nuclear density in independent of mass number A.

Section E

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

A dielectric slab is a substance which does not allow the flow of charges through it but permits them to exert electrostatic forces on one another. When a dielectric slab is placed between the plates, the field E_0 polarises the dielectric. This induces charge -Q_p on the upper surface and +Q_p on the lower surface of the dielectric. These induced charges set up a field E_p inside the dielectric in the opposite direction of $\vec{E}_0$ as shown.



(i) 20

$k = \frac{\text{Capacitance with dielectric}}{\text{Capacitance without dielectric}}$

$= \frac{80\mu F}{4\mu F} = 20$

(ii) 80 pF

Capacitance of the capacitor with air between plates

C' = $\frac{\varepsilon_0 A}{d}$ = 8 pF

With the capacitor is filled with dielectric (k = 5) between its plates and the distance between the plates is reduced by half, capacitance become

C = $\frac{\varepsilon_0 kA}{d/2} = \frac{\varepsilon_0 \times 5 \times A}{d/2}$ = 10 C' = 10 × 8 = 80 pF

(iii) increases the capacity of the condenser,

If a dielectric medium of dielectric constant K is filled completely between the plates then capacitance increases by K times.

OR

4

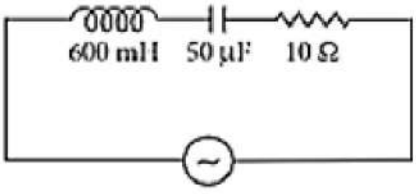
C = $\frac{\varepsilon_0 A}{d}$ = 1pF ...(i)

C' = $\frac{x\varepsilon_0 A}{(2d)}$ = 2pF ....(ii)

Divide (ii) by (i), $\frac{x}{2} = \frac{2}{1} \Rightarrow$ x = 4

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

In an a.c. circuit, values of voltage and current change every instant. Therefore, the power of an a.c. circuit at any instant is the product of instantaneous voltage (E) and instantaneous current (I). The average power supplied to a pure resistance R over a complete cycle of a.c. is P = $E_v I_\gamma$. When the circuit is inductive, the average power per cycle is $E_v I_v \cos\phi$



In an a.c. circuit, 600 mH inductor and a 50 μF capacitor are connected in series with 10 Ω resistance. The a.c. supply to the circuit is 230 V, 60 Hz.

(i) Average power transferred per cycle to resistance is $P_v = I_v^2 R$

As $X_L = \omega L = 2\pi\nu L = 2 \times \frac{22}{7} \times 60 \times 0.6$ = 226.28 Ω

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C} = \frac{7}{2\times 22/7\times 60\times 50\times 10^{-6}}$

= 53.03 Ω

$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(10)^2 + (226.28 - 53.03)^2}$ = 173.53 Ω

$I_V = \frac{E_v}{Z} = \frac{230}{173.53}$ = 1.32 A

$P_V = I_v^2 R = (1.32)^2 \times 10$ = 17.42 W

(ii) $P_L = E_v I_v \cos\phi$

In a capacitor, phase difference, $\phi = 90^o$

$P_L = E_v I_v \cos 90^\circ$ = zero

(iii) Total power absorbed per cycle P = $P_R + P_C + P_L$ = 17.42 + 0 + 0 = 17.42 W

OR

Energy spent = power × time

= 17.42 × 60 × 60 = 6.2 × 10^4 Joule