SAMPLE QUESTION PAPER

BLUE PRINT

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

S. No.	Chapter	VSA/ AR/ Case Based (1 mark)	SA-I (2 marks)	SA-II (3 marks)	LA (5 marks)	Total
1.	Electrostatics	2(5)	2(4)	1(3)	–	**7(16)**
2.	Current Electricity	1(1)	–	1(3)	–	
3.	Magnetic Effects of Current and Magnetism	2(2)	1(2)	–	1(5)	**9(17)**
4.	Electromagnetic Induction and Alternating Current	3(3)	1(2)	1(3)	–	
5.	Electromagnetic Waves	3(3)	1(2)	–	–	**9(18)**
6.	Optics	1(1)	2(4)	1(3)	1(5)	
7.	Dual Nature of Radiation and Matter	1(1)	1(2)	–	–	**4(12)**
8.	Atoms and Nuclei	1(4)	–	–	1(5)	
9.	Electronic Devices	2(2)	1(2)	1(3)	–	**4(7)**
	Total	**16(22)**	**9(18)**	**5(15)**	**3(15)**	**33(70)**

Subject Code : **042**

PHYSICS

Time allowed : 3 hours ***Maximum marks : 70***

(i) *All questions are compulsory. There are 33 questions in all.*

(ii) *This question paper has five sections: Section A, Section B, Section C, Section D and Section E.*

(iii) *Section A contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each. Section B has two case based questions of 4 marks each, Section C contains nine short answer questions of 2 marks each, Section D contains five short answer questions of 3 marks each and Section E contains three long answer questions of 5 marks each.*

(iv) *There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.*

SECTION - A

All questions are compulsory. In case of internal choices, attempt any one of them.

1. If a *LC* circuit is considered analogous to a harmonically oscillating spring block system, which energy of the *LC* circuit would be analogous to potential energy and which one analogous to kinetic energy?

2. What happens to the width of depletion layer of a *p-n* junction when it is (i) forward biased, (ii) reverse biased ?

OR

Can the potential barrier across a *p-n* junction be measured by simply connecting a voltmeter across the junction?

3. What is the rest mass of a photon?

4. Is Huygen's principle valid for longitudinal sound waves?

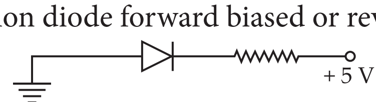
5. Geologists claim that besides the main magnetic *N-S* poles, there are several local poles on the earth's surface oriented in different directions. How is such a thing possible at all?

OR

If you made a map of magnetic field lines at Melbourne in Australia, would the lines seem to go into the ground or come out of the ground?

6. Name the electromagnetic waves, which (i) maintain the Earth's warmth and (ii) are used in aircraft navigation.

7. In the following diagram, is the junction diode forward biased or reverse biased?



8. Why are alloys used for making standard resistance coils?

OR

What are the factors on which the resistivity of a conductor depends ?

9. Both alternating current and direct current are measured in amperes. But how is the ampere defined for an alternating current?

10. Professor C.V. Raman surprised his student by suspending freely a tiny light ball in a transparent vacuum chamber by shining a laser beam on it. Which property of EM waves was he exhibiting? Give one more example of this property.

OR

Do electromagnetic waves carry energy and momentum?

For question numbers 11, 12, 13 and 14, 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.

11. **Assertion (A) :** When a magnetic dipole is placed in a non-uniform magnetic field, only a torque acts on the dipole.

Reason (R) : Force would act on dipole if magnetic field is uniform.

12. **Assertion (A) :** Electric potential of earth is taken zero.

Reason (R) : No electric field exists on earth surface.

13. **Assertion (A) :** UV radiation causes photo dissociation of ozone into O_2 and O, thus causing damage to the stratospheric ozone layer.

Reason (R) : Ozone hole is resulting in global warming and climate change.

14. **Assertion (A) :** An emf is induced in a closed loop where magnetic flux is varied.

Reason (R) : Line integral of induced electric field around the closed loop is non-zero.

SECTION - B

Questions 15 and 16 are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

15. According to Bohr's theory, electrons of an atom revolve around the nucleus on certain orbits, or electron shells. Each orbit has its specific energy level, which is expressed as a negative value. This is because the electrons on the orbit are "captured" by the nucleus via electrostatic forces, and impedes the freedom of the electron. The orbits closer to the nucleus have lower energy levels because they interact more with the nucleus, and vice versa.

(i) An excited state electron drops down to the ground state and emits a photon of yellow light. If instead the electron drops down to a lower excited state, then the light emitted would be

(a) red (b) blue (c) ultraviolet (d) green

(ii) Which of the following transitions in hydrogen atom will have the longest wavelength?

(a) $n = 4$ to $n = 1$ (b) $n = 5$ to $n = 4$ (c) $n = 7$ to $n = 1$ (d) $n = 2$ to $n = 1$

(iii) The electron in a hydrogen atom is in the first excited state, when the electron acquires an additional 2.86 eV of energy. What is the quantum number, n, of the state into which the electron moves?

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

(iv) Calculate the energy required to excite a hydrogen atom by causing an electronic transition from the energy level with $n = 1$ to the level with $n = 4$.

(a) 2.043×10^{-18} J (b) 1.632×10^{-29} J

(c) 2.192×10^{5} J (d) 2.254×10^{-18} J

(v) In the hydrogen atom, the transition that gives radiation in the visible region is

(a) from $n > 1$ to $n = 1$ (b) from $n > 1$ to $n = 1$

(c) from $n > 3$ to $n = 1$ (d) from $n > 2$ to $n = 2$

16. According to Coulomb's Law, force F_0 between two electrostatic charges q_1, q_2 separated in air/vacuum by a distance r is $F_0 = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$.

When air is replaced by an insulating medium of dielectric constant K, then $F_m = \frac{q_1 q_2}{4\pi\varepsilon r^2} = \frac{q_1 q_2}{4\pi\varepsilon_0 K r^2} = \frac{F_0}{K}$

where $\varepsilon = K\varepsilon_0$ or $K = \frac{\varepsilon}{\varepsilon_0} = \frac{F_0}{F_m}$

(i) If the medium between two charges is air, then the value of constant k in SI units will be

(a) 5×10^9 N m² C^{-2} (b) 7×10^9 N m² C^{-2} (c) 8×10^9 N m² C^{-2} (d) 9×10^9 N m² C^{-2}

(ii) Ratio of force of repulsion between two electrons and two protons separated by same distance in air is

(a) 1 : 1 (b) $m_e : m_p$ (c) $m_p : m_e$ (d) none of these.

(iii) Two charges +3μC and –5μC are held in air at unit distance. The ratio of the force exerted by one on the other is

(a) 3 : 5 (b) 5 : 3 (c) 1 : 1 (d) 15 : 1

(iv) Two charges +8μC and –6μC held certain distance apart in air attract each other with a force of 12 N. A charge of +4μC is added to each. The force between the new charges held the same distance apart in air would be

(a) 12 N (b) 2 N (c) 6 N (d) 24 N

(v) A force of 2.25 N acts on a charge of 15×10^{-4} C. The intensity of electric field at the point is

(a) 150 N C^{-1} (b) 15 N C^{-1} (c) 1500 N C^{-1} (d) 1.5 N C^{-1}

SECTION - C

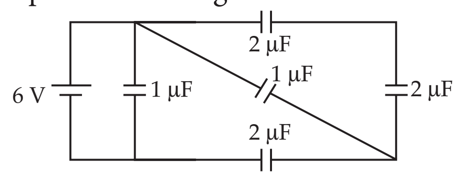
All questions are compulsory. In case of internal choices, attempt anyone.

17. Prove that the average energy density of the oscillating electric field is equal to that of the oscillating magnetic field.

18. **(a)** An electrostatic field line is a continuous curve, *i.e.*, a field line cannot have sudden breaks. Why?

(b) Explain why two field lines never cross each other at any point.

19. Find the total energy stored in the capacitors in the given network.



20. Can the instantaneous power output of an ac source ever be negative? Can the average power output be negative?

21. Light from bulb falls on a wooden table, but no photoelectrons are emitted. Why ?

OR

Draw a graph showing the variation of stopping potential with frequency of incident radiation. What does the slope of the line with frequency axis indicate ?

22. A magnetic dipole is under the influence of two magnetic fields. The angle between the field directions is 60°, and one of the fields has a magnitude of 1.2×10^{-2} T. If the dipole comes to stable equilibrium at an angle of 15° with this field, what is the magnitude of the other field?

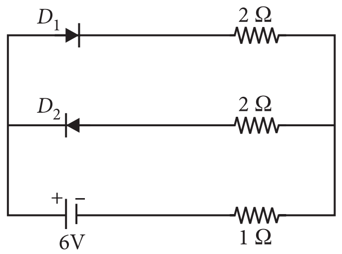
23. **(a)** State the condition for total internal reflection.

(b) Calculate the speed of light in the medium whose critical angle is 45°.

24. With what considerations in view is a photodiode fabricated ?

OR

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 1 Ω resistor.



25. Yellow light (λ = 6000 Å) illuminates a single slit of width 1×10^{-4} m. Calculate the distance between two dark lines on either side of the central maximum, when the diffraction pattern is viewed on a screen kept 1.5 m away from the slit.

OR

A ray of light travelling through rarer medium is incident at very small angle i on a glass slab and after refraction its velocity is reduced by 20%. Find the angle of deviation.

SECTION - D

All questions are compulsory. In case of internal choices, attempt any one.

26. Draw the energy band diagram of (i) n-type, and (ii) p-type semiconductors at temperatures $T > 0$ K.
In the case of n-type Si-semiconductor, the donor energy level is slightly below the bottom of conduction band whereas in p-type semiconductor, the acceptor energy level is slightly above the top of valence band. Explain, giving examples, what role do these energy levels play in conduction and valence bands.

27. In Young's double slit experiment, explain with reason in each case, how the interference pattern changes, when

(i) width of the slit is doubled

(ii) separation between the slits is increased and

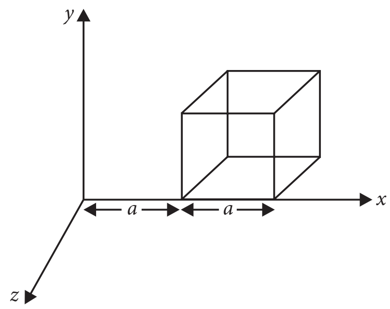
(iii) screen is moved away from the plane of slits.

OR

(a) Use Huygens geometrical construction to show how a plane wavefront at $t = 0$ propagates and produces a wavefront at a later time.

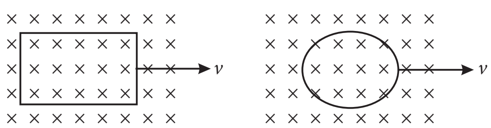
(b) When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency. Explain why?

28. State Gauss's law in electrostatics. A cube with each side 'a' is kept in an electric field is given by $\vec{E} = Cx\hat{i}$, (as is shown in the figure) where C is a positive dimensional constant. Find out



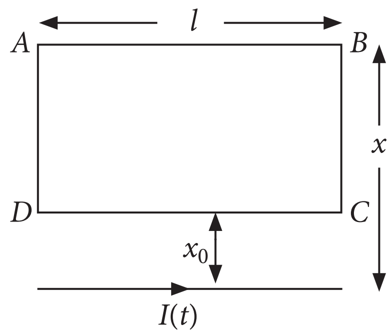
(i) the electric flux through the cube (ii) the net charge inside the cube.

29. A rectangular loop, and a circular loop having the same area, are moved out of a uniform magnetic field region, to a field free region, with a constant velocity $\vec{v}$. Would the induced emf remain constant in the two loops as they move out of the field region? Justify your answer.



OR

Consider an infinitely long wire carrying a current $I(t)$, with $\frac{dI}{dt} = \lambda$ (constant). Find the current produced in the rectangular loop of wire $ABCD$ placed next to the wire at distance x_0 if its resistance is R.



30. Two wires made of tinned copper having identical cross-section ($= 10^{-6}$ m^2) and lengths 10 cm and 15 cm are to be used as fuses. Show that the fuses will melt at the same value of current in each case.

SECTION - E

All questions are compulsory. In case of internal choices, attempt any one.

31. (a) Draw a ray diagram to show the formation of the image of an object placed on the axis of a convex refracting surface of radius of curvature 'R', separating the two media of refractive indices 'n_1' and 'n_2' ($n_2 > n_1$). Use this diagram to deduce the relation $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$, where u and v represent respectively the distance of the object and the image formed.

(b) A convex lens of focal length f_1 is kept in contact with a concave lens of focal length f_2. Find the focal length of the combination.

OR

(a) Draw a ray diagram showing the image formation by an astronomical telescope when the final image is formed at infinity.

(b) (i) A small telescope has an objective lens of focal length 140 cm and an eyepiece of focal length 5.0 cm. Find the magnifying power of the telescope for viewing distant objects when the telescope is in normal adjustment and the final image is formed at the least distance of distinct vision.

(ii) Also find the separation between the objective lens and the eyepiece in normal adjustment.

32. (a) What is the relationship between the current and the magnetic moment of a current carrying circular loop? Use the expression to derive the relation between the magnetic moment of an electron moving in a circle and its related angular momentum.

(b) A muon is a particle that has the same charge as an electron but is 200 times heavier than it. If we had an atom in which the muon revolves around a proton instead of an electron, what would be the magnetic moment of the muon in the ground state of such an atom?

OR

(a) Magnetic force is always normal to the velocity of a charge and therefore does no work. An iron nail held near a magnet, when released, increases its kinetic energy as it moves to cling to the magnet. What agency is responsible for this increase in kinetic energy if not the magnetic field?

(b) If magnetic monopoles existed, how would Gauss's law of magnetism be modified?

(c) Does a bar magnet exert a torque on itself due to its own field? Does one element of a current carrying wire exert a force on another element of the same wire?

(d) Magnetic field arises due to charges in motion. Can a system have magnetic moment even though its net charge is zero?

33. It is proposed to use the nuclear reaction:

$$_1H^2 + {}_1H^2 \rightarrow {}_2He^4$$

in a nuclear reactor of 200 MW rating. If the energy from the above reaction is used with a 25% efficiency in reaction, how many grams of deuterium fuel will be needed per day? The masses of $_1H^2$ and $_2He^4$ nuclei are 2.0141 a.m.u. and 4.0026 a.m.u. respectively?

OR

(a) Using Bohr's postulates for hydrogen atom, show that the total energy (E) of the electron in the stationary states can be expressed as the sum of kinetic energy (K) and potential energy (U), where $K = -2U$. Hence deduce the expression for the total energy in the n^{th} energy level of hydrogen atom.

(b) Using the postulates of Bohr's model of hydrogen atom, obtain an expression for the frequency of radiation emitted when atom make a transition from the higher energy state with quantum number n_i to the lower energy state with quantum number n_f ($n_f < n_i$).

SOLUTIONS

1. In *LC* circuit, magnetic energy is analogous to kinetic energy and electrical energy is analogous to potential energy.

2. (i) Forward biased : As forward voltage opposes the potential barrier, therefore effective barrier potential decreases. It makes the width of the depletion layer smaller.
(ii) Reverse biased : As reverse voltage supports the potential barrier, therefore effective barrier potential increases. It makes the width of the depletion layer larger.

OR

No, the voltmeter should have a very high resistance as compared to the resistance of *p-n* junction, which is nearly infinite.

3. Rest mass of a photon is zero.

4. Yes, Huygen's principle is valid for longitudinal as well as transverse waves and for all wave phenomena.

5. Localised magnetic dipoles can develop due to magnetised mineral deposits or movement of charged ions in atmosphere.

OR

Melbourne is closer to south pole, so north of the assumed magnet buried within earth lies inside, hence the field lines would seem to be coming out of the ground.

6. (i) Infra-red rays (ii) Microwaves.

7. Voltage at *p* side is less than voltage at *n* side of the diode, so it is in reverse bias.

8. Alloys are used for making standard resistance coils because they have low value of temperature coefficient of resistance and high resistivity.

OR

Resistivity of a material, *i.e.*, $\rho = \frac{m_e}{ne^2\tau}$, is inversely proportional to number density of electrons, and relaxation time.

9. Ampere for alternating current is defined in terms of Joule's heating effect, which is independent of direction of current.

10. The property exhibited from the experiment is radiation pressure exerted by electromagnetic waves. Tails of comets are due to radiation pressure from sun.

OR

Yes, electromagnetic waves carry energy and momentum.

11. (b) : A dipole placed in non-uniform magnetic field, experience magnetic force as well as torque while in uniform field on it experience torque only.

12. (c) : Electric potential of earth is taken as zero, because the capacitance of earth is taken infinite.

13. (b) : $O_3 \xrightarrow{\text{UV (sun)}} O_2 + O$

14. (a)

15. (i) (a) : When an electron is emitted from an excited state, the difference in energy of the orbitals is equal to the energy of emitted photon.

$E = h\upsilon.$

If instead of ground state, the electron drops to a lower excited state, the energy difference becomes lower and the frequency decreases.

(ii) (b)

(iii) (d) : Energy of n^{th} excited state,

$E_n = \frac{-13.6}{n^2}$

For $n = 2$, $E_2 = -3.4$ eV.

Given: $E_n = E_2 + 2.86 \text{ eV} = -0.54 \text{ eV}$

$\therefore \quad \frac{-13.6}{n^2} = -0.54 \text{ eV} \Rightarrow n = 5.$

(iv) (a) : The energy difference between levels $n = 1$ and $n = 4$

$$\Delta E = \left[\frac{-13.6}{1^2} + \frac{13.6}{4^2}\right] = -12.75 \text{ eV} = -2.04 \times 10^{-18} \text{ J}$$

(v) (d) : The hydrogen atom gives visible spectral lines in the balmer series because of the transitions from outer orbits to the 2nd orbit.

16. (i) (d) : $K = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{C}^{-2}.$

(ii) (a) : As $F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$

and charge on electron = charge on proton,

$\therefore$ *F* is same, *i.e.*, the ratio is 1 : 1.

(iii) (c) : Forces between two charges are equal and opposite. Therefore, the required ratio is 1 : 1.

(iv) (c) : As $F \propto q_1 q_2$

$$\therefore \quad \frac{F'}{F} = \frac{q_1' q_2'}{q_1 q_2} = \frac{(+8+4)(-6+4)}{(+8)(-6)}$$

$$\frac{F'}{12} = \frac{-24}{-48} = \frac{1}{2}$$

$F' = 6$ N

(v) (c) : Electric field, $E = \frac{F}{q} = \frac{2.25 \text{ N}}{15 \times 10^{-4} \text{ C}}$

$= 1500 \text{ N C}^{-1}$

17. In an electromagnetic wave, both E and B fields vary sinusoidally in space and time. The average energy density u of an e.m. wave can be obtained by replacing E and B by their rms value

$$u = \frac{1}{2}\varepsilon_0 E_{rms}^2 + \frac{1}{2\mu_0} B_{rms}^2 \quad \text{or} \quad u = \frac{1}{4}\varepsilon_0 E_0^2 + \frac{1}{4\mu_0} B_0^2$$

$$\left[\because \; E_{rms} = \frac{E_0}{\sqrt{2}}, B_{rms} = \frac{B_0}{\sqrt{2}}\right]$$

Moreover, $E_0 = cB_0$ and $c^2 = \frac{1}{\mu_0 \varepsilon_0}$, therefore

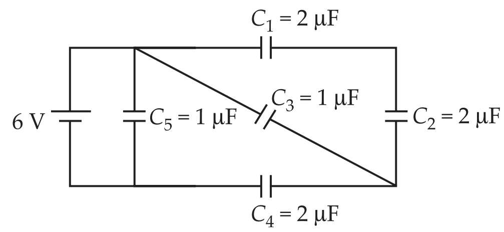
$$u_E = \frac{1}{4}\varepsilon_0 E_0^2 = \frac{1}{4}\varepsilon_0 (cB_0)^2$$

$$u_E = \frac{1}{4}\varepsilon_0 \cdot \frac{B_0^2}{\mu_0 \varepsilon_0} = \frac{1}{4\mu_0} B_0^2 = u_B$$

18. (a) An electrostatic field line is a continuous curve, because it represents the actual path of a unit positive charge, which experiences a continuous force. It cannot have sudden breaks because the moving test charge never jumps from one position to the other.

(b) No two electric field lines of force can intersect each other because at the point of intersection, we can draw two tangents to the two lines of force. This would mean two directions of electric field intensity at the same point which is not possible. Hence, no two electric lines of force can cross each other.

19.



As, C_1 and C_2 are in series, their equivalent capacitance,

$$C = \frac{2 \times 2}{2+2} = 1 \,\mu\text{F}$$

Now, C and C_3 are in parallel, their equivalent capacitance, $C' = 1 + 1 = 2$ μF

C' and C_4 are in series, their equivalent capacitance is

$$C'' = \frac{2 \times 2}{2+2} = 1 \,\mu\text{F}$$

Finally, C'' and C_5 are in parallel.

Thus the equivalent capacitance across the battery is

$C_{eq} = 1 + 1 = 2$ μF

Energy stored, $U = \frac{1}{2} C_{eq} V^2$

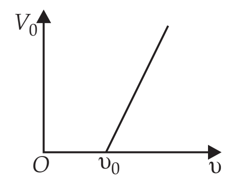
$$= \frac{1}{2} \times 2 \times 10^{-6} \times (6)^2 = 3.6 \times 10^{-5} \text{ J}$$

20. Instantaneous power output can be negative when E and I are out of phase in an ac circuit as $P = EI$. Average power over a cycle cannot be negative as $P_{av} = E_{rms} I_{rms} \cos\phi$ and $\cos\phi \geq 0$.

21. No photoelectrons are emitted, because frequency of light is less than the threshold frequency of wooden table.

OR

The V_0-υ graph is a straight line as shown in the figure.

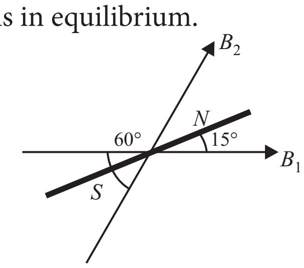


$eV_0 = h\upsilon - W_0$

$$V_0 = \frac{h}{e}\upsilon - \frac{W_0}{e}$$

Comparing the above relation with the equation of straight line, $y = mx + C$, we see the slope of V_0 - υ graph is $\frac{h}{e}$.

22. The magnetic dipole experiences torque due to both the fields and is in equilibrium.



$MB_1 \sin 15° = MB_2 \sin 45°$

$1.2 \times 10^{-2} \times 0.26 = B_2 (0.71)$

or $\quad B_2 = 0.44 \times 10^{-2}$ T.

23. (a) Conditions for total internal reflection are

(i) light must travel from denser to rarer medium.

(ii) angle of incidence must be greater than critical angle (C).

(b) We know that, $\sin C = \frac{1}{\mu} = \frac{v}{c}$

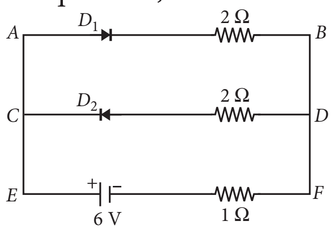
$$\Rightarrow \quad v = c \sin C = 3 \times 10^8 \times \sin 45° = 3 \times 10^8 \times \frac{1}{\sqrt{2}}$$

$$= 2.12 \times 10^8 \text{ m s}^{-1}$$

24. A photodiode is fabricated by allowing light to fall on a diode through a transparent window. It is fabricated such that the generation of *e*-*h* pairs take place near the depletion region.

OR

According to the question, $R = 2 + 1 = 3\ \Omega$



$$I_{EF} = \frac{\varepsilon}{R'} = \frac{6}{3/5} = 2\ \text{A}$$

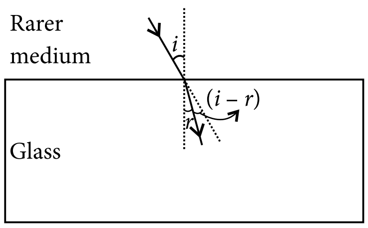
25. Here $a = 1 \times 10^{-4}$ m, $D = 1.5$ m
$\lambda = 6000\ \text{Å} = 6000 \times 10^{-10}$ m
The distance between the two dark bands on each side of central band is equal to width of the central bright band, *i.e.*,

$$\frac{2D\lambda}{a} = \frac{2 \times 1.5 \times 6000 \times 10^{-10}}{1 \times 10^{-4}} = 18\ \text{mm}$$

OR

Let velocity of light in rarer medium be v.

Then velocity of light in glass is $\frac{4v}{5}$.



∴ Refractive index of glass with respect to given rarer medium is $\mu = \frac{v}{4v/5} = \frac{5}{4}$

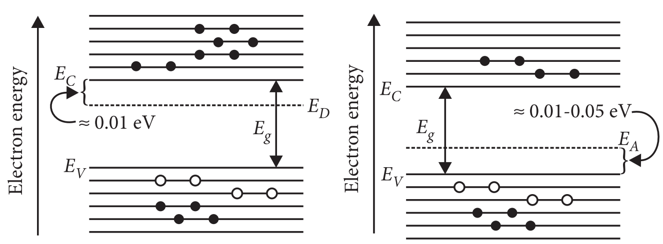
From Snell's law, $\mu = \frac{\sin i}{\sin r} \approx \frac{i}{r}$

($\because$ for small angles, $\sin\theta \approx \theta$)

$\therefore \quad \frac{i}{r} = \frac{5}{4} \quad$ or $\quad r = \frac{4i}{5}$

$\therefore$ Angle of deviation $= i - r = i - \frac{4i}{5} = \frac{i}{5}$

26. The required energy band diagrams are given here.



(a) Energy band diagram of *n*-type semiconductor at $T > 0$ K

(b) Energy band diagram of *p*-type semiconductor at $T > 0$ K

In *n*-type extrinsic semiconductors, the number of free electrons in conduction band is much more than the number of holes in valence band. The donor energy level lies just below the conduction band. In *p*-type extrinsic semiconductor, the number of holes in valence band is much more than the number of free electrons in conduction band. The acceptor energy level lies just above the valence band.

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

(i) When the width of the slit is doubled; the intensity of interfering waves increases and fringes become brighter.

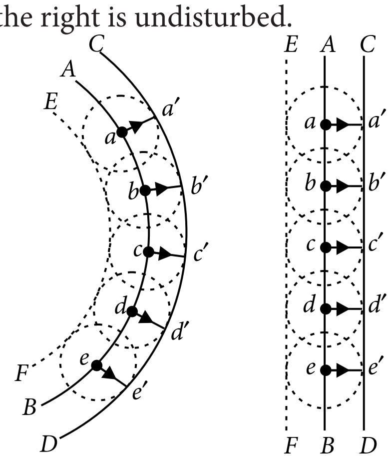
$$\frac{W_1}{W_2} = \frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} \Rightarrow \frac{W_2}{W_1} = \frac{a_2^2}{a_1^2} \Rightarrow \frac{a_2}{a_1} = \frac{\sqrt{2}}{1}$$

(ii) As $\beta \propto \frac{1}{d}$, therefore when separation between the slits is increased the fringe width decreases, *i.e.*, fringes come closer.

(iii) $\beta \propto D$, therefore when screen is moved away from the plane of the slits, the fringe width increases, *i.e.*, fringes become farther away.

OR

(a) Consider a spherical or plane wavefront moving towards right. Let *AB* be its position at any instant of time. The region on its left has received the wave while region on the right is undisturbed.



(a) (b)

Huygens geometrical construction for the propagation of (a) spherical, (b) plane wavefront.

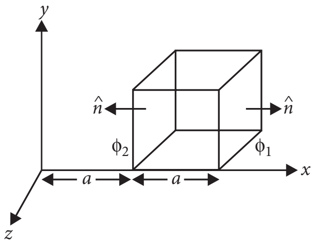
According to Huygens principle, each point on *AB* becomes a source of secondary disturbance, which takes with the same speed *c*. To find the new wavefront after time *t*, we draw spheres of radii *ct*, from each point on *AB*.

The forward envelope or the tangential surface *CD* of the secondary wavelets gives the new wavefront after time *t*.

The lines *aa*′, *bb*′, *cc*′, etc., are perpendicular to both *AB* and *CD*. Along these lines, the energy flows from *AB* to *CD*. So these lines represent the rays. Rays are always normal to wavefronts.

(b) Reflection and refraction arise through interaction of incident light with atomic constituents of matter which vibrate with the same frequency as that of the incident light. Hence frequency remains unchanged.

28. Gauss's law in electrostatics states that the total electric flux through a closed surface enclosing a charge is equal to $\frac{1}{\varepsilon_0}$ times the magnitude of that charge.



$$\phi = \oint \vec{E} \cdot d\vec{S} = \frac{q}{\varepsilon_0}$$

(i) Net flux, $\phi = \phi_1 + \phi_2$

where $\phi_1 = 2aC\, dS \cos 0°$

$= 2aC \times a^2 = 2a^3C$

$\phi_2 = aC \times a^2 \cos 180° = -a^3C$

$\phi = 2a^3C + (-a^3C) = a^3C \text{ Nm}^2 \text{ C}^{-1}$

(ii) Net charge $(q) = \varepsilon_0 \times \phi = a^3C\varepsilon_0$ coulomb

29. Magnitude of induced emf is directly proportional to the rate of area moving out of the field, for a constant magnetic field, $\varepsilon = -\frac{d\phi}{dt} = -B\frac{dA}{dt}$

For the rectangular coil, the rate of area moving out of the field remains same while it is not so for the circular coil. Therefore, the induced emf for the rectangular coil remains constant.

OR

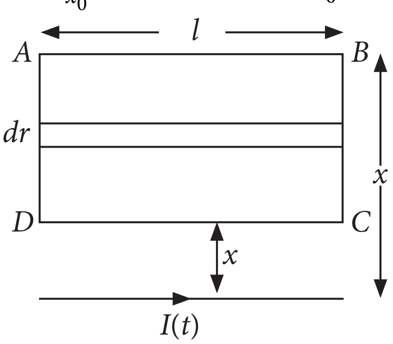
As per question, $\frac{dI}{dt} = \lambda$ = constant

Magnetic field at a distance r from the wire,

$B(r) = \frac{\mu_0 I}{2\pi r}$ (out of paper)

Magnetic flux linked with loop

$$\phi = \int_{x_0}^{x} B(r)dA = \int_{x_0}^{x} \frac{\mu_0 I}{2\pi r} l dr = \frac{\mu_0 Il}{2\pi} \ln \frac{x}{x_0}$$



Induced emf set up into the loop

$$|\varepsilon| = \frac{d\phi}{dt} = \frac{d}{dt}\left(\frac{\mu_0 Il}{2\pi} \ln \frac{x}{x_0}\right) = \frac{\mu_0 l}{2\pi}\left(\frac{dI}{dt}\right) \ln \frac{x}{x_0}$$

Current produced, $I = \frac{|\varepsilon|}{R} = \frac{\mu_0 l\lambda}{2\pi R} \ln \frac{x}{x_0}$

30. The temperature of the wire rises to a certain steady temperature θ if the heat produced per second by the current just becomes equal to the rate of loss of heat by radiation from it.

Heat produced per second by the current

$$H_1 = I^2R = \frac{I^2\rho l}{\pi r^2}$$

where l is the length, r is radius and ρ is the specific resistance of a wire.

Let H = heat lost per second per unit surface area of the wire.

Neglecting the loss of heat from the end faces of the wire.

Heat lost per second by the wire = $H \times 2\pi rl$

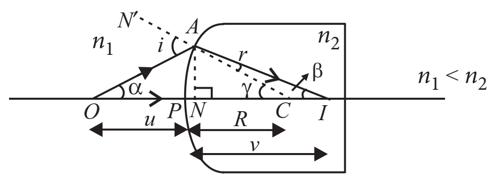
At steady state temperature,

$$H \times 2\pi rl = \frac{I^2\rho l}{\pi r^2} \quad \text{or} \quad H = \frac{I^2\rho}{2\pi^2 r^3} \quad ...(i)$$

From equation (i) we conclude that the rate of loss of heat (H), which in turn depends upon the temperature of wire, is independent of length of the wire. Hence the fuses of two wires of same values of r and ρ but of different lengths will melt for the same value of current in each case.

31. (a) Refraction at convex spherical surface

When object is in rarer medium and image formed is real.



In ΔOAC, $i = \alpha + \gamma$

and in ΔAIC, $\gamma = r + \beta$ or $r = \gamma - \beta$

$\therefore$ By Snell's law, ${}^1n_2 = \frac{\sin i}{\sin r} \approx \frac{i}{r} = \frac{\alpha + \gamma}{\gamma - \beta}$

or $\frac{n_2}{n_1} = \frac{\alpha + \gamma}{\gamma - \beta}$ or $n_2\gamma - n_2\beta = n_1\alpha + n_1\gamma$

or $(n_2 - n_1)\gamma = n_1\alpha + n_2\beta$ ...(i)

As α, β and γ are small and P and N lie close to each other, so $\alpha \approx \tan\alpha = \frac{AN}{NO} \approx \frac{AN}{PO}$

$\beta \approx \tan\beta = \frac{AN}{NI} \approx \frac{AN}{PI}$

$\gamma \approx \tan\gamma = \frac{AN}{NC} \approx \frac{AN}{PC}$

On using them in equation (i), we get

$$(n_2 - n_1)\frac{AN}{PC} = n_1\frac{AN}{PO} + n_2\frac{AN}{PI}$$

or $\dfrac{n_2 - n_1}{PC} = \dfrac{n_1}{PO} + \dfrac{n_2}{PI}$

where, $PC = +R$, radius of curvature

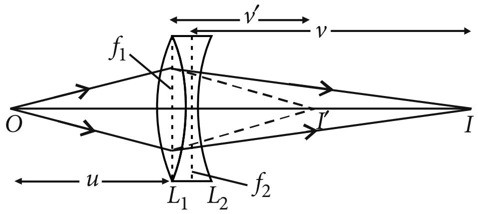
$PO = -u$, object distance

$PI = +v$, image distance

So, $\dfrac{n_2 - n_1}{R} = \dfrac{n_1}{-u} + \dfrac{n_2}{v}$ or $\dfrac{n_2 - n_1}{R} = \dfrac{n_2}{v} - \dfrac{n_1}{u}$

This gives formula for refraction at spherical surface when object is in rarer medium.

(b)



For convex lens

$$\frac{1}{f_1} = \frac{1}{v'} - \frac{1}{u} \quad ...(i)$$

For concave lens ($f_2 = -$ve)

$$-\frac{1}{f_2} = \frac{1}{v} - \frac{1}{v'} \quad ...(ii)$$

Adding equations (i) and (ii)

$$\frac{1}{f_1} - \frac{1}{f_2} = -\frac{1}{u} + \frac{1}{v}$$

Also, $\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$

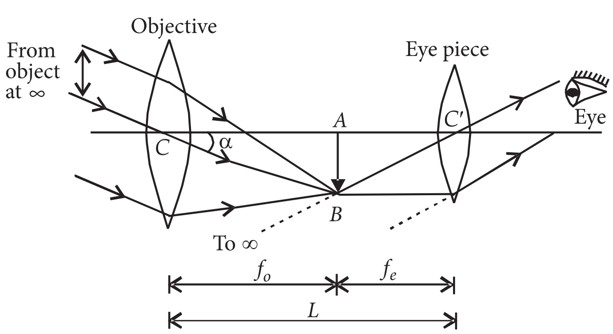
where f = focal length of combination

$$\therefore \frac{1}{f_1} - \frac{1}{f_2} = \frac{1}{f}$$

So, $f = \dfrac{f_1 f_2}{f_2 - f_1}$

OR

(a)



(b) (i) Given: $f_0 = 140$ cm, $f_e = 5$ cm

When final image is at infinity, magnifying power

$$m = \frac{-f_0}{f_e} = -\frac{140}{5.0} = -28$$

Negative sign shows that the image is inverted.

When final image is at the least distance of distinct vision, magnifying power,

$$m = \frac{-f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$$

$$= \frac{-140}{5.0}\left(1 + \frac{5.0}{25}\right) = -33.6$$

(ii) Separation between objective and eyepiece when final image is formed at infinity,

$L = f_0 + f_e$

$L = 140$ cm $+ 5.0$ cm $= 145$ cm

32. **(a)** Magnetic moment of current carrying loop is $M = IA$.

For an electron revolving in a circular orbit of radius r with speed v, effective current is

$$I = \upsilon e = \frac{ve}{2\pi r}$$

$\therefore$ Associated magnetic moment of electron revolving in orbit is

$$M = IA = \frac{ve}{2\pi r} \times \pi r^2 \quad \text{or} \quad M = \frac{evr}{2}$$

Related angular momentum is $\vec{L} = \vec{r} \times \vec{p}$

$L = rp \sin 90° = rmv \times 1$ or $L = mvr$

$$\Rightarrow L = m \times \frac{2M}{e} \qquad \left(\because vr = \frac{2M}{e}\right)$$

$$\Rightarrow L = \frac{2m}{e} M$$

(b) By Bohr's condition of quantisation, $mvr = \dfrac{nh}{2\pi}$

For ground state $n = 1$, so $mvr = \dfrac{h}{2\pi}$ or $vr = \dfrac{h}{2\pi m}$

or $\dfrac{evr}{2} = \dfrac{eh}{4\pi m}$ or $M = \dfrac{eh}{4\pi m}$

For muon, $M = \dfrac{1.6 \times 10^{-19}\,\text{C} \times 6.6 \times 10^{-34}\,\text{J s}}{4 \times 3.14 \times 200 \times 9.1 \times 10^{-31}\,\text{kg}}$

or $M = 4.6 \times 10^{-26}$ A m^2

OR

(a) An iron nail is made up of a large number of atoms, in which so many electronic charges are in motion. All these charges in motion experience a magnetic force when held near a magnet. The magnetic forces do not change speed of the charges, but they do change their velocity. The velocity of centre of mass may increase at the expense of nail's internal energy. Thus internal energy of the nail is responsible for increase in kinetic energy of the nail, as a whole.

(b) According to Gauss's law in magnetism, magnetic flux over any closed surface is always zero.

$$\oint_S \vec{B} \cdot d\vec{S} = 0$$

If monopoles existed, the magnetic flux would no longer be zero, but equal to μ_0 times the pole strength enclosed by the surface.

(c) No, there is no force or torque on an element due to the field produced by that element itself. But there is a force (or torque) on an element of the same wire. However, for the special case of a straight wire, this force is zero.

(d) Yes, a system can have magnetic moment even if its net charge is zero. For example, every atom of paramagnetic and ferromagnetic materials has a magnetic moment, though every atom is electrically neutral. Again, a neutron has no charge, but it does have some magnetic moment.

33. The fusion reaction used in the reactor is

$${}_1H^2 + {}_1H^2 \rightarrow {}_2He^4$$

Therefore, energy released per fusion reaction,

$E = [m_N({}_1H^2) + m_N({}_1H^2) - m_N({}_2He^4)] \times 931.5$

$= (2.0141 + 2.0141 - 4.0026) \times 931.5$

$0.0256 \times 931.5 = 23.846$ MeV

Power rating of the reactor,

$P = 200$ MW $= 200 \times 10^6$ J s^{-1}

Energy to be produced per day,

$W = P \times t = 200 \times 10^6 \times 24 \times 60 \times 60 = 1.728 \times 10^{13}$ J

Now, efficiency of the reactor is, $\eta = 25\% = \frac{25}{100} = \frac{1}{4}$

Hence, actual energy, the reactor is required to produce per day,

$$W' = \frac{W}{\eta} = \frac{1.728 \times 10^{13}}{1/4} = 6.912 \times 10^{13} \text{ J}$$

$$= \frac{6.912 \times 10^{13}}{1.6 \times 10^{-13}} = 4.32 \times 10^{26} \text{ MeV}$$

Therefore, number of fusion reactions needed per day,

$$n = \frac{W'}{E} = \frac{4.32 \times 10^{26}}{23.846} = 1.81 \times 10^{25}$$

Since in one fusion reaction, two deutrons are required, the number of deutrons needed per day,

$N = n \times 2 = 1.81 \times 10^{25} \times 2 = 3.62 \times 10^{25}$

Since a mass of 2g of ${}_1H^2$ contains number of deuterium nuclei equal to Avogadro number, *i.e.*, 6.02×10^{23}, mass of deuterium needed per day,

$$m = \frac{2}{\text{Avogadro number}} \times N = \frac{2 \times 3.62 \times 10^{25}}{6.02 \times 10^{23}}$$

$= 120.266$ g

OR

(a) According to Bohr's postulates for hydrogen atom, electron revolves in a circular orbit around the heavy positively charged nucleus. These are the stationary (orbits) states of the atom.

For a particular orbit, electron moves there, so it has kinetic energy.

Also, there is potential energy due to charge on electron and heavy positively charged nucleus.

Hence, total energy (E) of atom is sum of kinetic energy (K) and potential energy (U).

i.e., $E = K + U$

Let us assume that the nucleus has positive charge Ze. An electron moving with a constant speed v along a circle of radius r with centre at the nucleus.

Force acting on electron due to nucleus is given by

$$F = \frac{Ze^2}{4\pi\varepsilon_0 r^2}$$

The acceleration of electron $= \frac{v^2}{r}$ (towards the centre).

If m = mass of an electron, then from Newton's second law

$$F = m\left(\frac{v^2}{r}\right)$$

$$\Rightarrow \quad \frac{Ze^2}{4\pi\varepsilon_0 r^2} = m\left(\frac{v^2}{r}\right) \Rightarrow r = \frac{Ze^2}{4\pi\varepsilon_0 mv^2} \quad \text{...(i)}$$

From Bohr's quantisation rules,

$$mvr = n\frac{h}{2\pi} \quad \text{...(ii)}$$

Where, n is a positive integer

Substituting the value of r from eq. (i), we get

$$mv.\frac{Ze^2}{4\pi\varepsilon_0(mv^2)} = n\frac{h}{2\pi}$$

$$v = \frac{Ze^2}{2\varepsilon_0 hn} \quad \text{...(iii)}$$

So, kinetic energy, $K = \frac{1}{2}mv^2 = \frac{Z^2e^4}{8\varepsilon_0^2 h^2 n^2}$ ...(iv)

Potential energy of the atom,

$$U = -\frac{Ze^2}{4\pi\varepsilon_0 r} \quad \text{...(v)}$$

Using eq. (iii) in eq. (i), we get

$$r = \frac{Ze^2}{4\pi\varepsilon_0 m\frac{(Ze^2)^2}{(2\varepsilon_0 hn)^2}} = \frac{4\varepsilon_0^2 h^2 n^2}{(4\pi\varepsilon_0)mZe^2}$$

$$r = \frac{\varepsilon_0 h^2 n^2}{\pi m Ze^2}$$

Using value of r in eq. (v), we get

$$U = \frac{-Ze^2}{4\pi\varepsilon_0\left(\frac{\varepsilon_0 h^2 n^2}{\pi m Z e^2}\right)} = \frac{-Z^2 e^4 m}{4\varepsilon_0^2 h^2 n^2}$$

So, the total energy,

$E = K + U$

$$= +\frac{mZ^2e^4}{8\varepsilon_0^2 h^2 n^2} - \frac{mZ^2e^4}{4\varepsilon_0^2 h^2 n^2} = -\frac{Z^2 e^4 m}{8\varepsilon_0^2 h^2 n^2}$$

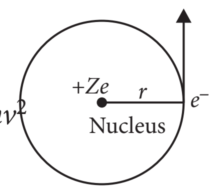
For H-atom $Z = 1$, so the total energy of the n^{th} energy level of H-atom.

$$E_n = -\frac{me^4}{8n^2\varepsilon_0^2 h^2}$$

(b) Suppose m be the mass of an electron and v be its speed in n^{th} orbit of radius r. The centripetal force for revolution is produced by electrostatic attraction between electron and nucleus.

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{r^2} \quad \text{...(i)}$$

or, $mv^2 = \dfrac{1}{4\pi\varepsilon_0}\dfrac{Ze^2}{r}$



So, kinetic energy $K = \dfrac{1}{2}mv^2$

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

Potential energy $= \dfrac{1}{4\pi\varepsilon_0}\dfrac{(Ze)(-e)}{r} = -\dfrac{1}{4\pi\varepsilon_0}\dfrac{Ze^2}{r}$

Total energy, E = K.E. + P.E.

$$= \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r} + \left(-\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}\right)$$

$$E = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r}$$

For n^{th} orbit, E can be written as

$$E_n = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r}$$

Again from Bohr's postulate for quantization of angular momentum.

$$mvr = \frac{nh}{2\pi}, \quad v = \frac{nh}{2\pi\, mr}$$

Substituting this value of v in equation (i), we get

$$\frac{m}{r}\left[\frac{nh}{2\pi mr}\right]^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r^2}$$

or, $r = \dfrac{\varepsilon_0 h^2 n^2}{\pi m Z e^2}$ or, $r_n = \dfrac{\varepsilon_0 h^2 n^2}{\pi m Z e^2}$ ...(ii)

Substituting value of r_n in equation (ii), we get

$$E_n = -\frac{1}{2\times 4\pi\varepsilon_0}\frac{Ze^2}{\left(\frac{\varepsilon_0 h^2 n^2}{\pi m Z e^2}\right)} = \frac{mZ^2e^4 \times ch}{8\varepsilon_0^2 ch^3 n^2}$$

or, $E_n = -\dfrac{Z^2 Rhc}{n^2}$, where $R = \dfrac{me^4}{8\varepsilon_0^2 ch^3}$

R is called Rydberg constant. For hydrogen atom $Z = 1$.

$$E_n = \frac{-Rch}{n^2}$$

If n_i and n_f are the quantum numbers of initial and final states and E_i and E_f are energies of electron in H-atom in initial and final state, we have

$$E_i = \frac{-Rch}{n_i^2} \quad \text{and} \quad E_f = \frac{-Rch}{n_f^2} \quad \text{...(iii)}$$

If υ is the frequency of emitted radiation.

we get $\upsilon = \dfrac{E_i - E_f}{h}$

from eq. (iii)

$$\upsilon = \frac{1}{h}\left(\frac{-Rch}{n_i^2} + \frac{Rch}{n_f^2}\right)$$

$$\upsilon = Rc\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

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