Class-XII
Session - 2022-23
Subject - Physics (Theory)
Sample Question Paper - 37
With Solution

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Ch. No.	Chapter Name	Per Unit Marks	Section-A MCQs 1 Mark	Section-B SA 2 Marks	Section-C LA-I 3 Marks	Section-D LA-II 5 Marks	Section-E Case Study 4 Marks	Total Marks
1	Electric Charges and Fields	16	2 (Q. 1, 2)		1 (Q. 29)			5
2	Electrostatic Potential and Capacitance		2 (Q. 3, 17)	1 (Q. 20)				4
3	Current Electricity		2 (Q. 4, 5)	1 (Q. 19)	1 (Q. 27)			7
4	Moving Charges and Magnetism	17	2 (Q. 6, 7)			1 (Q. 31)		7
5	Magnetism and Matter		1 (Q. 8)					1
6	Electromagnetic Induction		1 (Q. 18)		1 (Q.26)			4
7	Alternating Current		2 (Q. 9, 16)		1 (Q.28)			5
8	Electromagnetic Waves	18	1 (Q. 11)	1 (Q. 21)				3
9	Ray optics and Optical Instruments		3 (Q.12, 13, 14)	2 (Q. 22, 25)				7
10	Wave Optics		1 (Q. 15)	1 (Q. 23)		1 (Q. 33)		8
11	Dual Nature of Radiation and Matter	12				1 (Q. 32)		5
12	Atoms						1 (Q. 34)	4
13	Nuclei				1 (Q. 30)			3
14	Semiconductor Electronics: Materials, Devices and Simple Circuits	7	1 (Q.10)	1 (Q. 24)			1 (Q. 35)	7
	Total Marks (Total Questions)		**18 (18)**	**14 (7)**	**15 (5)**	**15 (3)**	**8 (2)**	**70 (35)**

NOTE : The number given inside the bracket denotes question number, ask in the sample paper, while the number given outside the bracket are the number of questions from that particular chapter.

Time Allowed : 3 Hours **Max. 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. Two point charges placed in a medium of dielectric constant 5 are at a distance r between them, experience an electrostatic force 'F'. The electrostatic force between them in vacuum at the same distance r will be-

(a) 5F (b) F (c) F/2 (d) F/5

2. When an electric dipole $\overline{P}$ is placed in a uniform electric field $\overline{E}$ then at what angle between $\overline{P}$ and $\overline{E}$ the value of torque will be maximum?

(a) 90° (b) 0° (c) 180° (d) 45°

3. From a point charge, there is a fixed point A. At A, there is an electric field of 500 V/m and potential difference of 3000 V. Distance between point charge and A will be

(a) 6m (b) 12m (c) 16m (d) 24m

4. Resistance of conductor is doubled keeping the potential difference across it constant. The rate of generation of heat will

(a) become one fourth (b) be halved

(c) be doubled (d) become four times

5. A wire of a certain material is stretched slowly by ten per cent. Its new resistance and specific resistance become respectively:

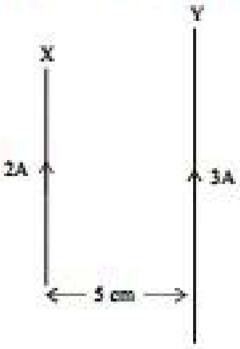
(a) 1.2 times, 1.3 times (b) 1.21 times, same

(c) both remain the same (d) 1.1 times, 1.1 times

6. A coil of one turn is made of a wire of certain length and then from the same length a coil of two turns is made. If the same current is passed in both the cases, then the ratio of the magnetic inductions at their centres will be

(a) 2 : 1 (b) 1.4 (c) 4 : 1 (d) 1 : 2

7. A wire X of length 50 cm carrying a current of 2 A is placed parallel to a long wire Y of length 5 m. The wire Y carries a current of 3 A. The distance between two wires is 5 cm and currents flow in the same direction. The force acting on the wire Y is :



(a) 1.2×10^{-5} N directed towards wire X.

(b) 1.2×10^{-4} N directed away from wire X.

(c) 1.2×10^{-4} N directed towards wire X.

(d) 2.4×10^{-5} N directed towards wire X.

8. Among which of the following the magnetic susceptibility does not depend on the temperature?

(a) Dia-magnetism (b) Para-magnetism (c) Ferro-magnetism (d) Ferrite

9. An alternating voltage $V = V_0 \sin \omega t$ is applied across a circuit. As a result, a current $I = I_0 \sin (\omega t - \pi/2)$ flows in it. The power consumed per cycle is

(a) zero (b) $0.5\, V_0I_0$ (c) $0.707\, V_0I_0$ (d) $1.414\, V_0I_0$

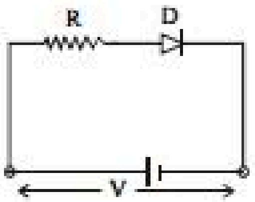
10. A d.c. battery of V volt is connected to a series combination of a resistor R and an ideal diode D as shown in the figure below. The potential difference across R will be

(a) 2V when diode is forward biased

(b) zero when diode is forward biased

(c) V when diode is reverse biased

(d) V when diode is forward biased



11. The electromagnetic waves

(a) travel with the speed of sound
(b) travel with the same speed in all media
(c) travel in free space with the speed of light
(d) do not travel through a medium

12. Magnifying power of an objective of a compound microscope is 8. If the magnifying power of microscope is 32 then magnifying power of eye piece is

(a) 7 (b) 5 (c) 4 (d) 3

13. A ray of light travelling inside a rectangular glass block of refractive index $\sqrt{2}$ is incident on the glass-air surface at an angle of incidence of 45°. The refractive index of air is one. Under these conditions the ray will

(a) emerge into the air without any deviation
(b) be reflected back into the glass
(c) be absorbed
(d) emerge into the air with an angle of refraction equal to 90°

14. Which of the following is incorrect statement?

(a) the magnification produced by a convex mirror is always less than one
(b) a virtual, erect, same-sized image can be obtained using a plane mirror
(c) a virtual, erect, magnifield image can be formed using a concave mirror
(d) a real, inverted, same-sized image can be formed using a convex mirror

15. A slit of width a is illuminated by red light of wavelength 6500 Å. If the first minimum falls at $\theta = 30°$, the value of a is

(a) 6.5×10^{-4} mm (b) 1.3 micron (c) 3250 Å (d) 2.6×10^{-4} cm

For question numbers 16, 17 and 18, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

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

16. **Assertion (A) :** A capacitor blocks direct current in the steady state.
Reason (R) : The capacitive reactance of the capacitor is inversely proportional to frequency f of the source of emf.

17. **Assertion (A) :** For a charged particle moving from point P to point Q, the net work done by an electrostatic field on the particle is independent of the path connecting point P to point Q.
Reason (R) : The net work done by a conservative force on an object moving along a closed loop is zero.

18. **Assertion (A) :** Lenz's law violates the principle of conservation of energy.
Reason (R) : Induced emf always opposes the change in magnetic flux responsible for its production.

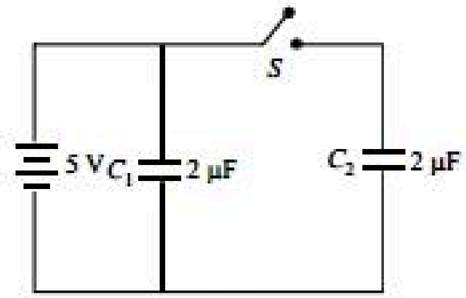
SECTION-B

19. Consider n cells connected in series in a row and m such rows connected in parallel. Obtain an expression for the maximum current from such a combination.

OR

Draw a graph showing the variation of resistivity with temperature for nichrome. Which property of nichrome is used to make standard resistance coils ?

20. Figure shows two identical capacitors C_1 and C_2, each of 2 μF capacitance, connected to a battery of 5V. Initially switch ‘S’ is closed. After some time S is left open and dielectric slabs of dielectric constant $K = 5$ are inserted to fill completely the space between the plates of the two capacitors. How will the (i) charge and (ii) potential difference between the plates of the capacitors be affected after the slabs are inserted?



OR

Net capacitance of three identical capacitors in series is 1 μ*F*. What will be their net capacitance if connected in parallel? Find the ratio of energy stored in the two configurations if they are both connected to the same source.

21. Identify the part of the electromagnetic specturm which is :

(a) suitable for radar system used in aircraft navigation.

(b) produced by bombarding a metal target by high speed electrons.

22. Derive the relation, $\delta = \left(n_{12} - 1\right) A$.

23. What is the shape of the wavefront in each of the following cases;

(a) Light diverging from a point source.

(b) Light emerging out of a convex lens when a point source is placed at its focus.

(c) The portion of the wavefront of light from a distant star intercepted by the Earth.

24. A student wants to use two p-n junction diodes to convert alternating current into direct current. Draw the labelled circuit diagram she would use and explain how it works.

OR

In an intrinsic semiconductor, explain how current flow takes place.

25. A convex lens of focal length 20 cm and a concave lens of focal length 5 cm are kept along the same axis with a separation 'd' between them. What is the value of d, if a parallel beam of light incident on convex lens, leaves the concave lens as a parallel beam?

SECTION-C

26. Derive the formula for the self-inductance of a long solenoid.

27. A battery of emf E and internal resistance r when connected across an external resistance of 12 ohm produces a current of 0.5 A. When connected across a resistance of 25 ohm it produces a current of 0.25 A. Determine the (i) emf and (ii) internal resistance of the cell.

OR

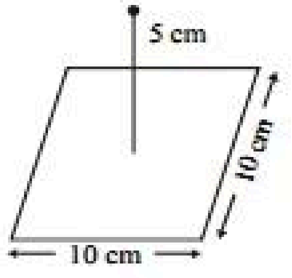
Write a relation between current and drift velocity of electrons in a conductor. Use this relation to explain how the resistance of a conductor changes with the rise in temperature.

28. Derive an expression for the root mean square value (R.M.S.) of an alternating current.

OR

Derive an expression for the a.c. across a resistance R connected to an alternating source of e.m.f. $E = E_0 \sin \omega t$. Explain the variations of e.m.f. and current graphically and with a phasor diagram.

29. A point charge +10 μC is at a distance 5 cm directly above the centre of a square of side 10 cm, as shown in Fig. What is the magnitude of the electric flux through the square? (Hint: Think of the square as one face of a cube with edge 10 cm.)



30. (a) Two stable isotopes of lithium ${}^{6}_{3}\text{Li}$ and ${}^{7}_{3}\text{Li}$ 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.

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

SECTION-D

31. Derive an expression for the torque on a rectangular coil of area A, carrying a current I placed in a magnetic field B. The angle between the direction of B and the vector perpendicular to the plane of the coil is α.

OR

Deduce an expression for the frequency of revolution of a charged particle in a magnetic field and show that it is independent of velocity or energy of the particle.

32. Define the terms 'cut-off voltage' and 'threshold frequency' in relation to the phenomenon of photoelectric effect.

Using Einstein's photoelectric equation show how the cut-off voltage and threshold frequency for a given photosensitive material can be determined with the help of a suitable plot/graph.

OR

A proton and a deuteron are accelerated through the same accelerating potential. Which one of the two has

(a) greater value of de-Broglie wavelength associated with it, and

(b) less momentum?

Give reasons to justify your answer.

33. (a) In Young's double-slit experiment, monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ is K units. What is the intensity of light at a point where path difference is $\frac{\lambda}{3}$?

(b) In double-slit experiment using light of wavelength 600 nm, the angular width of a fringe formed on a distant screen is 0.1°. What is the spacing between the two slits?

OR

A beam of light consisting of two wavelengths, 650 nm and 520 nm is used to obtain interference fringes in a Young's double-slit experiment.

(a) Find the distance of the third bright fringe on the screen from the central maximum for wavelength 650 nm.

(b) What is the least distance from the central maximum where the bright fringes due to both wavelengths coincide?

SECTION-E

34. Case Study: Energy Levels of Hydrogen Atom

Read the following paragraph and answer the questions.

In a mixture of H-He$^+$ gas (He$^+$ is singly ionized He atom), H atoms and He$^+$ ions are excited to their respective first excited states. Subsequently, H atoms transfer their total excitation energy to He$^+$ ions (by collisions). Assume that the Bohr model of atom is exactly valid.

(i) Find the quantum number n of the state finally populated in He$^+$ ions.

(ii) Find the wavelength of light emitted in the visible region by He$^+$ ions after collisions with H atoms.

(iii) Find the ratio of the kinetic energy of the n = 2 electron for the H atom to that of He$^+$ ion.

OR

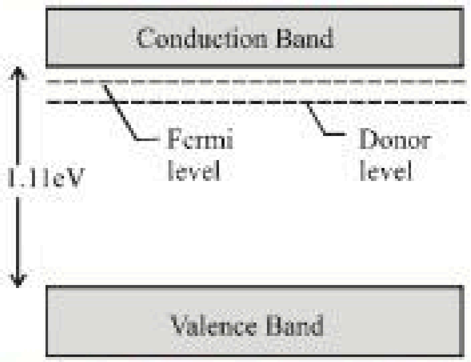
(iii) In a hydrogen atom following the Bohr's postulates the product of linear momentum and angular momentum is proportional to $(n)^x$ where 'n' is the orbit number. Find the value of 'x'.

35. Case Study: Energy Band Theory of Solids

Read the following paragraph and answer the questions.

Doping changes the fermi energy of a semiconductor. Consider silicon, with a gap of 1.11 eV between the top of the valence bond and the bottom of the conduction band. At 300K the Fermi level of the pure material is nearly at the midpoint of the gap.

Suppose that silicon is doped with donor atoms, each of which has a state 0.15 eV below the bottom of the silicon conduction band, and suppose further that doping raises the Fermi level to 0.11 eV below the bottom of that band.



(i) What is the ratio of number of conduction electrons to the number of holes in intrinsic semiconductor?

(ii) Name the impurity which is added to a pure silicon to make it a p-type semiconductor.

(iii) How does the conductance of a semiconducting material change when an impurity is doped into an intrinsic semiconductor

OR

(iii) In full wave rectification, if the input frequency is 60 Hz, then find the output frequency.

Solutions

SAMPLE PAPER-10

1. (a) $Q_1 \underset{r}{\rule{3cm}{0.5pt}} Q_2$ $K = 5$ $\qquad F = \frac{1}{4\pi\varepsilon_0 k}\frac{Q_1Q_2}{r^2}$

$Q_1 \underline{\hspace{3cm}} Q_2$ force in the charges in the air is

$F' = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2} = K\,F = 5\,F$ (1 mark)

2. (a) Torque, $\tau = \rho E \sin\theta$
$\tau = \rho E \sin 90°$
$= \rho E$ (Maximum) (1 mark)

3. (a) $E = 500$ V/m $\quad V = 3000$ V.
We know that electric field $(E) = 500 = \frac{V}{d}$

or $d = \frac{3000}{500} = 6\text{m}$ (1 mark)

4. (b) The rate of generation of heat, for a given potential difference is, $P = V^2/R$ (1 mark)

5. (b) Resistance of a wire is given by $R = \rho\frac{l}{a}$
If the length is increased by 10% then new length $l' = l + \frac{1}{10} = \frac{11}{10}l$
In that case, area of cross-section of wire would decrease by 10%
∴ New area of cross-section

$A' = A - \frac{A}{10} = \frac{9}{10}A \qquad \therefore R' = \rho\frac{\ell'}{A'} = \rho\frac{\frac{1}{10}l}{\frac{9}{10}A}$

$R' = \frac{11}{9}\rho\frac{l}{R} \qquad R' = 1.21R$

Thus the new resistance increases by 1.21 times. The specific resistance (resistivity) remains unchanged as it depends on the nature of the material of the wire.(1 mark)

6. (b) Let ℓ be length of wire

Ist case : $\ell = 2\pi r \Rightarrow r = \frac{\ell}{2\pi}$

$B = \frac{\mu_0 I}{2\pi r} = \frac{\mu_0 I}{\ell}$

2nd Case : $\ell = 2(2\pi r') \Rightarrow r' = \frac{\ell}{4\pi}$

$B' = \frac{\mu_0 I n}{2\pi\frac{\ell}{4\pi}} = \frac{2\mu_0 I}{\frac{\ell}{2}}$ (where n = 2)

on putting the value of B $\Rightarrow B' = 4\left(\frac{\mu_0 I}{l}\right) = 4B$ (1 mark)

7. (a) Given, length of wire X, $\ell_1 = 50$ cm $= 0.5$ m
Length of wire Y, $\ell_2 = 5$m
Distance between two wire, $r = 5$ cm $= 5 \times 10^{-2}$ m
Force of interaction $= I_1\,\ell_1\,B_{12}$

$= \frac{\mu_0 I_1 I_2}{2\pi r} \quad \left(\therefore B_{12} = \frac{\mu_0 I_2}{2\pi r}\right)$

$= \frac{4\pi\times10^{-7}\times6\times0.5}{2\pi\times5\times10^{-2}} = 1.2\times10^{-5}$ towards X (1 mark)

8. (a) Diamagnetic substance do not obey Curie's law and χ_m is independent of T. (1 mark)

9. (a) The phase angle between voltage V and current I is $\pi/2$. Therefore, power factor $\cos\phi = \cos(\pi/2) = 0$. Hence the power consumed is zero. (1 mark)

10. (d) In forward biasing, the diode conducts. For ideal junction diode, the forward resistance is zero; therefore, entire applied voltage occurs across external resistance R *i.e.*, there occur no potential drop, but potential across R is V in forward biased. (1 mark)

11. (c) The electromagnetic waves of all wavelengths travel with the same speed in space which is equal to velocity of light. (1 mark)

12. (c) Let magnifying power of eye and objective is m_e and m_0. therefore, $m = m_0 \times m_e \Rightarrow 32 = 8 \times m_e$
$\Rightarrow m_e = 4$ (1 mark)

13. (d) $\sin C = \frac{1}{\mu} = \frac{1}{\sqrt{2}} \qquad \therefore C = \sin^{-1}\left(\frac{1}{\sqrt{2}}\right) = 45°$

Now $\frac{\sin C}{\sin r} = \frac{1}{\mu}$ or $\frac{\sin 45°}{\sin r} = \frac{1}{\sqrt{2}}$
$\sin r = 1$ or $r = 90°$ (1 mark)

14. (d) Convex mirror always forms, virtual, erect and smaller image. (1 mark)

15. (b) According to principle of diffraction, $a \sin\theta = n\lambda$
where, n = order of secondary minimum
or, $a \sin 30° = 1 \times (6500 \times 10^{-10})$
or, $a = 1.3 \times 10^{-6}$ m, or, a = 1.3 micron. (1 mark)

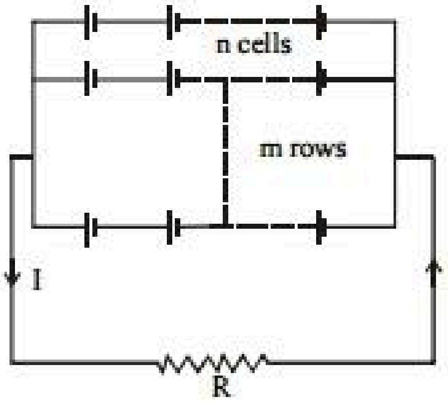
16. (b) Capacitive reactance $= \frac{1}{\omega c} = \frac{1}{2\pi fc}$

Here, f = frequency of source of emf
For direct current, $f = 0$
∵ capacitive reactance = ∞ (1 mark)

17. (b) Assertion (A) is true. Reason (R) is true and is the correct explanation of Assertion (A). (1 mark)

18. (a) Lenz's law (that the direction of induced emf is always such as to oppose the change that cause it) is direct consequence of the law of conservation of energy. (1 mark)

19. Total e.m.f = nE, Total resistance = $R + \frac{nr}{m}$



[∵ Total internal resistance

$$\frac{1}{r_p} = \frac{1}{nr} + \frac{1}{nr} + \text{.......... m times} = \frac{m}{nr} \;\therefore r_p = \frac{nr}{m}\Bigg]$$

$$\therefore \quad \text{Current} = I = \frac{nE}{R + \frac{nr}{m}} \Rightarrow I = \frac{mnE}{mR + nr}$$

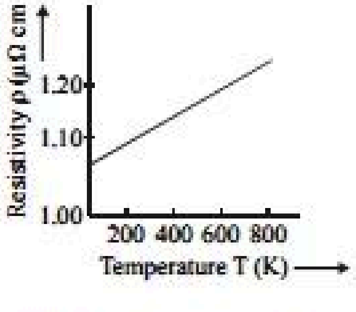
I will be maximum if mR + nr is minimum. (1 mark)

That is possible if mR = nr i.e. $R = \frac{nr}{m}$

i.e. External resistance of the circuit = Total internal resistance of all the cells. (1 mark)

OR

Graph of variation of resistivity with temperature for nichrome



(1 mark)

Property of nichrome used to make standard resistance coils : Its low temperature coefficient of resistance. (1 mark)

20. Two identical capacitors C_1 and C_2 gets fully charged with 5V battery initially.

So, the charge and potential difference on both capacitors becomes

$q = CV = 2 \times 10^{-6} \times 5\text{V} = 10\ \mu\text{C}$

and $V = 5\text{V}$

On introduction of dielectric medium of $K = 5$. (1 mark)

For C_1 (Continue to be connected with battery) potential difference of C_1, $(V') = 5\text{V}$

Capacitance of $C_1' = KC = 5 \times 2\mu\text{F} = 10\ \mu\text{F}$

Charge $q' = C'V; = (10\ \mu\text{F})(5\ \text{V}) = 50\ \mu\text{C}$ (½ mark)

For C_2 (Disconnected with battery)

Charge $q' = q = 10\ \mu\text{C}$

Potential difference

$$V'' = \frac{V}{K} = \frac{5}{5} = 1\ \text{V}$$ (½ mark)

OR

In series combination,

$$C_s = \frac{C}{n}$$

In parallel combination,

$\Rightarrow \quad C_p = nC$

According to problem,

$C = nC_s = 3 \times 1\mu F = 3\mu F$

In parallel combination,

$$C_p = nC = 3 \times 3 = 9\mu F$$

$C_p = 9\mu\text{F}$ (1 mark)

For same voltage,

Energy stored, $U \propto C$

$$\therefore \quad \frac{U_s}{U_p} = \frac{C_s}{C_p} \Rightarrow \frac{U_s}{U_p} = \frac{1}{9}$$

or, $U_s : U_P = 1 : 9$ (1 mark)

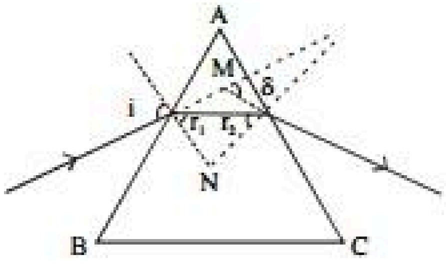
21. (a) Microwaves are suitable for radar system in aircraft navigation.

(b) X-rays are produced by bombarding a metal target by high speed electrons. (2 × 1 = 2 marks)

22. ∠i = angle of incidence

∠e = angle of emergence

δ = angle of deviation



In the quadrilateral AQNR,

$\angle A + \angle QNR = 180°$ ...(i)

In the traingle QNR

$r_1 + r_2 + \angle QNR = 180°$ ...(ii)

$\therefore r_1 + r_2 = \angle A$ ...(iii)

The angle of deviation,

$\delta = (i - r_1) + (e - r_2) = i + e - (r_1 + r_2)$

$\therefore \delta = i + e - A$ ...(iv) (1 mark)

According to snell's law, $\frac{\sin i}{\sin r_1} = n_{21}$

or, $\frac{i}{r_1} = n_{21}$ (since angles are small)

$\therefore i = r_1 . n_{21}$

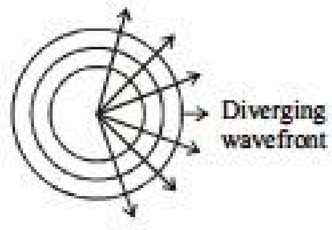
Also, $\frac{\sin e}{\sin r_2} = n_{21} \Rightarrow \frac{e}{r_2} = n_{21}$ $\therefore e = r_2 . n_{21}$

using the equation (iv)

$\delta = r_1 . n_{21} + r_2 . n_{21} A = (r_1 + r_2) n_{21} A = A . n_{21} A$

$\therefore \delta = (n_{21} - 1) A$ (1 mark)

23. (a) Spherical.



(1 mark)

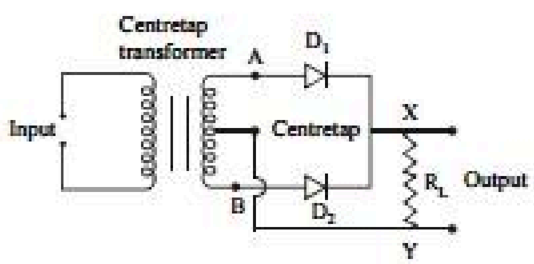
(b) Plane.

When a point source is placed at the focus of a convex lens, the emergent rays are parallel, hence the wavefont is plane. (½ mark)

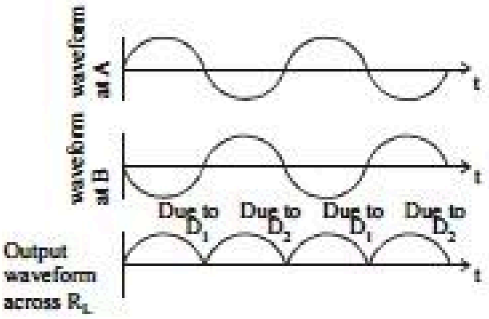
(c) Plane.

As the star is very far away, therefore the wavefront reacting us is a very large sphere and a small area on the surface of a large sphere is nearly plannar. (½ mark)

24. **P-N junction diode as a full wave rectifier :** The circuit uses two diodes connected to the ends of a centre tapped transformer. The voltage rectified by the two diodes is half of the secondary voltage i.e., each diode conducts for half cycle of input but alternately so that net output across load comes as half sinusoids with positive values only.



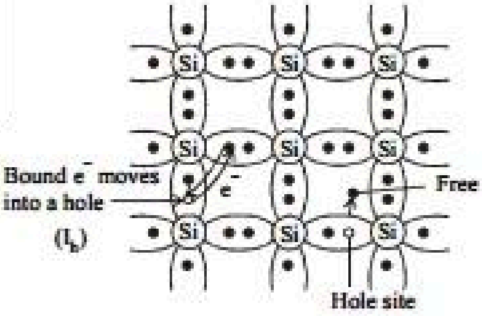
For positive cycle diode D_1 conducts (FB) but D_2 is being out of phase is reverse biased and does not conduct. Thus output across R_L is due to D_1 only. In negative cycle of input D_1 is R.B. but D_2 is F.B. and conducts as with respect to centretap point A is negative but B is positive. Hence output across R_L is due to D_2.



(2 marks)

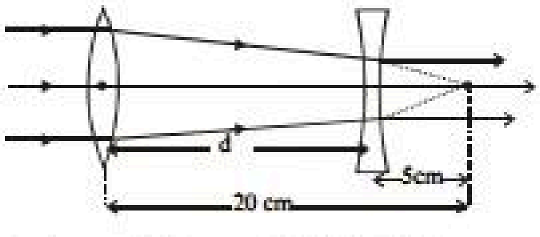
OR

In an intrinsic semiconductor, each of the 4 valence electrons is between two atoms (Si or Ge) in a shared covalent bond. It is bound at low temperatures, but at high temperatures it can pick thermal energy and move out of the valence band and into the interstitial space. This electron is free to conduct. The vacancy left behind by it is called a **hole** and it also conducts charge.



Another electron from a different band can come and occupy this vacancy, hence creating a vacancy elsewhere and causing motion of bound electrons. These holes move towards the negative potential giving rise to hole current I_h. The total current I, is sum of hole current I_h and electron current I_e. (2 marks)

25.



As the parallel beam of light is incident on convex lens, $u = -\infty$, $f = 20$ cm

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} - \frac{1}{-\infty} = \frac{1}{20} \Rightarrow \frac{1}{v} = \frac{1}{20}$ $\therefore v = 20\text{cm}$

(1 mark)

In the absence of concave lens, the image would have been formed at a distance of 20 cm. This image acts as an object for concave lens which, formes its image at infinity.

$\therefore$ d = distance between the convex lens and concave lens

$\therefore$ virtual object distance for concave lens $= (20 - d)$ cm.

$v = \infty$, $f = -5$ m.

As, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ $\qquad \therefore \frac{1}{\infty} - \frac{1}{(20-d)} = \frac{1}{-5}$

$\Rightarrow (20 - d) = 5 \Rightarrow 20 - 5 = d$ $\qquad \therefore d = 15$ cm (1 mark)

26. Magnetic field at a point inside the solenoid is

$$B = \frac{\mu_0 NI}{\ell}$$

Where N is the total number of turns of the solenoid and *l* is its length. B is constant throughout the length of the solenoid.

Magnetic flux through each turn = B × area of each turn.

$$\therefore \quad \phi_1 = \mu_0 \frac{N}{\ell} I \times A$$

where A is the area of each turn.

$\therefore$ Total magnetic flux linked with the solenoid

$$= \phi = \mu_0 \frac{N}{\ell} IA \times N$$

But from the definition of self inductance (L), $\phi = LI$.

$$\therefore \quad LI = \mu_0 \frac{N}{\ell} IA \times N \Rightarrow L = \frac{\mu_0 N^2 A}{\ell} \quad \text{(3 marks)}$$

27. Given : $I_1 = 0.5$ A, $R_1 = 12$ ohm, $I_2 = 0.25$ A, $R_2 = 25$ ohm

From formula, $I = \frac{E}{(R + r)}$ or $E = I(R + r)$ (1 mark)

$0.5 \times (12 + r) = 0.25 \times (25 + r)$ (1 mark)

Solving we get, r = 1 ohm and emf,

$E = 0.5\,(12 + 1) = 6.5$ V (1 mark)

OR

Relation between current (I) and drift velocity (v_d) :

$I = V_d enA$

$$I = \frac{e^2 VnA}{mL}\tau \quad \left(\because V_d = \frac{eV}{mL}T\right) \quad \text{(1½ mark)}$$

It is clear from this expression that with the rise in temperatue τ decreases, this decreases the current in the circuit, which in turn increases the resistance of the conductor. (1½ mark)

28. Let $I = I_0 \sin \omega t$ is the alternating current flowing through a resistance R in a small time dt.

$\therefore$ Heat produced $= dH = I^2 Rdt$ ...(i)

If $I_{r.m.s}$ be the r.m.s value of current then by definition, heat produced in time t,

$$H = I^2_{r.m.s} RT \quad \text{...(ii)} \quad \text{(1 mark)}$$

Comparing equations (i) and (ii),

$$I^2_{r.m.s} RT = \int_0^T I^2 Rdt = R\int_0^T I^2 dt = R\int_0^T I_0^2 \sin^2 \omega t dt$$

$$I^2_{r.m.s} T = \frac{I_0^2}{2}\int_0^T 2\sin^2 \omega t dt = \frac{I_0^2}{2}\int_0^T (1 - \cos 2\omega t)dt$$

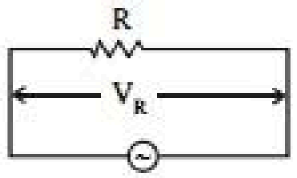
$$= \frac{I_0^2}{2}\left| t - \frac{\sin 2\omega t}{2\omega} \right|_0^T = \frac{I_0^2}{2}\left[t - \frac{1}{2\omega}\left(\sin 2 \times \frac{2\pi}{T} t\right)\right]_0^T$$

(1 mark)

$$= \frac{I_0^2}{2}\left[t - \frac{1}{2\omega}(\sin 4\pi - \sin 0)\right] = \frac{I_0^2 T}{2}$$

$$\therefore \quad I^2_{rms} = \frac{I_0^2}{2} \qquad \therefore \quad I_{rms} = \frac{I_0}{\sqrt{2}} \quad \text{(1 mark)}$$

OR



Let V_R be the instantaneous voltage drop across R.

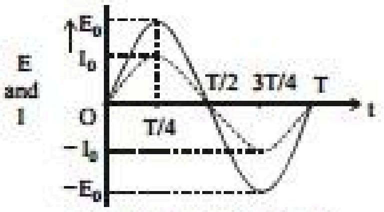
E is the applied alternating e.m.f. to the circuit. E_0 is the maximum voltage.

$$\therefore \quad E = E_0 \sin \omega t = IR$$

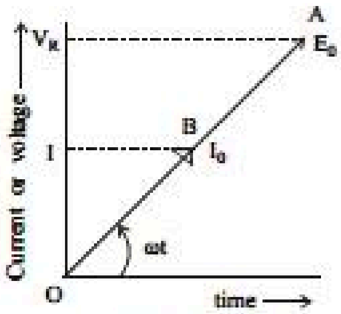
$$\therefore \quad I = \frac{E_0}{R}\sin \omega t = I_0 \sin \omega t \quad \text{(1 mark)}$$

where $I_0 = \frac{E_0}{R}$ = Maximum value of current.

$\therefore$ Current and voltage are in phase with each other.



Graphical representation of voltage and current



Phasor Diagram

(2 marks)

The reflections of E_0 and I_0 on y-axis gives the instantaneous voltage drop across R (V_R). ωt is called the phase angle.

29. The situation is shown in figure.

The square can be considered as one of the faces of a cube of each side 10 cm, enclosing the point charge inside it. The cube surface will act as Gaussian surface. (1 mark)

Given, $q = 10\mu C = 10\times10^{-6}C$,

$\varepsilon_0 = 8.854\times10^{-12}C^2N^{-1}m^2$ (taken)

By Gauss's law for whole closed surface,

$$\phi = q/\varepsilon_0 = \frac{10\times10^{-6}}{8.854\times10^{-12}}$$

$= 1.13\times10^6 Nm^2/C$ (1 mark)

As one face area is *one-sixth* of total surface area of the cube,

Flux through one face $= \frac{\phi}{6} = \frac{1.13\times10^6}{6}$

$= 1.88\times10^5$ Nm²/C (1 mark)

30. (a) The isotope ${}^6_3Li$ has abundance 7.5% and ${}^7_3Li$ has 92.5%. $m({}^6_3Li) = 6.01512\,u$ $m({}^7_3Li) = 7.01600\,u$

Average mass of Li

$$= \frac{6.01512\times7.5+7.01600\times92.5}{7.5+92.5}$$

$= \frac{45.1140+648.98}{7.5+92.5} = \frac{694.094}{100} = 6.94000$ u. (1½ marks)

(b) $m({}^{10}_5B) = 10.01294\,u; m({}^{11}_5B)$
$= 11.00931\,u; m(B)$
$= 10.811\,u.$

Let abundance of ${}^{10}_5B$ be x% thus abundance of ${}^{11}_5B$ will be $(100-x)$%

Average mass of Boron

$$= \frac{10.01294x + 11.00931(100-x)}{100} = 10.811\,u$$

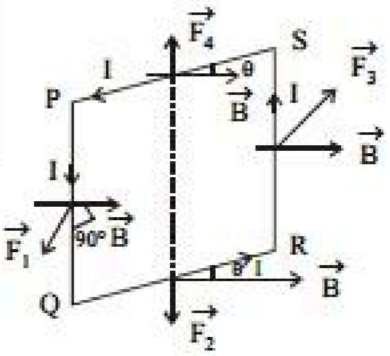
$\Rightarrow$ $10.01294x + 1100.931 - 11.00931x = 1081.1$

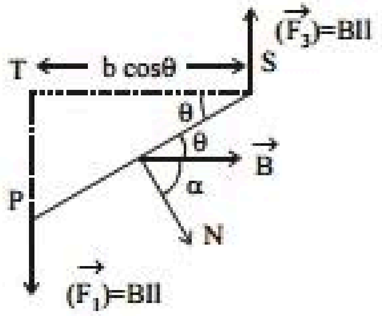
$\Rightarrow$ $0.996x = 19.831$

$\Rightarrow$ $x = 19.91\% =$ abundance of ${}^{10}_5B$; and $(100-x)$

$= (100-19.91) = 80.1\%$ abundance of ${}^{11}_5B$ (1½ marks)

31. Here $PQ = RS = \ell =$ length of the coil
$QR = SP = b =$ breadth of the coil
θ is the angle between plane of the coil and $\vec{B}$.





(1 mark)

$\overline{F_1}, \overline{F_2}, \overline{F_3}, \overline{F_4}$ are forces on four arms PQ, QR, RS and SP respectively.

$\overline{F_4} = I(\overline{SP}\times\overline{B})$

$\Rightarrow$ $IB(SP)\sin(180^\circ-\theta) = IbB\sin\theta$

$\overline{F_2} = I(\overline{QR}\times\overline{B}) \Rightarrow F_2 = IB(QR)\sin\theta = IbB\sin\theta$ (1 mark)

They are equal in magnitude but opposite in direction, and will cancel each other.

$\overline{F_1} = I(\overline{PQ} \times \overline{B}) \Rightarrow F_1 = IB\,(PQ)\sin 90°$

$= I\ell B\ (\because\ \overline{PQ} \perp \overline{B})$

This is perpendicular to the plane of the coil and directed outwards.

$\overline{F_3} = I(\overline{RS} \times \overline{B}) \Rightarrow F_3 = I(RS)\,B\sin 90°$

$= I\ell B\ \ (\because\ \overline{RS} \perp \overline{B})$ (1 mark)

This is perpendicular to the plane of the coil and directed inwards.

They are equal, parallel but oppositely directed along their line of action, so they will form a couple which will try to rotate the coil in anticolockwise direction about its axis.

Torque on the coil = moment of the couple = $\overline{F} \times \overline{r}$

$\Rightarrow\ \ \tau = I\ell B \times b\cos\theta$ [$\because$ perpendicular distance between the force = b cos θ]

$\Rightarrow\ \tau = IBA\cos\theta$ where A = ℓb = area of the coil (1 mark)

If the coil has n number of turns, $\tau = nIBA\cos\theta$.

If the angle between the normal on the plane of the coil and $\overline{B}$ is α then $\theta + \alpha = 90° \Rightarrow \theta = 90° - \alpha$

$\Rightarrow\ \ \cos\theta = \cos(90° - \alpha) = \sin\alpha$

$\therefore\ \ \tau = nIBA\sin\alpha = MB\sin\alpha = |\overline{M} \times \overline{B}|$

Where M = magnetic dipole moment of the coil = nIA

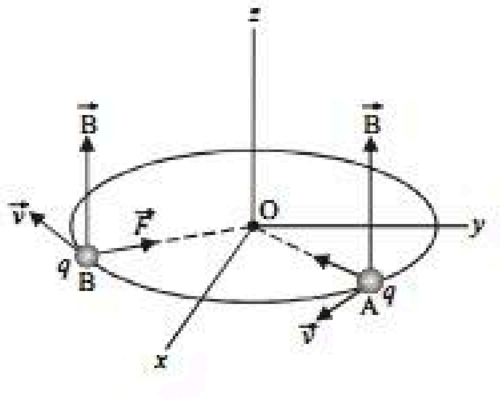
(1 mark)

OR

When a charged particle with charge q moves inside a magnetic field $\overline{B}$ with velocity v, it experiences a force, which is given by:

$\vec{F} = q(\vec{v} \times \overline{B})$ (1 mark)

Here, $\vec{v}$ is perpendicular to $\overline{B}$ and $\vec{F}$ is the force on the charged particle which acts as the centripetal force and makes it move along a circular path.



Let m be the mass of the charged particle and r be the radius of the circular path.

$$q(\vec{v} \times \overline{B}) = \frac{mv^2}{r}$$ (1 mark)

Since, v and B are perpendicular to each other.

$$\therefore\quad qvB = \frac{mv^2}{r}\quad \boxed{r = \frac{mv}{Bq}}$$ (1 mark)

Time period of circular motion of the charged particle can be calculated as shown below:

$$T = \frac{2\pi r}{v} = \frac{2\pi}{v}\frac{mv}{Bq}$$

$$T = \frac{2\pi m}{Bq}$$ (1 mark)

$\therefore$ Angular frequency is

$$\omega = \frac{2\pi}{T} \qquad \boxed{\therefore \omega = \frac{Bq}{m}}$$

Therefore, the frequency of the revolution of the charged particle is independent of the velocity or the energy of the particle. (1 mark)

32. **Cut-off voltage :** The minimum negative voltage (V_0) applied an anode plate with respect to the cathode for which photocurrent in the circuit reduces to zero. (1 mark)

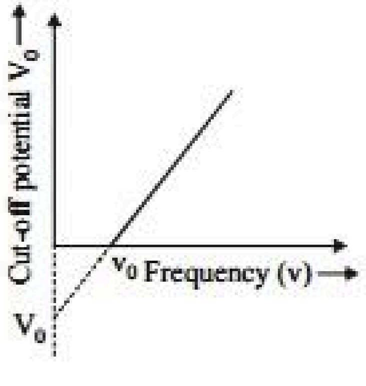
Threshold frequency : The minimum frequency of incident radiation which is required for photoelectric, effect or the ejection of photoelectrons from metal surface. (1 mark)

Einstein's photo-electric equation,

$$hv = hv_0 + KE_{max} = hv_0 + eV_0$$

$$V_0 = \frac{h}{e}(v - v_0)$$

The variation of cut-off potential with frequency of incident radiation is shown below



From this graph, we can calculate the value of threshold frequency (point of intersection of frequency axis) and stopping potential (point of intersection on potential axis). (3 marks)

OR

(a) de-Broglie wavelength of a charged particle is given by, $\lambda \propto \frac{1}{\sqrt{mq}}$

If m_p and e are mass and charge of a proton respectively, and, m_D and e are mass and charge of a deutron respectively, then

$$\frac{\lambda_P}{\lambda_D} = \sqrt{\frac{m_D q_D}{m_P q_P}} = \sqrt{\frac{(2m_p)(e)}{(m_p)(e)}} = \sqrt{2}$$

$$\lambda_P = \sqrt{2}\lambda_D$$

Thus, de-broglie wavelength associated with proton is $\sqrt{2}$ times of the de-broglie wavelength of deutron and hence it is more. (2½ marks)

(b) Momentum, is given by, $P = \frac{h}{\lambda}$ or, $p \propto \frac{1}{\lambda}$

where, h = plank's constant

Since the wavelength of a proton is more than that of deutron thus, the momentum of a proton is lesser than that of deutron. Hence, the momentum of proton is less. (2½ marks)

33. (a) As the resultant intensity at a point,

$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$ (1 mark)

When the path difference = λ,

phase difference = 0°

$\therefore I_R = I + I + 2\sqrt{I \times I}\cos 0°$

$= 2I + 2\sqrt{I^2} \times 1 = 2I + 2I = 4I = K.$ (1 mark)

When the path difference $= \frac{\lambda}{3}$, phase difference $\phi = \frac{2\pi}{3}$

$\therefore I'_R = I + I + 2\sqrt{I.I}.\cos\left(\frac{2\pi}{3}\right)$

$= 2I + 2\sqrt{I^2} \times \left(-\frac{1}{2}\right) = 2I - \frac{2I}{2} = I$ (1 mark)

$\therefore \quad I' = \frac{K}{4}$ (½ marks)

(b) Angular width $\theta = \frac{\lambda}{d}$

$0.1° = \frac{0.1}{180}\pi = \frac{6\times10^{-7}}{d}$

$d = \frac{6\times180\times10^{-7}}{0.1\times\pi} = 3.44 \times 10^{-4}\text{ m}$ (1½ marks)

OR

Here $d = 2$ mm, $D = 1.2$ m, $\lambda_1 = 650$ nm, $\lambda_2 = 520$ nm

(a) Distance of third bright fringe from the central maximum for the wavelength 650 nm.

$y_3 = \frac{3\lambda D}{d} = \frac{3\left(650\times10^{-9}\right)1.2}{2\times10^{-3}} = 1.17\text{ m}$ (2 marks)

(b) Let at linear distance 'y' from center of screen the bright fringes due to both wavelength coincides. Let n_1 number of bright fringe with wavelength λ_1 coincides with n_2 number of bright fringe with wavelength λ_2.

We can write

$y = n_1\beta_1 = n_2\beta_2$

$n_1 = \frac{\lambda_1 D}{d} = n_2\frac{D\lambda_2}{d}$

or $\quad n_1\lambda_1 = n_2\lambda_2$ ...(i) (1 mark)

Also at first position of coincide the n^th^ bright of one will coincide with (n + 1)^th^ bright fringe of other.

If $\lambda_2 < \lambda_1$

So then $n_2 > n_1$

then $n_2 = n_1 + 1$ ...(ii) (1 mark)

Using equation (ii) in equation (i)

$n_1\lambda_1 = (n_1 + 1)\,\lambda_2$

$n_1\,(650) \times 10^{-9} = (n_1 + 1)\,520 \times 10^{-9}$

$65\,n_1 = 52\,n_1 + 52$ or $12\,n_1 = 52$ or $n_1 = 4$

So, the fourth bright fringe of wavelength 520 nm coincides with 5th bright fringe of wavelength 650 nm. (1 mark)

34. (i) For hydrogen or hydrogen like atoms

$E_n = \frac{-13.6\,Z^2}{n^2}\text{eV / atom}$

For hydrogen atom $\quad E_1 = -13.6\text{eV}$ (for $n = 1$)

(Z = 1) $\quad E_2 = -3.4\text{eV}$ (for $n = 2$)

$\therefore \Delta E = E_2 - E_1 = -3.4 - (-13.6) = 10.2\text{ eV}$

i.e., When hydrogen comes to ground state from its first excited state it will release 10.2 eV of energy.

For He^+ ion (Z = 2)

$E_1 = -13.6 \times 4$ eV = -54.4 eV (for $n = 1$)

$E_2 = -13.6$ eV (for $n = 2$)

$E_3 = -6.04$ eV (for $n = 3$)

$E_4 = -3.4$eV (for $n = 4$)

Here He^+ ion is in the first excited state i.e., possessing energy – 13.6 eV. After receiving energy of + 10.2 eV from excited hydrogen atom on collision, the energy of electron will be (–13.6 + 10.2) eV = –3.4 eV. Hence the quantum number of the state finally populated in He^+ ions, $n = 4$.

(2 marks)

(ii) Wavelength of visible light lies in the range, $\lambda_1 = 4000$Å to $\lambda_2 = 7000$Å.

Therefore

$$E_1 = \frac{12375}{\lambda_1} = \frac{12375}{4000} = 3.09 \text{ eV}$$

$$E_2 = \frac{12375}{\lambda_2} = \frac{12375}{7000} = 1.77 \text{ eV}$$

For He^+ atom in transition from $n = 4$ to $n = 3$, energy of photon released will lie between E_1 and E_2.

$$E_4 - E_3 = -3.4 - (-6.04) = 2.64 \text{ eV}$$

∴ Wavelength of photon corresponding to this energy, (2.64 eV)

$$\lambda = \frac{12375}{2.64} \text{Å} = 4687.5 \text{ Å} = 4.68 \times 10^{-7} \text{ m}$$ (1 mark)

(iii) Kinetic energy for hydrogen or hydrogen like atom K

$$K = \frac{-13.6Z^2}{n^2} \Rightarrow K \propto Z^2$$

$$\frac{K_H}{K_{He^+}} = \left(\frac{Z_H}{Z_{He^+}}\right)^2 = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$$ (1 mark)

OR

(iii) The value of x = 0.

The product of linear momentum and angular momentum is independent of value of n. (1 mark)

35. **(i)** Ratio = 1 (1 mark)

(ii) Boron (1 mark)

(iii) Conductivity increases (2 marks)

OR

(iii) Output frequency = 2 × 60 Hz = 120 Hz (2 marks)