Class-XII

Session - 2022-23

Subject - Physics (Theory)

Sample Question Paper - 30

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		1 (Q. 16)			1 (Q. 31)	1 (Q. 34)	10
2	Electrostatic Potential and Capacitance	16	2 (Q. 1, 17)					2
3	Current Electricity		1 (Q. 2)		1 (Q. 27)			4
4	Moving Charges and Magnetism		1 (Q. 3)	1 (Q.19)				3
5	Magnetism and Matter		1 (Q. 15)	1 (Q.24)				3
6	Electromagnetic Induction	17		1 (Q. 22)	1 (Q. 26)			5
7	Alternating Current		1 (Q. 4)			1 (Q. 32)		6
8	Electromagnetic Waves		2 (Q. 5, 14)					2
9	Ray optics and Optical Instruments	18	2 (Q. 13,18)	1 (Q. 25)			1 (Q. 35)	8
10	Wave Optics		1 (Q. 6)	1 (Q. 20)		1 (Q. 33)		8
11	Dual Nature of Radiation and Matter		1 (Q. 9)		1 (Q. 28)			4
12	Atoms	12	1 (Q. 8)		1 (Q. 29)			4
13	Nuclei		1 (Q. 7)		1 (Q. 30)			4
14	Semiconductor Electronics: Materials, Devices and Simple Circuits	7	3 (Q. 10, 11, 12)	2 (Q. 21, 23)				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. The capacitors of capacity C_1 and C_2 are connected in parallel, then the equivalent capacitance is

(a) $C_1 + C_2$ (b) $\frac{C_1C_2}{C_1 + C_2}$ (c) $\frac{C_1}{C_2}$ (d) $\frac{C_2}{C_1}$

2. The powers of two electric bulbs are 100 watt and 200 watt. Both of them are joined with 220 volt. The ratio of resistance of their filament will be

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

3. A moving coil galvanometer has N number of turns in a coil of effective area A, it carries a current I. The magnetic field B is radial. The torque acting on the coil is

(a) NA^2B^2I (b) $NABI^2$ (c) N^2ABI (d) $NABI$

4. The transformer voltage induced in the secondary coil of a transformer is mainly due to

(a) a varying electric field (b) a varying magnetic field
(c) the vibrations of the primary coil (d) the iron core of the transformer

5. The magnetic field in a travelling electromagnetic wave has a peak value of 20 nT. The peak value of electric field strength is

(a) 3 V/m (b) 6 V/m (c) 9 V/m (d) 12 V/m

6. If the width of the slit in single slit diffraction experiment is doubled, then the central maximum of diffraction pattern becomes

(a) broader and brighter (b) sharper and brighter
(c) sharper and fainter (d) broader adn fainter.

7. If the total binding energies of ${}^2_1H$, ${}^4_2He$, ${}^{56}_{26}Fe$ & ${}^{235}_{92}U$ nuclei are 2.22, 28.3, 492 and 1786 MeV respectively, identify the most stable nucleus of the following.

(a) ${}^{56}_{26}Fe$ (b) ${}^2_1H$ (c) ${}^{235}_{92}U$ (d) ${}^4_2He$

8. The significant result deduced from the Rutherford's scattering experiment is that

(a) whole of the positive charge is concentrated at the centre of atom
(b) there are neutrons inside the nucleus
(c) α-particles are helium nuclei
(d) electrons are embedded in the atom

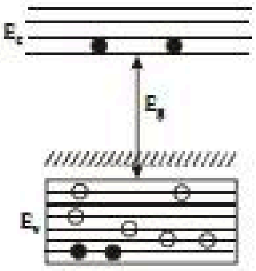
9. With reference to the observations in photo-electric effect, identify the correct statements from below:

A. The square of maximum velocity of photoelectrons varies linearly with frequency of incident light.
B. The value of saturation current increases on moving the source of light away from the metal surface.
C. The maximum kinetic energy of photo-electrons decreases on decreasing the power of LED (light emitting diode) source of light.
D. The immediate emission of photo-electrons out of metal surface can not be explained by particle nature of light/ electromagnetic waves.
E. Existence of threshold wavelength can not be explained by wave nature of light/electromagnetic waves.

Choose the correct answer from the options given below:

(a) A and B only (b) A and E only (c) C and E only (d) D and E only

10. In the energy band diagram of a material shown below, the open circles and filled circles denote holes and electrons respectively. The material is



(a) an insulator (b) a metal (c) an n-type semiconductor (d) a p-type semiconductor

11. In the half wave rectifier circuit operating from 50 Hz mains frequency, the fundamental frequency in the ripple would be

(a) 25 Hz (b) 50 Hz (c) 70.7 Hz (d) 100 Hz

12. A pure semiconductor has equal electron and hole concentration of 10^{16} m^{-3}. Doping by indium increases n_h to 5×10^{22} m^{-3}. Then, the value of n_e in the doped semiconductor is

(a) $10^6/m^3$ (b) $10^{22}/m^3$ (c) $2 \times 10^6/m^3$ (d) $2 \times 10^9/m^3$

13. The focal length of the objective of a telescope is 60 cm. To obtain a magnification of 20, the focal length of the eye piece should be

(a) 2 cm (b) 3 cm (c) 4 cm (d) 5 cm

14. In electromagnetic spectrum, the frequencies γ-rays, X-rays and ultraviolet rays are denoted by n_1, n_2 and n_3 respectively then

(a) $n_1 > n_2 > n_3$ (b) $n_1 < n_2 < n_3$ (c) $n_1 > n_2 < n_3$ (d) $n_1 < n_2 > n_3$

15. Metals getting magnetised by orientation of atomic magnetic moments in external magnetic field are called

(a) diamagnetic (b) paramagnetic (c) ferromagnetic (d) antimagnetic

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) :** On going away from a point charge or a small electric dipole, electric field decreases at the same rate in both the cases.

Reason (R) : Electric field is inversely proportional to square of distance from the charge or an electric dipole.

17. **Assertion (A):** When a dielectric slab is gradually inserted between the plates of an isolated parallel-plate capacitor, the energy of the system decreases.

Reason (R): The force between the plates decreases.

18. **Assertion (A) :** The objective of telescope has small focal length.

Reason (R): If objective and eye lenses of a microscope are interchanged then it can work as telescope.

SECTION-B

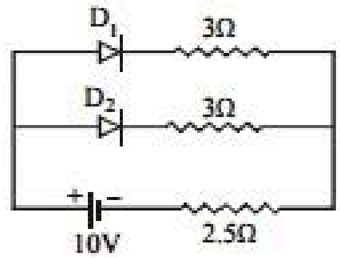
19. Derive an expression for the magnetic field at the centre of a circular current carrying coil using Biot – Savart's law.

20. A plane wavefront is incident on

(i) a prism (ii) a convex lens.

Draw the emergent wavefront in each case.

21. Assuming that the two diodes D_1 and D_2 used in the electric circuit shown in the figure are ideal, find out the value of the current flowing through 2.5Ω resistor.



22. A small piece of metal wire is dragged across the gap between the pole piece of a magnet in 0.5 s. The magnetic flux between the pole pieces is known to be 8×10^{-4} Wb. Calculate the induced emf in the wire.
–ve sign gives the direction of e.m.f.

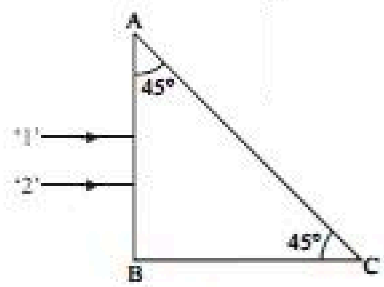
OR

If the rate of change of current is 2 A/s and induces an e.m.f. of 40 mV in the solenoid, what is the self-inductance of the solenoid?

23. What are the requirements for an element to be a good dopant?

24. A circular coil of N turns and radius R carries a current I. It is unwound and rewound to make another coil of radius R/2, current I remaining the same. Calculate the ratio of the magnetic moments of the new coil and the original coil.

25. Two monochromatic rays of light are incident normally on the face AB of an isosceles right-angled prism ABC. The refractive indices of the glass prism for the two rays '1' and '2' are respectively 1.35 and 1.45. Trace the path of these rays after entering the prism.



OR

A ray of light passes through an equilateral prism in such a manner that the angle of incidence is equal to angle of emergence and each of these angle is equal to $\frac{3}{4}$ of angle of prism. Find angle of deviation.

SECTION-C

26. Define the term mutual inductance. Write its S.I. unit. Give two factors on which the coefficient of mutual inductance between a pair of coil depends.

27. Define the term resistivity of a conductor. Give its S.I. unit. Show that the resistivity of a conductor is given by $\frac{m}{ne^2\tau}$ where symbols have their usual meanings.

28. Write Einstein's photoelectric equation. Mention the underlying properties of photons on the basis of which this equation is obtained.
Write two important observations of photoelectric effect which can be explained by Einstein's equation.

OR

A proton and an alpha particle are accelerated through the same potential. Which one of the two has (i) greater value of de–Broglie wavelength associated with it and (ii) less kinetic energy. Give reasons to justify your answer.

29. Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum numbers of the atom.

30. How the size of a nuclus is experimentally determined? Write the relation between the radius and mass number of the nucleus. Show that the density of nucleus is independent of its mass number.

OR

(a) In a nuclear reaction :

$^{3}_{2}He + ^{3}_{2}He \longrightarrow ^{4}_{2}He + ^{1}_{1}H + ^{1}_{1}H + 12.86\ MeV,$

though the number of nucleons is conserved on both sides of the reaction, yet the energy is released. How? Explain.

(b) Draw a plot of potential energy between a pair of nucleons as a function of their separation. Mark the regions where potential energy is (i) positive and (ii) negative.

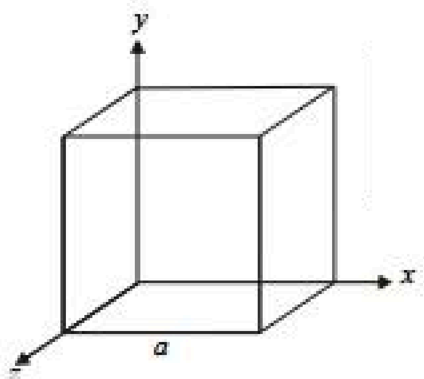
SECTION-D

31. State Gauss theorem in electrostatics and write its mathematical form. Using it, derive an expression for electric field at a point near a thin infinite plane sheet of electric charge. How does this electric field change with a uniformly thick sheet of charge?

OR

(a) An electric dipole of dipole moment $\vec{p}$ consists of point charges +q and –q separated by a distance 2a apart. Deduce the expression for the electric field $\vec{E}$ due to the dipole at a distance x from the centre of the dipole on its axial line in terms of the dipole moment $\vec{p}$. Hence show that in the limit $x >> a$, $\vec{E} \longrightarrow 2\vec{P}/(4\pi\varepsilon_0 x^3)$.

(b) Given the electric field in the region $\vec{E} = 2x\hat{i}$, find the net electric flux through the cube and the charge enclosed by it



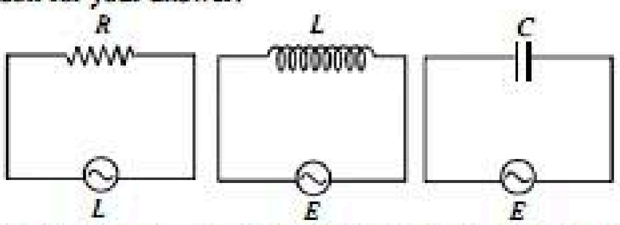
32. A series L-C-R circuit is connected to an AC source having voltage $V = V_m \sin \omega t$. Derive the expression for the instantenous current I and its phase relationship to the applied voltage.

Obtain the condition for resonance to occur.

OR

(a) What do you understand by sharpness of resonance in a series *L-C-R* circuit? Derive an expression for *Q*-factor of the circuit.

(b) Three electrical circuits having AC sources of variable frequency are shown in the figures. Initially, the current flowing in each of these is same. If the frequency of the applied AC source is increased, how will the current flowing in these circuits be affected? Give the reason for your answer.



33. (a) Define a wavefront. Using Huygens' principle, verify the laws of reflection at a plane surface.

(b) In a single slit diffraction experiment, the width of the slit is made double the original width. How does this affect the size and intensity of the central diffraction band? Explain.

(c) When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the obstacle. Explain why?

OR

(i) What is the effect on the interference fringes to the Young's double slit experiment when

(a) the separation between the two slits is decreased?

(b) the width of the source-slit is increased?

(ii) The intensity at the central maxima in Young's double slit experimental setup is I_0. Show that the intensity at a point where the path difference is $\lambda/3$, is $I_0/4$.

SECTION-E

34. Case Study: Electric Flux & Gauss's Law

Read the following paragraph and answer the questions.

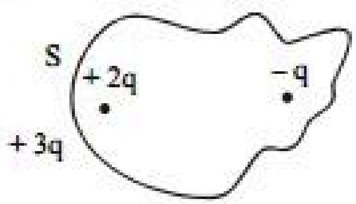
Electric flux over an area in an electric field is the total number of electric lines of force crossing this area.

It is measured by the product of surface area and the corresponding component of electric field normal to the area.

$$\phi = \oint \vec{E} . d\vec{s}$$

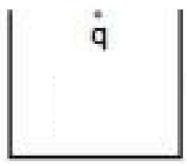
It is a scalar quantity. Its SI unit is volt metre (Vm) or Nm^2/C.

(i) Figure shows three point charges, + 2q, – q and + 3q. Two charges + 2q and – q are enclosed within a surface S. What is the electric flux due to this configuration through the surface S?



(ii) How does the electric flux due to a point charge enclosed by a spherical Gaussian surface get affected when its radius is increased?

(iii) A charge q is placed at the centre of the open end of a cylindrical vessel. Find the flux of the electric field through the surface of the vessel.



OR

(iii) At the centre of a cubical box + Q charge is placed. Find the value of total flux that is coming out a wall.

35. Case Study: Total internal Reflection

Read the following paragraph and answer the questions.

When light travels from an optically denser medium to a rarer medium at the interface, it is partly reflected back into the same medium and partly refracted to the second medium. This reflection is called the internal reflection.

If the angle of incidence is increased still further, refraction is not possible, and the incident ray is totally reflected. This is called total internal reflection.

(i) When monochromatic light travels from one medium to another, its wavelength changes but frequency remains the same. Explain.

(ii) What is the relation between critical angle and refractive index?

(iii) In total internal reflection when the angle of incidence is equal to the critical angle for the pair of media in contact, what will be angle of refraction ?

OR

(iii) State the criteria for the phenomenon of total internal reflection of light to take place.

SOLUTIONS

SAMPLE PAPER-1

1. (a) In parallel grouping of capacitors
$C_{eq} = C_1 + C_2 + \ldots\ldots\ldots\ldots C_n$ (1 mark)

2. (d) As $R = \frac{1}{\text{Power}}$ $\therefore$ $R_1 : R_2 = 2 : 1$ (1 mark)

3. (d) $\tau = MB\sin\theta \Rightarrow \tau_{max} = NIAB$, $(\theta = 90°)$ (1 mark)

4. (b) Voltage induced in the secondary coil of a transformer is mainly due to a varying magnetic field. (1 mark)

5. (b) From question,
$B_0 = 20\text{ nT} = 20 \times 10^{-9}\text{T}$
$\vec{E}_0 = \vec{B}_0 \times \vec{C}$
$|\vec{E}_0| = |\vec{B}_0| \cdot |\vec{C}| = 20 \times 10^{-9} \times 3 \times 10^8 = 6$ V/m. (1 mark)
($\because$ velocity of light in vacuum $C = 3 \times 10^8\text{ ms}^{-1}$)

6. (b) Width of central maximum in diffraction pattern due to single slit $= \frac{2\lambda D}{d}$ where λ is the wavelength, D is the distance between screen and slit and a is the slit width. As the slit width a increases, width of central maximum becomes sharper or narrower. As same energy is distributed over a smaller area. Therefore central maximum becomes brigther. (1 mark)

7. (a) $B.E_H = \frac{2.22}{2} = 1.11$
$B.E_{He} = \frac{28.3}{4} = 7.08$
$B.E_{Fe} = \frac{492}{56} = 8.78 = \text{maximum}$
$B.E_U = \frac{1786}{235} = 7.6$
${}^{56}_{26}Fe$ is most stable as it has maximum binding energy per nucleon. (1 mark)

8. (a) The significant result deduced from the Rutherford's scattering is that whole of the positive charge is concentrated at the centre of atom i.e. nucleus. (1 mark)

9. (d) Intensity $\propto 1/(\text{distance})^2$; No. of photoelectrons emitted is proportional to intensity of incident light. (1 mark)

10. (d) For a p-type semiconductor, the acceptor energy level, as shown in the diagram, is slightly above the top E_v of the volume band. With very small supply of energy an electron from the valence band can jump to the level E_A and ionise acceptor negatively. (1 mark)

11. (b) In half wave rectifier, we get the output only in one half cycle of input a.c. therefore, the frequency of the ripple of the output is same as that of input a.c. *i.e.*, 50 Hz. (1 mark)

12. (d) Here, $n_i = 10^{16}\text{ m}^{-3}$, $n_h = 5 \times 10^{22}\text{ m}^{-3}$
As $n_e n_h = n_i^2$
$\therefore$ $n_e = \frac{n_i^2}{n_h} = \frac{(10^{16}\text{ m}^{-3})^2}{5 \times 10^{22}\text{ m}^{-3}} = 2 \times 10^9\text{ m}^{-3}$ (1 mark)

13. (b) In normal adjustment,
$M = \frac{f_0}{f_e} = 20$, $f_e = \frac{f_0}{20} = \frac{60}{20} = 3$ cm (1 mark)

14. (a) From electromagnetic spectrum, frequencies of γ-rays is greater than frequency of X-rays. Frequency of X-rays is greater than frequency of ultraviolet rays. (1 mark)

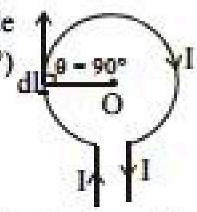
15. (b) Paramagnetic (1 mark)

16. (d) A is false but R is also false (1 mark)

17. (c) A is true but R is false (1 mark)

18. (d) A is false but R is also false (1 mark)

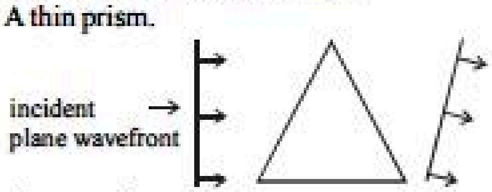
19. From Biot – Savart's law, the magnetic field due to an element of length $2l$ of the current carrying conductor is
$dB = \frac{\mu_0}{4\pi}\frac{Id\ell\sin\theta}{r^2}$ (½ mark)
Here $\theta = 90°$ ($\because$ $d\ell$ is tangential, angle between the radius and the tangent is 90°)



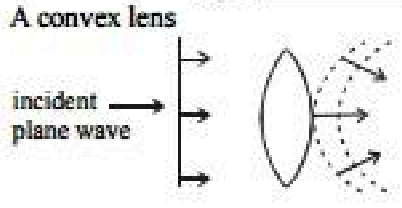
$\therefore$ $dB = \frac{\mu_0}{4\pi}.\frac{Id\ell}{r^2}$

$\therefore$ Total magnetic field at the centre O due to the whole circular coil
$= B = \int dB = \frac{\mu_0 I}{4\pi r^2}\int d\ell = \frac{\mu_0 I}{4\pi r^2}.2\pi r = \frac{\mu_0 I}{2r}$
For a coil of n number of turns, $B = \frac{\mu_0 nI}{2r}$ (1½ marks)
It is perpendicular to the plane of the coil and directed inwards.

20. Refraction of a plane wave form by
(i) A thin prism.



(ii) A convex lens



(1 + 1 = 2 marks)

21. Diodes D_1 and D_2 are ideal, therefore, they do not offer any resistance. Hence the two 3 ohm resistors are in parallel, hence,
$R_P = 3 \times 3/3 + 3 = 9/6 = 1.5\,\Omega$
Now, R_P and 2.5 ohm resistors are in series, hence, net resistance
$R = R_P + 2.5 = 1.5 + 2.5 = 4.0\Omega$
Hence, current through the circuit and through 2.5 Ω resistors
$I = V/R = 10/4 = 2.5$ A (2 marks)

22. Induced emf $= e = -\frac{d\phi}{dt} = -\frac{8\times10^{-4}}{0.5}$

$= -1.6\times10^{-3}\,V = -1.6\,mV$

–ve sign gives the direction of e.m.f. (2 marks)

OR

Iuduced e.m.f. $= e = -L\frac{di}{dt}$

$\therefore \quad L = \left|\frac{e}{di/dt}\right| = \frac{40\times10^{-3}}{2}$

$= 20\times10^{-3}\,H = 20\,mH.$ (2 marks)

23. The impurity atoms should be such that (i) it doesn't distort the original pure semiconductor lattice, (ii) it occupies only a few of the original semiconductor atom sites in the crystal and (iii) size of the dopant and semiconductor atom should be same. (2 marks)

24. Length of the wire is same in both cases

$\therefore N_1\times(2\pi R) = N_2\times 2\pi\left(\frac{R}{2}\right)$

So, $N_2 = 2N_1$

Now, the ratio of magnetic moments is given by

$$\frac{M_1}{M_2} = \frac{N_1 I A_1}{N_2 I A_2} = \frac{N_1\times\pi R_1^2}{N_2\times\pi R_2^2}$$

$$\frac{M_1}{M_2} = \left(\frac{N_1}{2N_1}\right)\times\left(\frac{R}{R/2}\right) = \frac{1}{2}\times4 = 2$$

$M_1 : M_2 = 2:1$ (2 marks)

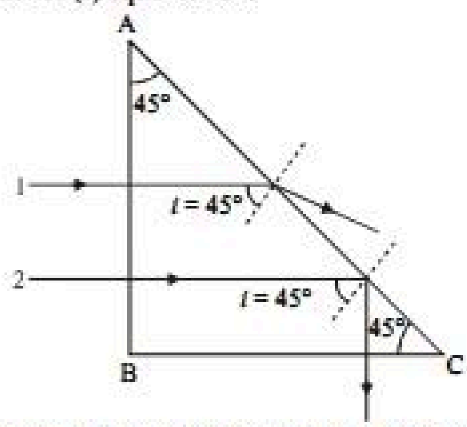
25. Critical angle of ray 1:

$\sin(c_1) = 1/\mu_1 = 1/1.35 \Rightarrow c_1 = \sin-1(1/1.35) = 47.73°$

Similarly, critical angle of ray 2:

$\sin(c_2) = 1/\mu_2 = 1/1.45 \Rightarrow c_2 = \sin-1(1/1.45) = 43.6°$

Both the rays will fall on the side AC with angle of incidence (i) equal to 45°.



(2 marks)

Critical angle of ray 1 is greater than that of i. Hence, it will emerge from the prism, as shown in the figure. Critical angle of ray 2 is less than that of i. Hence, it will be internallyreflected.

OR

Here, $i = e = \frac{3}{4}A$, $A = 60°$; $\delta = i + e - A$

$= 2\times\frac{3}{4}A - A = \frac{2A}{4} = \frac{1}{2}\times60° = 30°$ (2 marks)

26. Coefficient of mutual inductance between a pair of coils is numerically equal to the amount of magnetic flux linked with one coil when unit current flows through the other coil. Its S.I. unit is Henry.

It depends on size, shape, number of turns and nature of material of two coils. It also depends on the relative placement of the two coils. (1+1+1=3 marks)

27. Specific resistance of a material is defined as the resistance of unit length and unit cross-sectional area of the conductor. S.I. unit is ohm - m.

$R = \frac{m\ell}{ne^2 A\tau} = \left(\frac{m}{ne^2\tau}\right)\frac{\ell}{A}$ (1+½ marks)

Also $\quad R = \frac{\rho\ell}{A}$ (1 + ½ marks)

28. Einstein's photoelectric equation

$h\nu = h\nu_0 + \frac{1}{2}mv^2 \qquad h\nu = h\nu_0 + eV_s,$

where v is the velocity of the ejected electrons and V_s is the stopping potential.

This equation is based on the following properties of photons:

(i) A photon is a packet of energy. It frequency and h plank's constant.

(ii) When a photon is incident on a photoelectric material, it is completely absorbed by the electron. The energy of the photon is used in ejecting electron and the balance if any is used up in imparting kinetic energy to the electron.

Two important observation which can be explained by the equation :

(i) The photoelectric emission takes place only if the incident light has a frequency greater than the threshold frequency ν_0. If $\nu < \nu_0$, then $\frac{1}{2}mv^2$ will be –ve, which is not possible. Hence, electron will not be emited.

(1 + 1 + 1 = 3 marks)

(ii) When the frequency of the incident light increases, then $\frac{1}{2}mv^2$ i.e., kinetic energy of electron increases because work function $= h\nu_0$ is fixed. With increase in frequency more and more energy is available to the electron ejected and hence stopping potential also increases.

OR

(i) 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_α and $2e$ are mass and charge of an alpha particle respectively, then,

$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_p q_p}} = \sqrt{\frac{(4m_p)(2e)}{(m_p)(e)}} = 2\sqrt{2}$ (1½ marks)

$\lambda p = 2\sqrt{2}$

Thus, de-broglie wavelength associated with proton is $2\sqrt{2}$ times of the de-broglie wavelength of alpha particle.

(ii) For same accelerating potential K.E. $\propto$ q

Charge of an alpha particle is more as compared to a proton. So, it will have a greater value of K.E.

Hence, proton will have lesser kinetic energy.

(1½ marks)

29. Electron revolves in a stable orbit, the centripetal force is provided by electrostatic force of attraction acting on it, due to positive charges in the nucleus.

Hence,

$$\frac{mv_n^2}{r_n} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{e^2}{r_n^2}$$

$$\Rightarrow v_n^2 = \frac{e^2}{4\pi\varepsilon_0 m r_n} \quad ...(i) \qquad (1 \text{ mark})$$

and from Bohr's quantum condition, we have

$$m v_n r_n = \frac{nh}{2\pi} \text{ or } v_n = \frac{nh}{2\pi m r_n} \quad ...(ii) \qquad (1 \text{ mark})$$

Squaring Eq (ii) and then equating it with Eq. (i), we get

$$\frac{n^2h^2}{4\pi^2 m^2 r_n^2} = \frac{e^2}{4\pi\varepsilon_0 m r_n} \qquad (1 \text{ mark})$$

$$\Rightarrow r_n = \frac{n^2h^2}{4\pi^2 m^2}\times\frac{4\pi\varepsilon_0 m}{e^2} = \frac{\varepsilon_0 h^2}{\pi m e^2}.n^2$$

30. The size of the nucleus is experimentally determined using Rutherford's α-scattering experiment and the distance of closed approach and impact parameter.

The relation between radius and mass number of nucleus is,

$R = R_0 A^{1/3}$, where $R_0 = 1.2$ fm

Nuclear density,

$$\rho = \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}} = \frac{mA}{\frac{4}{3}\pi(R_0 A^{1/3})^3}$$

$$\rho = \frac{mA}{\frac{4}{3}\pi R_0^3 A} \text{ or } \rho = \frac{m}{\frac{4}{3}\pi R_0^3} \qquad (1+1+1=3 \text{ marks})$$

It is clear that ρ does not depend on mass number.

OR

(a) In the nuclear reaction

$${}_2^3He + {}_2^3He \longrightarrow {}_2^4He + {}_1^1H + {}_1^1H + 12.86 \text{ MeV}$$

Number of nucleons on left side

= number of nucleons on right side

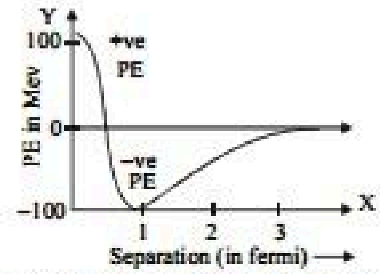
3 + 3 = 4 + 1 + 1 = 6. Thus, total number of nucleons is conserved. The energy is being released because sum of the masses of ${}_2^3He$ and ${}_2^3He$ is more than the sum of the masses of ${}_2He^4$, ${}_1H^1$ and ${}_1H^1$ i.e., products. Thus there is some mass defect Δm. (1½ marks)

According to Einstein's mass energy relation

$\Delta E = \Delta mc^2$

Hence in nuclear reaction though the number of nucleons is conserved, the energy is released.

(b) Plot of potential energy between a pair of nucleons as a function of their separation :



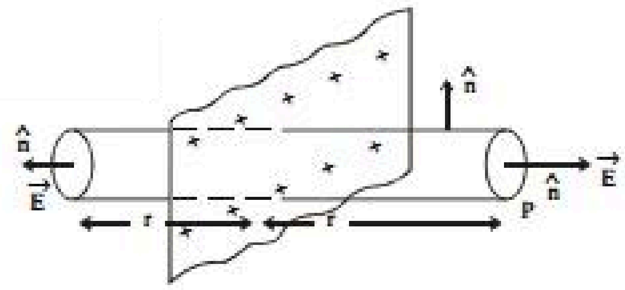
(1 ½ marks)

31. **Gauss's theorem:–** The surface integral of electrostatic field $(\vec{E})$ produced by any source over any closed surface S in vacuum, or the total electric flux over the closed surface in vacuum is $\frac{1}{\varepsilon_0}$ times the total charge (Q) contained inside S.

$$\phi_E = \oint \vec{E}.d\vec{S} = \frac{Q}{\varepsilon_0} \qquad (1 \text{ mark})$$

Electric field intensity due to a thin infinite sheet of charge:

Let σ be the surface density of charge and P be a point at a distance r from the sheet where $\vec{E}$ has to be calculated. $\vec{E}$ on either side is perpendicular to the sheet.



Imagine a cylinder of cross-sectional area ds around P and length 2r, piercing through the sheet. At the two edges, $\vec{E} \parallel \hat{n}$ (or $\overline{dS}$). At the curved surfaces $\vec{E} \perp \hat{n}$ (or $\overline{dS}$). So, there is no contribution to electric flux from the curved surfaces of the cylinder.

Electric flux over the edges $= 2\vec{E}.\overline{dS} = 2EdS$

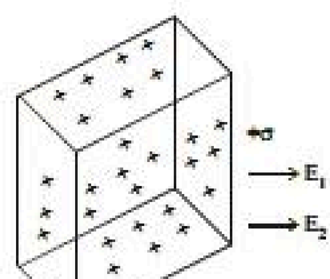
Total charge enclosed by the cylinder = σ dS

By Gauss's theorem, $2EdS = \frac{q}{\varepsilon_0} = \frac{\sigma dS}{\varepsilon_0}$

$\therefore E = \frac{\sigma}{2\varepsilon_0}$.

If the infinite plane sheet has uniform thickness, the surface density of charge is same on both the surfaces of the sheet.

Electric field intensity at any point P due to each surface $= E_1 = E_2 = \sigma/2\varepsilon_0$

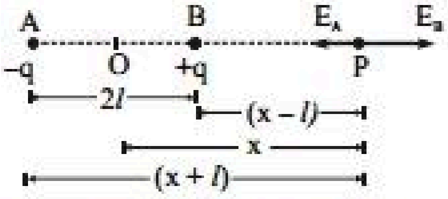


$\therefore$ By superposition principle, total electric field intensity

$$= E = E_1 + E_2 = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}. \qquad (2 \text{ marks})$$

OR

(a) We have to calculate the field intensity (E) at a point P on the axial line of the dipole and at a distance OP = x from the centre O of the dipole.



Electric field on axial line of an electric dipole

Resultant electric field intensity at the point P is

$E_p = E_A + E_B$

The vectors E_A and E_B are collinear and opposite.

$\therefore \quad E_p = E_B - E_A$

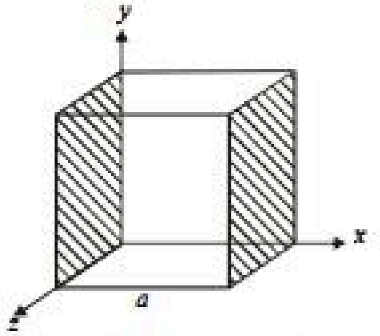
Here, $E_A = \frac{1}{4\pi\varepsilon_0}.\frac{q}{(x+l)^2} \Rightarrow E_B = \frac{1}{4\pi\varepsilon_0}.\frac{q}{(x-l)^2}$

$\therefore E_p = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{(x-l)^2} - \frac{q}{(x+l)^2}\right] = \frac{1}{4\pi\varepsilon_0}\frac{4qlx}{(x^2-l^2)^2}$

Hence, $E_p = \frac{1}{4\pi\varepsilon_0}\frac{4px}{(x^2-l^2)^2}$ (2½ marks)

If dipole is short, $2l << x$, then $E_p = \frac{2px}{4\pi\varepsilon_0 x^3}$

(b) The electric field has only x component, for faces normal to x direction, the angle between E and Δs is $\pm\frac{\pi}{2}$. Therefore, the flux is separately zero for each face of the cube except the two shaded ones.



The magnitude of the electric field at the left face is $E_L = 0$ (As x = 0 at the left face)

The magnitude of the electric field at the right face is $E_R = 2a$ (As $x = a$ at the right face)

Their corresponding fluxes are

$\phi_L = \vec{E}_L . \Delta\vec{S} = 0$

$\phi_R = \vec{E}_L . \Delta\vec{S} = E_R \Delta S \cos\theta = E_R \Delta S$ ($\because \theta = 0°$)

$\Rightarrow \phi_R = E_R a^2$

Net flux (ϕ) through the cube $= \phi_L + \phi_R = 0 + E_R a^2 = E_R a^2$

$\phi = 2a(a^2) = 2a^3$

From, Gauss's law

$\phi = \frac{q}{\varepsilon_0} \Rightarrow q = \phi\varepsilon_0$ (2½ marks)

$\therefore q = 2a^3\varepsilon_0$

32. Phase difference between voltage and current,

$\tan\phi = \frac{X_L - X_C}{R}$ .....(i)

and, $I_0 = \frac{V_0}{2} = \frac{V_0}{\sqrt{(X_L - X_C)^2 + R^2}}$

$\therefore$ Expression of AC, $I = I_0 \sin(\omega t = \phi)$ (2 marks)

Condition for resonance

Inductive reactance must be equal to capacitive reactance

i.e., $X_L = X_C$

As, $X_L = X_C$ (1 mark)

$\Rightarrow \omega_0 L = \frac{1}{\omega_0 C} \Rightarrow \omega_0^2 = \frac{1}{LC}$

$\omega_0 = \frac{1}{\sqrt{LC}}$

where, ω_0 = resonant angular frequency.

Impedance becomes minimum and equal to ohmic resistance

i.e., $Z = Z_{minimum} = R$

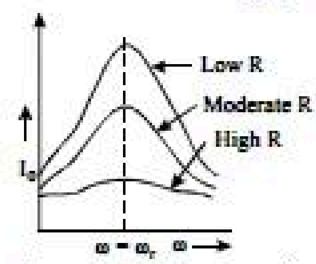
AC becomes maximum,

$\therefore I_{max} = \frac{V_{max}}{Z_{min}} = \frac{V_{max}}{R}$ (2 marks)

Voltage and current arrives in same phase.

OR

(a)



The sharpness of resonance in series L-C-R circuit refers how quick fall of alternating current in circuit takes place when frequency of alternating voltage shifts away from resonant frequency. It is measured by quality factor (Q-factor) of circuit.

The Q-factor of series resonant circuit is defined as the ratio of the voltage developed across the capacitance or inductance at resonance to the impressed voltage which is the voltage applied.

i.e., quality factor (Q) = $\frac{\text{voltage across L or C}}{\text{applied voltage}}$

$Q = \frac{(\omega_r L) I}{RI}$

[$\because$ applied voltage = voltage across R]

or $Q = \frac{\omega_r L}{R}$ or $Q = \frac{(1/\omega_r IC) I}{RI} = \frac{1}{RC\omega_r}$

$\therefore Q = \frac{L}{RC.\frac{1}{\sqrt{LC}}}$ $\left[\text{using } \omega_r = \frac{1}{\sqrt{LC}}\right]$

$= \frac{1}{R}\sqrt{\frac{L}{C}}$

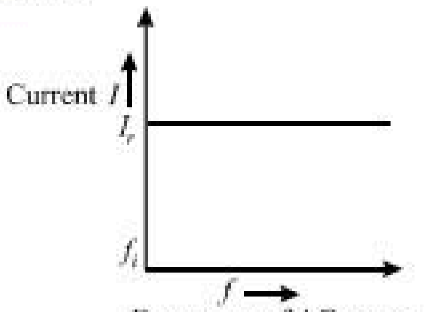
or $Q = \frac{1\sqrt{LC}}{RC} = \frac{1}{R}\sqrt{\frac{L}{C}}$ $\left[\text{using } \omega_r = \frac{1}{\sqrt{LC}}\right]$

Thus, $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$ (2 marks)

This is required expression.

(b) Let initially I_r current is flowing in all the three circuits. If frequency of applied AC source is increased then, the change in current will occur in following manner:

Circuit containing resistance R only There will not be any effect in the current, on changing the frequency of AC source.



(1 mark)

where, f_i = initial frequency of AC source.

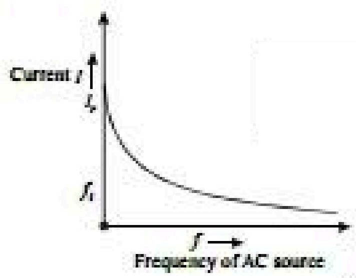
There is no effect on current with the increase in frequency.

AC circuit containing inductance only With the increase of frequency of AC source, inductive reactance increase as

$$I = \frac{V_{rms}}{X_L} = \frac{V_{rms}}{2\pi fL}$$

For given circuit,

$$I \propto \frac{1}{f}$$



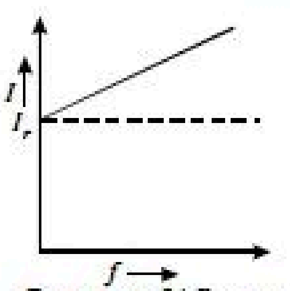
(1 mark)

Current decreases with the increase of frequency.

AC circuits containing capacitor only

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$$

Current, $I = \frac{V_{rms}}{X_C} = \frac{V_{rms}}{\left(\frac{1}{2\pi fC}\right)}$



(1 mark)

$$I = 2\pi fCV_{rms}$$

For given circuit, $I \propto f$

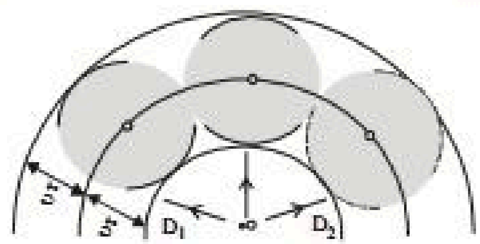
Current increases with the increase of frequency.

33. (a) **A wavefront** is defined as the continuous locus of all the particles of a medium, which are vibrating in the same phase or it is a surface of constant phase. (½ mark)

Huygens' principle:

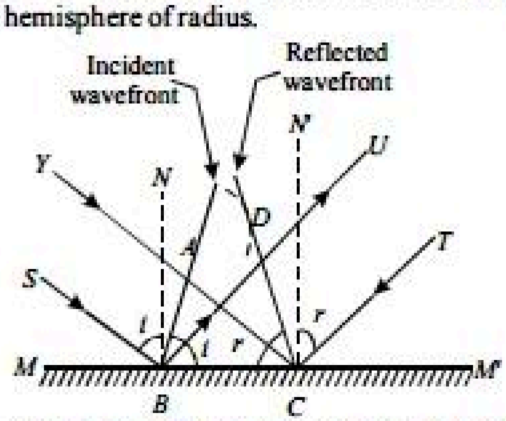
(1) Every points on the given wavefront (called primary wavefront) acts as a fresh source of new disturbance (secondary wavelets), which travel in all directions with the velocity of light in the medium.

(2) A surface touching these secondary wavelets, tangentially in the forward direction at any instant gives the new wavefront at that instant. This is called secondary wavefront. (1 mark)



The above model has one shortcoming: we also have a backwave which is shown as D_1D_2 in figure. Huygens argued that the amplitude of the secondary wavelets is maximum in the forward direction and zero in the backward direction, by making this assumption, Huygens could explain the absence of the backwave.

Let a plane wavefront AB is incident on the plane mirror MM'. As per Huygen's wave theory, every point on wavefront again behaves like a light source and emits secondary wavelets. In the time taken by the wave to reach from A to C, the secondary wavelets from B gets spread over a hemisphere of radius.



where, c is velocity of light and t is the time taken by wave in going from A to C. The tangent plane CD drawn from the point C over this hemisphere of radius ct gives new reflected wavefront CD corresponding to incident wavefront AB.

Let i and r be angles of incidence and reflection respectively.

Now, in ΔABC and ΔDCB

$\angle BAC = \angle CDB$ [each 90°, ray ⊥ wavefront]

BC = BC (common)

AC = DB [From Eq. (i)]

$\Rightarrow \Delta ABC \cong \Delta DCB$ (RHS congruence)

$\Rightarrow \angle ABC = \angle DCB$

or $i = r$

$$\left[\because SB \perp AB \Rightarrow \angle NBA = 90° - i \text{ and } BN \perp BC \Rightarrow \angle ABC = i\right]$$

Similarly, $\angle N'CT = \angle DCB = r$

$\Rightarrow$ Angle of incidence = Angle of reflection

Also, incident ray, reflected ray and normal meet at one point on a plane.

Thus, laws of reflection are verified using Huygen's principle. (2 marks)

(b) As the number of point sources increases, their contribution towards intensity also increases. Intensity varies as square of the slit width. Thus, when the width of the slit is made double the original width, intensity will get four times of its original value.

Width of central maximum is given by, $\beta = \frac{2D\lambda}{b}$

So, with the increase in size of slit, the width of central maxima decreases. Hence, double the size of the slit would results as half the width of the central maxima. (1 mark)

(c) The waves diffracted from the edge of the circular obstacle interfere constructively at the centre of the shadow producing a bright spot. (½ mark)

OR

(i) (a) From the fringe width expression,

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

With the decrease in separation between two slits, the fringe-width d increases. (1 mark)

(b) For interference fringes to be seen,

$$\frac{s}{S} < \frac{\lambda}{d}$$

Condition should be satisfied

where, s = size of the source,

S = distance of the source from the plane of two slits.

As the source-slit-width increase, fringe pattern gets less and less sharp.

When the source-slit is so wide, the above condition does not satisfied and the interference pattern disappears. (1 mark)

(ii) Intensity at a point is given by,

$I = 4I' \cos^2 \phi/2$ (1 mark)

where, ϕ = phase difference,

I' = intensity produced by each one of the individual sources.

At central maxima, $\phi = 0$, the intensity at the central maxima,

$I = I_0 = 4I'$

or $I' = \frac{I_0}{4}$ ....(i)

As, path difference $= \frac{\lambda}{3}$

Phase difference,

$\phi' = \frac{2\pi}{\lambda} \times$ path difference $= \frac{2\pi}{\lambda} \times \frac{\lambda}{3} = \frac{2\pi}{3}$ (1 mark)

Now, intensity at the point,

$I'' = 4I' \cos^2 \frac{1}{2}\left(\frac{2\pi}{3}\right) = 4I' \cos^2 \frac{\pi}{3} = 4I' \times \frac{1}{4} = I'$ (1 mark)

or $I'' = \frac{I_0}{4}$ [From eq. (i)]

34. (i) By Gauss's theorem

Electric flux through the closed surface S is

$$\phi_s = \frac{\Sigma q}{\varepsilon_0} = \frac{+2q - q}{\varepsilon_0} = \frac{q}{\varepsilon_0}$$ (1 mark)

(ii) According to Gauss's law, flux through a closed surface is given by $\phi = \frac{q}{\varepsilon_0}$

Here, q is the charge enclosed by the Gaussian surface. Since, on increasing the radius of the Gaussian surface, charge through the spherical Gaussian surface will not be affected when its radius is increased. (1 mark)

(iii) The flux is zero according to Gauss' Law because it is a open surface which enclosed a charge q. (2 marks)

OR

(iii) According to Gauss' Law

$$\oint E.ds = \frac{Q_{\text{enclosed by closed surface}}}{\varepsilon_0} = \text{flux}$$

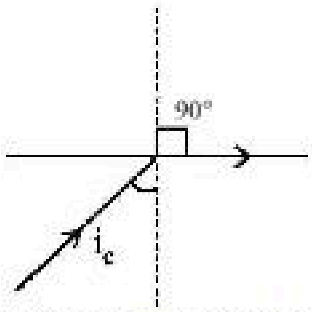
so total flux = Q/ε_0

Since cube has six face, so flux coming out through one wall or one face is $Q/6\varepsilon_0$. (2 marks)

35. (i) Because refractive index for a given pair of media is independent of frequency of light. (1 mark)

(ii) Refractive index, $\mu = \frac{1}{\sin C}$ (1 mark)

(iii) For total internal reflection when $i = i_c$, then



refracted ray grazes with the surface. That means the angle of refraction $r = 90°$. (2 marks)

OR

(iii) Criteria for total internal reflection of light are.

(a) Light must travel from a denser to a rarer medium. (1 mark)

(b) Angle of incidence must be greater than the critical angle. (1 mark)