Class-XII
Session - 2022-23
Subject - Physics (Theory)
Sample Question Paper - 36
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	Electrostatic Potential and Capacitance			2 (Q. 21, 24)		1 (Q. 31)		9
3	Current Electricity		2 (Q. 1, 5)	1 (Q. 22)	1 (Q. 27)			7
4	Moving Charges and Magnetism	17	2 (Q. 4, 7)	1 (Q. 19)	1 (Q. 26)			7
5	Magnetism and Matter		1 (Q. 2)					1
6	Electromagnetic Induction					1 (Q. 32)		5
7	Alternating Current						1 (Q. 34)	4
8	Electromagnetic Waves	18	3 (Q. 3, 6, 18)	1 (Q. 25)				5
9	Ray optics and Optical Instruments					1 (Q. 33)	1 (Q. 35)	9
10	Wave Optics		2 (Q. 8, 17)	1 (Q. 20)				4
11	Dual Nature of Radiation and Matter	12			1 (Q. 28)			3
12	Atoms		1 (Q. 9)		1 (Q. 29)			4
13	Nuclei		2 (Q. 10, 11)		1 (Q. 30)			5
14	Semiconductor Electronics: Materials, Devices and Simple Circuits	7	5 (Q. 12, 13, 14, 15, 16)	1 (Q. 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. A 25 W and 100 W bulb are joined in series and connected to the mains. Which bulb will glow brighter?
(a) 25 W bulb (b) 100 W bulb
(c) Both bulb will glow brighter (d) None will glow brighter

2. Relative permittivity and permeability of a material are ε_r and μ_r, respectively. Which of the following values of these quantities are allowed for a diamagnetic material?
(a) $\varepsilon_r = 1.5, \mu_r = 0.5$ (b) $\varepsilon_r = 0.5, \mu_r = 0.5$ (c) $\varepsilon_r = 1.5, \mu_r = 1.5$ (d) $\varepsilon_r = 0.5, \mu_r = 1.5$

3. An em wave is propagating in a medium with a velocity $\vec{V} = V\hat{i}$. The instantaneous oscillating electric field of this em wave is along +*y* axis. Then the direction of oscillating magnetic field of the em wave will be along
(a) $-z$ direction (b) $+z$ direction (c) $-x$ direction (d) $-y$ direction

4. A long straight wire of radius a carries a steady current I. The current is uniformly distributed over its cross-section. The ratio of the magnetic fields B and B', at radial distances $\frac{a}{2}$ and 2a respectively, from the axis of the wire is :
(a) 1/4 (b) 1/2 (c) 1 (d) 4

5. The resistance of a metal increases with increasing temperature because
(a) the collisions of the conducting electrons with the electrons increase
(b) the collisions of the conducting electrons with the lattice consisting of the ions of the metal increase
(c) the number of conduction electrons decreases
(d) the number of conduction electrons increases

6. When light propagates through a material medium of relative pemittivity ϵ_r and relative permeability μ_r, the velocity of light, v is given by: (c-velocity of light in vacuum)
(a) $v = \sqrt{\frac{\mu_r}{\epsilon_r}}$ (b) $v = \sqrt{\frac{\epsilon_r}{\mu_r}}$ (c) $v = \frac{c}{\sqrt{\epsilon_r \mu_r}}$ (d) $v = c$

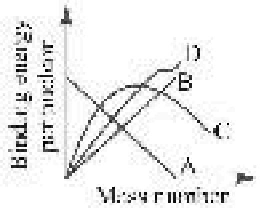
7. Current sensitivity of a moving coil galvanometer is 5 div/mA and its voltage sensitivity (angular deflection per unit voltage applied) is 20 div/V. The resistance of the galvanometer is
(a) 40 Ω (b) 25 Ω (c) 500 Ω (d) 250 Ω

8. In Young's double slit expt. the distance between two sources is 0.1 mm. The distance of the screen from the source is 20 cm. Wavelength of light used is 5460 Å. The angular position of the first dark fringe is
(a) 0.08° (b) 0.16° (c) 0.20° (d) 0.32°

9. The energy of a hydrogen atom in the ground state is – 13.6 eV. The energy of a He^+ ion in the first excited state will be
(a) $-13.6\,eV$ (b) $-27.2\,eV$ (c) $-54.4\,eV$ (d) $-6.8\,eV$

10. A certain mass of Hydrogen is changed to Helium by the process of fusion. The mass defect in fusion reaction is 0.02866 a.m.u. The energy liberated per a.m.u. is
(Given : 1 a.m.u = 931 MeV)
(a) 26.7 MeV (b) 6.675 MeV (c) 13.35 MeV (d) 2.67 MeV

11. Binding energy per nucleon plot against the mass number for stable nuclei is shown in the figure. Which curve is correct?
(a) A
(b) B
(c) C
(d) D



12. If the two ends of a p-n junction are joined by a wire
(a) there will not be a steady current in the circuit
(b) there will be a steady current from the n-side to the p-side
(c) there will be a steady current from the p-side to the n-side
(d) there may or may not be a current depending upon the resistance of the connecting wire

13. Pure Si at 500K has equal number of electron (n_e) and hole (n_h) concentrations of $1.5 \times 10^{16}\ m^{-3}$. Doping by indium increases n_h to $4.5 \times 10^{22}\ m^{-3}$. The doped semiconductor is of
(a) n–type with electron concentration $n_e = 5 \times 10^{22}\ m^{-3}$
(b) p–type with electron concentration $n_e = 2.5 \times 10^{10}\ m^{-3}$
(c) n–type with electron concentration $n_e = 2.5 \times 10^{23}\ m^{-3}$
(d) p–type having electron concentration $n_e = 5 \times 10^{9}\ m^{-3}$

14. A p-type semiconductor is
(a) positively charged (b) negatively charged (c) uncharged
(d) uncharged at 0K but charged at higher temperatures

15. In a p-type semiconductor the acceptor level is situated 60 meV above the valence band. The maximum wavelength of light required to produce a hole will be
(a) 0.207×10^{-5} m (b) 2.07×10^{-5} m (c) 20.7×10^{-5} m (d) 2075×10^{-5} m

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) :** When two semi conductor of *p* and *n* type are brought in contact, they form *p-n* junction which act like a rectifier.
Reason (R) : A rectifier is used to convent alternating current into direct current.

17. **Assertion (A) :** In YDSE, if $I_1 = 9I_0$ and $I_2 = 4I_0$ then $\frac{I_{max}}{I_{min}} = 25$.
Reason (R) : In YDSE $I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$ and $I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$.

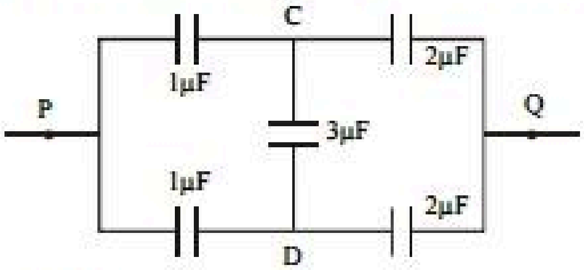
18. **Assertion (A) :** Ultraviolet radiations of higher frequency waves are dangerous to human being.
Reason (R) : Ultraviolet radiation are absorbed by the atmosphere.

SECTION-B

19. Define the S.I. unit of magnetic field. "A charge moving at right angles to a uniform magnetic field does not undergo change in kinetic energy." – Why?

20. Write the distinguishing features between a diffraction pattern due to a single slit and the interference fringes produced in Young's double slit experiment.

21. Calculate the equivalent capacitance of the combination between the points P and Q as shown in figure.



22. Deduce ohm's law using the concept of drift velocity.

23. The acceptor levels in p–type semiconductor are 57 meV above the valence band. Determine the maximum wavelength which can create a hole.

24. Two uniformly large parallel thin plates having charge densities $+\sigma$ and $-\sigma$ are kept in the X-Z plane at a distance d apart. Sketch an equipotential surface due to electric field between the plates. If a particle of mass m and charge – q remains stationary between the plates. What is the magnitude and direction of this field?

OR

Two point charges Q and q are placed at a distance of x and x/2 respectively from a third point charge 4q, all charges are on the same straight line. Calculate the magnitude and nature of charge Q, such that the net force experienced by the charge q is zero.

25. When can a charge act as a source of electromagnetic waves? How are the directions of electric and magnetic field vectors, in an electromagnetic wave related to each other and to the direction of propagation of the wave?
Which physical quantity, if any, has the same value for waves belonging to the different parts of electromagnetic spectrum?

OR

What do electromagnetic waves consist of? Explain on what factors does its velocity in vacuum depend.

SECTION-C

26. Derive an expression for the force on a current carrying conductor placed in a magnetic field.

27. A cell of emf 'E' and internal resistance 'r' is connected across a variable load resistor R. Draw the plots of the terminal voltage V versus (i) R and (ii) the current I.

28. A proton and an α-particle have the same de-Broglie wavelength. Determine the ratio of (i) their accelerating potentials (ii) their speeds.

OR

(i) Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. The power emitted is 2.0×10^{-3} W. Estimate the number of photons emitted per second on an average by the source.

(ii) Draw a plot showing the variation of photoelectric current versus the intensity of incident radiation on a given photosensitive surface.

29. Using Bohr's postulates, derive the expression for the frequency of radiation emitted when electron in hydrogen atom undergoes transition from higher energy state (quantum number n_i) to the lower state, (n_f).
When electron in hydrogen atom jumps from energy state $n_i = 4$ to $n_f = 3, 2, 1$. Identify the spectral series to which the emission lines belong.

OR

What do you understand by energy level diagram? Discuss the various series of hydrogen spectrum with its help.

30. From the relation $R = R_0 A^{1/3}$, where R_0 is a constant and A is the mass number of a nucleus, show that the nuclear matter density is nearly constant (i.e. independent of A).

SECTION-D

31. Using Gauss's law obtain the expression for the electric field due to uniformly charged spherical shell of radius R at a point outside the shell. Draw a graph showing the variation of electric field with r, for $r > R$ and $r < R$.

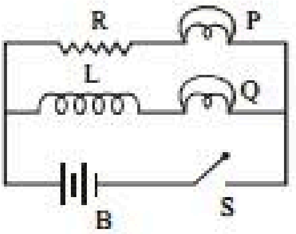
OR

(a) Derive the expression for the capacitance of a parallel plate capacitor having plate area A and plate separation d.

(b) Two charged spherical conductors of radii R_1 and R_2 when connected by a conducting wire acquire charges q_1 and q_2 respectively. Find the ratio of their surface charge densities in terms of their radii.

32. (i) State Faraday's laws of electromagnetic induction. Express it mathematically.

(ii) The given figure shows an inductor L and resistor R connected in parallel to a battery B through a switch S. The resistance of R is same as that of the coil that makes L. Two identical bulbs, P and Q are put in each arm of the circuit as shown in the figure. When S is closed, which of the two bulbs will light up earlier? Justify your answer.



OR

What do you mean by mutual inductance of two nearby coils? Find an expression for mutual inductance of a solenoid.

33. Define magnifying power of a telescope. Write its expression.

A small telescope has an objective lens of focal length 150 cm and an eyepiece of focal length 5 cm. If this telescope is used to view a 100 m high tower 3 km away, find the height of the final image when it is formed 25 cm away from the eyepiece.

OR

A ray of light passes through an equilateral prism in such a way that the angle of incidence is equal to the angle of emergence and each of these angles is 3/4th the angle of the prism. Determine the (i) angle of deviation and (ii) the refractive index of the prism.

SECTION-E

34. Case Study: Transformers

Read the following paragraph and answer the questions.

A thermal power plant produces electric power of 600 kW at 4000 V, which is to be transported to a place 20 km away from the power plant for consumers' usage. It can be transported either directly with a cable of large current carrying capacity or by using a combination of step-up and step-down transformers at the two ends. The drawback of the direct transmission is the large energy dissipation. In the method using transformers, the dissipation is much smaller. In this method , a step-up transformer is used at the plant side so that the current is reduced to a smaller value. At the consumers' end, a step-down transformer is used to supply power to the consumers at the specified lower voltage. It is reasonable to assume that the power cable is purely resistive and the transformers are ideal with power factor unity. All the currents and voltages mentioned are rms values.

(i) How can the flux leakage in a transformer be reduced?

(ii) What is the cause of hysteresis loss in a transformer?

(iii) Why can't transformer be used to step up or step down dc voltage?

OR

(iii) In a transformer $\frac{V_S}{V_P} = \frac{N_S}{N_P}$. What are the assumption made in obtaining the relation?

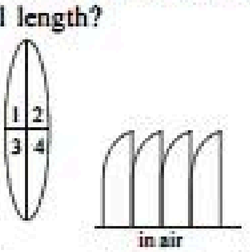
35. Case Study: Combination of thin lenses in contact

Read the following paragraph and answer the questions.

Combination of lenses helps to obtain diverging or converging lenses of desired magnification. It also enhances sharpness of the image. The total magnification m of the combination is a product of magnification (m_1, m_2, m_3,...) of individual lenses $m = m_1\ m_2\ m_3$ ... System of combination of lenses is commonly used in designing lenses for cameras, microscopes, telescopes and other optical instruments.

(i) Two identical thin plano-convex glass lenses (refractive index 1.5) each having radius of curvature of 20 cm are placed with their convex surfaces in contact at the centre. The intervening space is filled with oil of refractive index 1.7. Find the focal length of the combination.

(ii) The given lens is broken into four parts rearranged as shown. If the initial focal length is f, then after rearrangment. What is the equivalent focal length?



(iii) The power of a lens (biconvex) is 1.25 m^{-1} in particular medium. Refractive index of the lens is 1.5 and radii of curvature are 20 cm and 40 cm respectively. Find the refractive index of surrounding medium.

OR

(iii) A biconvex lens has radii of curvature, 20 cm each, if the refractive index of the material of the lens is 1.5. Find the power of the lens.

Solutions

SAMPLE PAPER-9

1. (a) Power, $P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P}$

i.e., $R \propto \frac{1}{P}$

i.e., the resistance of 25 W bulb is greater than 100 W bulb.
Heat produced by the bulbs, $H = I^2Rt$.
Since the bulbs are connected in series, current remains same.
i.e., $H \propto R$
i.e., The heat produced by 25 W bulb is greater and hence it will glow brighter. (1 mark)

2. (a) $\mu_r < 1$ and $\varepsilon_r > 1$. (1 mark)

3. (b) As we know,

$\vec{E} \times \vec{B} = \vec{V}$

$(E\hat{j}) \times (\vec{B}) = V\hat{i}$ ($\because$ Electric field vector is along +y axis)

So, $\vec{B} = B\hat{k}$ (1 mark)

i.e., direction of magnetic field vector is along +z direction.

4. (b) For radial distance r = a/2

$$B_1 = \frac{\mu_0 ir}{2\pi a^2} \Rightarrow B_1 = \frac{\mu_0 i}{4\pi a}$$

For radial distance r = 2a

$$B_2 = \frac{\mu_0 i}{4\pi a} \quad \therefore \frac{B_1}{B_2} = 1$$ (1 mark)

5. (a) The conduction electrons collides with each other more. the specific resistance of a conductor increases with temperature according to the reaction $\rho_T = \rho_0 e^{Eg/kgT}$ where ρ_0 is the specific resistance at 0° C, E_g = energy of the gap between the valence and the conduction band, k_B is the Boltzmann constant and T, the temperature of the resistor. (1 mark)

6. (c) We know that

$$V = \frac{1}{\sqrt{\mu\varepsilon}} \text{ and } C = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

So, $$\frac{V}{C} = \frac{\sqrt{\mu_0\varepsilon_0}}{\sqrt{\mu\varepsilon}} = \frac{\sqrt{\mu_0\varepsilon_0}}{\sqrt{\mu_0\varepsilon_0\mu_r\varepsilon_r}} = \frac{1}{\sqrt{\mu_r\varepsilon_r}}$$

$$V = \frac{C}{\sqrt{\mu_r\varepsilon_r}}$$ (1 mark)

7. (d) Current sensitivity of moving coil galvanometer

$$I_s = \frac{NBA}{C} \quad ...(i)$$

Voltage sensitivity of moving coil galvanometer,

$$V_s = \frac{NBA}{CR_G} \quad ...(ii)$$

Dividing eqn. (i) by (ii)
Resistance of galvanometer

$$R_G = \frac{I_s}{V_s} = \frac{5 \times 1}{20 \times 10^{-3}} = \frac{5000}{20} = 250\,\Omega$$ (1 mark)

8. (b) The position of n^{th} dark fringe. So position of first dark fringe in $x_1 = \lambda D / 2d$.
d = 20 cm, D = 0.1mm, λ = 5460 Å, x_1 = 0.16 (1 mark)

9. (a) Energy of a H-like atom in it's n^{th} state is given by

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

For, first excited state of He^+, n = 2, Z = 2 (1 mark)

$\therefore \quad E_{He^+} = -\frac{4}{2^2} \times 13.6 = -13.6 eV$

10. (b) Mass defect Δm = 0.02866 a.m.u.
Energy = 0.02866 × 931 = 26.7 MeV
As ${}_1H^2 + {}_1H^2 \longrightarrow {}_2He^4$
Energy liberated per a.m.u = 13.35/2 MeV
= 6.675 MeV (1 mark)

11. (c) Binding energy is lower for both light and heavy nuclei. (1 mark)

12. (a) If two ends of a p-n junction are joined by a wire, there will not be a steady current in the circuit. (1 mark)

13. (d) $n_i^2 = n_e n_h$
$(1.5 \times 10^{16})^2 = n_e(4.5 \times 10^{22})$
$\Rightarrow n_e = 0.5 \times 10^{10}$
or $n_e = 5 \times 10^9$
Given $n_h = 4.5 \times 10^{22}$
$\Rightarrow n_h >> n_e$
$\therefore$ Semiconductor is p-type and
$n_e = 5 \times 10^9 \, m^{-3}$. (1 mark)

14. (c) By doping, the band gap reduce from 1eV to 0.3 to 0.7 eV & electron can achieve this energy (0.3eV to 0.7eV) at room temperature & reach in C.B (conduction band). (1 mark)

15. (b) $$\lambda = \frac{hc}{E} = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{(60 \times 10^{-3} \times 1.6 \times 10^{-19})} = 2.07 \times 10^{-5} \text{ m}$$ (1 mark)

16. (b) Study of junction diode characteristics shows that the junction diode offers a low resistance path, when forward biased and high resistance path when reverse biased. This feature of the junction diode enables it to be used as a rectifier. (1 mark)

17. (b) $I_{max} = \left(\sqrt{9I_0} + \sqrt{4I_0}\right)^2 = 25I_0$

$I_{min} = \left(\sqrt{9I_0} - \sqrt{4I_0}\right)^2 = I_0$ (1 mark)

$\therefore \frac{I_{max}}{I_{min}} = 25$

18. (c) The wavelength of these wave ranges between 4000 Å to 100 Å that is smaller wavelength and higher frequency. They are absorbed by atmosphere and convert oxygen into ozone. They cause skin diseases and they are harmful to eye and cause permanent blindness. (1 mark)

19. The S.I. unit of magnetic field is tesla. (T)

The strength of magnetic field at a point is said to be 1T if a charge of 1C while moving at right angles to a magnetic field, with a velocity of 1 m/s experiences a force of 1 N at that point.

The force on a moving charged particle is F

$= qBv\sin\theta$

If $\theta = 90°$, i.e. the particle moves at right angles to the magnetic field, F = qBv which provides the necessary centripetal force for the circular motion of the particle. There is no linear acceleration. So no increase in linear velocity and hence in kinetic energy. (2 marks)

20. (i) In interference, all the bright frings have same intensity i.e., are equally bright while in difraction, all the bright fringes are not of the same intensity i.e., are not equally bright.

(ii) In interference, there is a good contrast between the bright and the dark fringes while in diffraction, there is a poor contrast between the dark and the the bright fringes. $(1 \times 2 = 2$ marks)

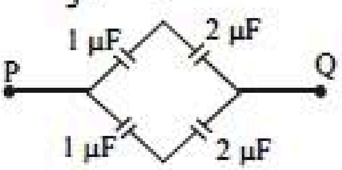
21. The potential at points C and D will be same, so no charge will flow through the 3 μF capacitor.

$\therefore$ The equivalent circuit is

1 μF and 2 μF are connected in series,

$\therefore\ C_1 = \frac{2\times1}{2+1} = \frac{2}{3}\mu F,\ C_2 = \frac{2}{3}\mu F$ (1 mark)

Two $\frac{2}{3}\ \mu F$ capacitors are connected in parallel,



$\therefore\ C_{eq} = C_1 + C_2 \Rightarrow C_{eq} = \frac{2}{3} + \frac{2}{3} = \frac{4}{3}\mu F$ (1 mark)

22. As we know, $I \propto v_d$ and $v_d \propto E$ and $E \propto V$

$\therefore I \propto V$ = which is ohm's law.

$v_d = -\frac{eE\tau}{m}$ and $E = -\frac{V}{\ell}$ $\therefore v_d = \frac{eV\tau}{m\ell}$ and I $= nAev_d$ (1 mark)

$\therefore I = neA\left(\frac{eV}{m\ell}\right)\tau = \left(\frac{ne^2A\tau}{m\ell}\right)V = \frac{1}{R}V$

or V = IR where $R = \frac{m\ell}{nAe^2\tau}$ is a constant for a particular conductor at a particular temperature and is called the resistance of the conductor. (1 mark)

OR

Let n be the number of free electrons per unit volume of the conductor.

Volume of the conductor = $A\ell$

Number of free electrons of the conductor = n

Total free charge of the conductor = $nA\ell e$, where e is the charge of an electron.

If t be the time taken to cover a distance ℓ by this change, then $t = \frac{\ell}{v_d}$

$\therefore I = \frac{q}{t} = \frac{nAe\ell}{\ell/v_d} = nAev_d \Rightarrow v_d = \frac{I}{enA}$

$\therefore v_d \propto I$ (2 marks)

23. Energy separation $= 57 \times 10^{-3}$ eV

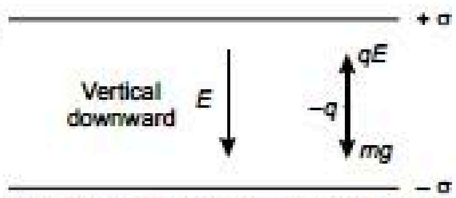
$= 57 \times 10^{-3} \times 1.6 \times 10^{-19}$ J (1 mark)

$\text{Energy} = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E}$

$= \frac{6.6\times10^{-34}\times3\times10^{8}}{57\times10^{-3}\times1.6\times10^{-19}}$

$= 2.177 \times 10^{-5}$ m = maximum wavelength to create a hole. (1 mark)

24.



Negative q charge experiences force in a direction opposite to the direction of electric field.

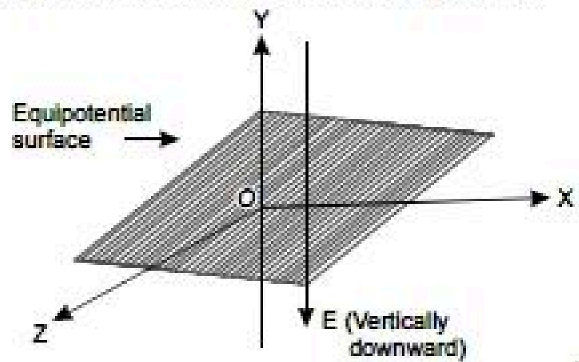
$\therefore$ Negative q charge balances when

$qE = mg$

$E = \frac{mg}{q}$ (1 mark)

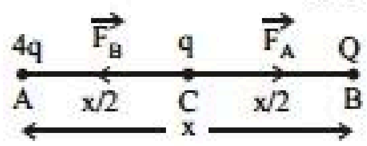
The direction of electric field is along vertically downward direction.

The equipotential surface between the plates is:



(1 mark)

OR



Force on q due to 4q charge, $F_A = \frac{k\ 4q.q}{(x/2)^2} = \frac{k\ 4q^2}{(x/2)^2}$ (1 mark)

Force on q due to Q, $F_B = \frac{k.Qq}{(x/2)^2}$

Net force on q = 0 if $F_B = F_A$

i.e. $\frac{k\ Qq}{(x/2)^2} = \frac{k\ 4q^2}{(x/2)^2} \Rightarrow Q = 4q$ (1 mark)

25. An accelerated or retarded charge or an oscillating LC circuit can be a source of electromagnetic waves. (1 mark)

Electric and magnetic field vectors are perpendicular to each other and perpendicular to the direction of propagation of the wave.

The speed of all electromagnetic waves is same in vacuum. (1 mark)

OR

Electromagnetic waves consist of time varying sinusoidal electric and magnetic fields in perpendicular direction. (1 mark)

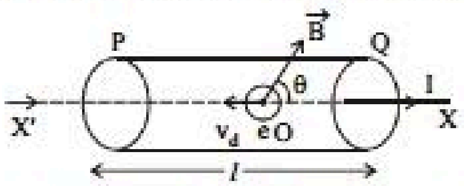
It's velocity in vacuum is given by $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ and it doesn't depend on any factor, as it is same for all electromagnetic waves in vacuum. (1 mark)

26. Let PQ be a conductor of length ℓ.

I be the current through the conductor.

$\vec{B}$ is the magnetic field intensity. $\overline{v_d}$ is the drift speed of electrons. θ is the angle between $\vec{B}$ and I.

n be the no. of electrons per unit volume of the conductor. A is the cross-sectional area of the conductor.



Total no. of free electrons in the conductor $N = nA\ell$

Magnetic Lorentz force on each electron $\vec{f} = -e(\overline{v_d} \times \vec{B})$

∴ Total force of all free electrons

$\vec{F} = N\vec{f} = -nA\ell e(\overline{v_d} \times \vec{B})$

But $I = nAev_d$

∴ $I\ell = nA\ell ev_d$

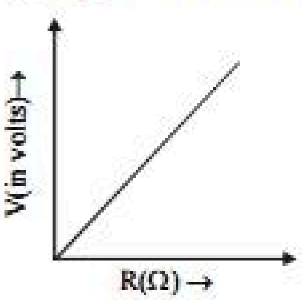
$I\vec{\ell}$ is called current element vector and is opposite to $\overline{v_d}$

∴ $I\vec{\ell} = -nA\ell e\overline{v_d}$

∴ $\vec{F} = I\vec{\ell} \times \vec{B}$

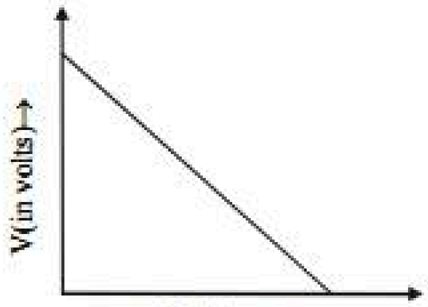
∴ $|\vec{F}| = I|\vec{\ell} \times \vec{B}| \Rightarrow F = I\ell B\sin\theta$ (3 marks)

27. (i) Graph between terminal voltage V and resistance (R)



(1½ marks)

(ii) Graph between terminal voltage (V) and current (I)



(1½ marks)

28. The de-Broglie wavelength of a particle is given by

$$\lambda \propto \frac{1}{\sqrt{mq}}$$

If m_p and q are mass and charge of a proton respectively, and m_α and $2q$ are mass and charge of a alpha particle respectively. Then,

According to question

$\lambda_p = \lambda_\alpha$

(i) For accelerating potential,

$$\lambda = \frac{12.27}{\sqrt{V}}$$

$$\lambda_p = \frac{12.27}{\sqrt{V_p}} \text{ or } V_p = \left(\frac{12.27}{\lambda_p}\right)^2$$

$$\text{and } \lambda_\alpha = \frac{12.27}{\sqrt{V_\alpha}} \text{ or } V_\alpha = \left(\frac{12.27}{\lambda_\alpha}\right)^2$$

$$\text{Now, } \frac{V_p}{V_\alpha} = \frac{(12.27/\lambda_p)^2}{(12.27/\lambda_\alpha)^2}$$

$$\frac{V_p}{V_\alpha} = \left(\frac{\lambda\alpha}{\lambda p}\right)^2 \quad (\because \lambda_p = \lambda_\alpha)$$ (1½ marks)

$V_p : V_\alpha = 1.$

(ii) For, speed

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

$$\text{Now, } \lambda_p = \frac{h}{m_p v_p} \text{ or } = v_p = \frac{h}{m_p \lambda_p}$$

$$\text{and } \lambda_\alpha = \frac{h}{m_\alpha v_\alpha} \text{ or } v_\alpha = \frac{h}{m_\alpha \lambda_\alpha}$$

$$\frac{v_p}{v_\alpha} = \frac{h/m_p\lambda_p}{h/m_\alpha\lambda_\alpha}$$

$$\frac{v_p}{v_\alpha} = \frac{m_p\lambda_p}{m_p v_p} \quad (\because \lambda_p = \lambda_\alpha \text{ and } m_\alpha = 4m_p)$$

$$\Rightarrow \frac{v_p}{v_\alpha} = \frac{4m_p}{m_p}$$

$v_p : v_\alpha = 4 : 1$ (1½ marks)

OR

(i) Energy of a photon is given by, ν

$E = h\nu$

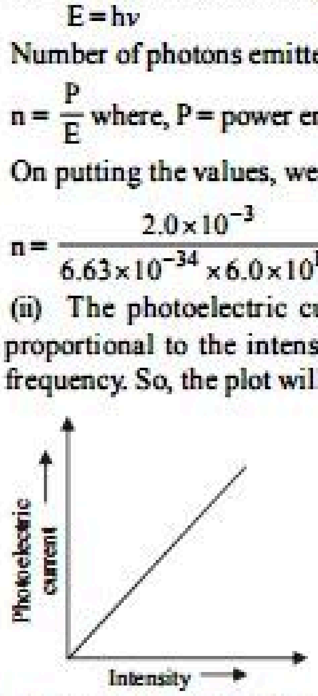
Number of photons emitted per second,

$n = \frac{P}{E}$ where, P = power emitted (1 mark)

On putting the values, we get,

$$n = \frac{2.0\times10^{-3}}{6.63\times10^{-34}\times6.0\times10^{14}} = 5.03\times10^{15}$$ (1 mark)

(ii) The photoelectric current is known to be directly proportional to the intensity of incident light with fixed frequency. So, the plot will be a straight line shown as,

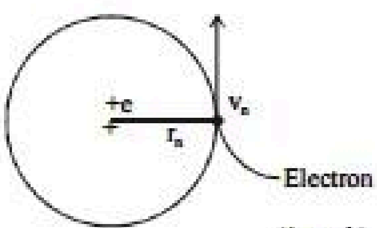


(1 mark)

29. Let an electron of mass m, carrying a charge e revolving around the nucleus of hydrogen atom carrying a charge +e. Let r_n be the radius of the orbit and v_n is the speed of the electron in that orbit. The necessary centripetal force to revolve the electron is provided by the electrostatic force between the electron and hydrogen nucleus

$$\therefore \quad k\frac{e^2}{r_n^2} = m\frac{v_n^2}{r_n}, \text{ where } k = \frac{1}{4\pi\epsilon_0}$$

$$\therefore \quad r_n = \frac{ke^2}{mv_n^2} \quad ...(i)$$



$$\text{or,} \quad mv_n^2 = \frac{ke^2}{r_n} \quad ...(ii)$$ (1 mark)

According to the angular momentum postulate

$$mv_nr_n = \frac{nh}{2\pi} \text{ or } v_n = \frac{nh}{2\pi mr_n} \quad ...(iii)$$

Putting the value of v_n from (iii) into (i), we have

$$r_n = \frac{ke^2}{m.n^2h^2}4\pi^2m^2r_n^2$$

$$\text{or} \quad r_n = \frac{n^2h^2}{4\pi^2ke^2m} \quad ....(iv)$$

$$\text{KE of the electron} = \frac{1}{2}mv_n^2 = \frac{1}{2}\frac{ke^2}{r_n}$$

$$= \frac{1}{2}\frac{ke^2}{n^2h^2}.4\pi^2kme^2 = \frac{2\pi^2k^2me^4}{n^2h^2} \quad ....(v)$$

Potential energy of the electron

$$PE = -\frac{kq_1q_2}{r} = -\frac{k.e.e}{r_n} = -\frac{ke^2}{r_n} = \frac{-ke^2}{n^2h^2}4\pi^2ke^2m$$

$$PE = \frac{-4\pi^2k^2e^4m}{n^2h^2}$$

$$\therefore \text{ Total energy of the electron} = \frac{2\pi^2k^2me^4}{n^2h^2} - \frac{4\pi k^2me^4}{n^2h^2}$$

$$\text{or, } E_n = \frac{-2\pi^2k^2me^4}{n^2h^2}$$ (1 mark)

If E_{ni} and E_{nf} are the energies of the electron for which $n = n_i$ and n_f

$$\therefore \; E_{ni} = \frac{-2\pi^2k^2me^4}{n_i^2h^2} \text{ and } E_{nf} = \frac{-2\pi^2k^2me^4}{n_f^2h^2}$$

If hν is the energy of the photon when the electron jumps from $n = n_i$ to $n = n_f$, then

$$h\nu = \frac{2\pi^2k^2me^4}{h^2n_f^2} + \frac{-2\pi^2k^2me^4}{h^2n_i^2}$$

$$\Rightarrow \; h\nu = \frac{2\pi^2k^2me^4}{h^2}\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

$$\text{or,} \quad \nu = \frac{2\pi^2k^2me^4}{h^3}\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$ (1 mark)

Spectral series when the transition of the electron takes place from

$n_i = 4$ to $n_f = 3 \rightarrow$ Paschen series

$n_i = 4$ to $n_f = 2 \rightarrow$ Balmer series

$n_i = 4$ to $n_f = 1 \rightarrow$ Lyman series

OR

According to Bohr's theory, when an electron jumps from inner to outer orbits it absorbs energy and when it jumps from outer to inner orbits it emits energy. The energy of the emitted radiation is equal to the difference of the two energy levels involved and the total number of energies of electron in different orbits of an atom are diagrammatically represented by the energy level diagram. Total energy of electron in n^{th} orbit is given by

$$E = \frac{-2\pi^2mk^2e^4}{n^2h^2} \text{ where } k = \frac{1}{4\pi\varepsilon_0} \text{ and hence}$$

$$E = \frac{-13.6eV}{n^2} \text{ for H-atom}$$ (1 mark)

Also the number of waves given per unit length is

$$\bar{\nu} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$ (1 mark)

$$\text{For hydrogen, } Z = 1 \quad \therefore \quad \bar{\nu} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

Where n_1 and n_2 are n^{th} orbit numbers and $R = 1.097\times10^7\,m^{-1}$ is Rydberg constant.

(i) When electron jumps from outer orbit to $n = 1$ orbit then $\bar{v}_1 = R\left[\frac{1}{1^2} - \frac{1}{k^2}\right]$ where $k = 2, 3, 4$ etc. is Lyman series for energy $E_1 = -13.6$ eV of the electron in $n = 1$ orbit.

(ii) When electron jumps from outer to second orbit then $\bar{v}_2 = R\left[\frac{1}{2^2} - \frac{1}{k^2}\right]$ where $k = 3, 4, 5$........ and energy of electron is $E_2 = \frac{-13.6}{2^2}$

$= -3.4$ eV. This is Balmer Series.

(iii) When electron jumps from any outer orbit to third orbit then

$\bar{v}_3 = R\left[\frac{1}{3^2} - \frac{1}{k^2}\right]$ where $k = 4, 5, 6$........ is **Paschen series** and energy is

$E_3 = \frac{-13.6}{3^2} = -1.51$ eV

Similarly, for $n_1 = 4$ and $n_2 = 5, 6, 7$...... we get **Brackett series** whose electron energy is $E_4 = -0.85$ eV.

We get Pfund Series for $n_1 = 5$ and $n_2 = 6, 7$ .... where electron in stationary orbit has energy $E_5 = -0.54$ eV. As n increases, E_n increases until at $n = \infty$, $E = 0$. (1 mark)

The energy level diagram is drawn in figure 4.

30. $R = R_0 A^{1/3}$ where R_0 = constant, A mass number of a nucleus. Considering, nucleus to be nearly spherical.

Volume of nucleus = constant × R^3

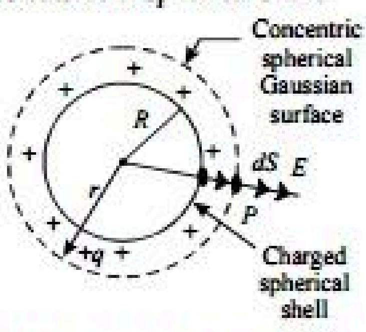
= constant × $R_0^3 A$ = constant × A

Density = $\frac{\text{mass}}{\text{volume}}$ for a nucleus, mass = A,

$\therefore$ Density = $\frac{A}{\text{const.} \times A} = \frac{1}{\text{const.}}$

$\therefore$ Density = constant, independent of A. (3 marks)

31. Let us consider charge +q is uniformly distributed over a spherical shell of radius R. Let electric field is to be obtained at P lies outside of spherical shell.



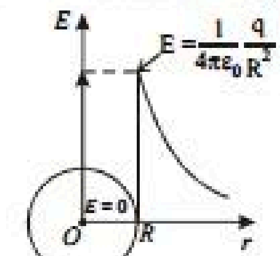
E at any point is radially outward and has same magnitude at all points which lies at the same distance (r) from centre of spherical shell. Therefore, consider a Gaussian surface of radius r such that r > R.

Gaussian surface enclosed charge q inside it.

By Gauss's theorem,

$$\oint E.dS = \frac{q}{\varepsilon_0}$$

$\oint E.dS \cos 0° = \frac{q}{\varepsilon_0}$ [$\because$ E and dS are along the same direction]



$E\oint dS = \frac{q}{\varepsilon_0}$

$E \times 4\pi r^2 = \frac{q}{\varepsilon_0}$

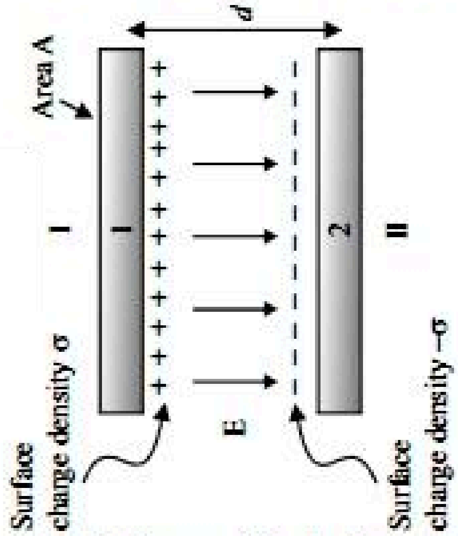
$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$

Variation of E with r for a charged spherical shell.

(5 marks)

OR

(a) A parallel plate capacitor consists of two large plane parallel conducting plates separated by a small distance.



(1 mark)

Let A be the area of each plate and d be the separation between them. The two plates have charges Q and –Q. Plate 1 has surface charge density, $\sigma = Q/A$,

And plate 2 has a surface charge density $-\sigma$.

Electric field in, Outer region I,

$E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$

In outer region II,

$E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$ (1 mark)

In the inner region between plates 1 and 2, the electric fields due to the two charged plates add up.

$E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}$ (1 mark)

The direction of electric field is from positive to the negative plate. For uniform electric field, potential difference is simply the electric field times the distance between the plates.

$V = E\,d = \frac{1}{\varepsilon_0}\frac{Qd}{A}$

Capacitance (C) of the parallel plate capacitor, $C = \frac{Q}{V} = \frac{\varepsilon_0 A}{d}$

(1 mark)

(b) The surface charge density for a spherical conductor is given by, $\sigma = \frac{Q}{4\pi r^2}$

For spherical conductor R_1, the surface charge density is given by, $\sigma_1 = \frac{q_1}{4\pi R_1^2}$

Similarly, for spherical conductor R_2, the surface charge density is given by, $\sigma_2 = \frac{q_2}{4\pi R_2^2}$

$$\therefore \quad \frac{\sigma_1}{\sigma_2} = \left(\frac{q_1}{q_2}\right)\left(\frac{R_2^2}{R_1^2}\right)$$

Since the two conductors are connected, we have,

$q_1 = q_2$

$$\therefore \quad \frac{\sigma_1}{\sigma_2} = \frac{R_2^2}{R_1^2} = \left(\frac{R_2}{R_1}\right)^2$$ (1 mark)

32. (i) Faraday's laws of electromagnetic induction:

First law: Wherever there is a change in magnetic flux associted with a coil, an e.m.f. is induced in the coil. It last so long as the change continues. (1 mark)

Second law: The induced e.m.f. is directly proportional to the rate of change of magnetic flux of the coil and has a direction opposite to that of the change of magnetic flux.

Mathematically, (1 mark)

$$e \propto -\frac{d\phi}{dt} \Rightarrow e = -k\frac{d\phi}{dt}$$

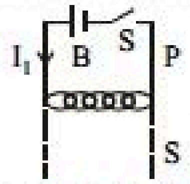
[k = 1 for all system of units]

$$\therefore \quad e = -\frac{d\phi}{dt}$$ (1 mark)

(ii) When the switch is closed the flux associated with L changes, an e.m.f. is induced in L which will oppose the growth of current in Q. But no such induced e.m.f. will be produced in R. So P will light up faster. (2 marks)

OR

When current flowing in one of two nearby coil is charged, the magnetic flux linked with the other coil changes, due to which an emf is induced in the other coil. This phenomenon is called mutual induction. The coil in which current is changed is called primary coil and the coil in which emf is induced is called secondary coil.



(1 mark)

Suppose there are two coils P and S. The current I_1 is flowing in primary coil P due to which an effective magnetic flux ϕ_2 is linked with secondary coil S.

By experiment, $\phi_2 \propto I_1$ $\quad \therefore \phi_2 = MI_1$

Where M is a constant, called coefficient of mutual induction or mutual inductance.

$\therefore M = \frac{\phi_2}{I_1}$ If $I_1 = 1$ A, then $M = \phi_2$

$\therefore$ Mutual inductance between two coils is numerically equal to the effective flux linkage with secondary coil, when current flowing in primary coil is 1A.

From Faraday's law,

induced e.m.f in secondary coil $= e_2 = -\frac{d\phi_2}{dt}$

$$\Rightarrow e_2 = -\frac{d}{dt}(MI_1) = -M\frac{dI_1}{dt}$$ (1 mark)

$$\therefore \quad M = -\frac{e_2}{\frac{dI_1}{dt}}$$

If $dI_1/dt = 1$ A/s $\quad \therefore M = e_2$ (numerically)

$\therefore$ Mutual inductance between two coils is numerically equal to the emf induced with secondary coil, when rate of change of current in primary coil is 1 A/s. (1 mark)

Mutual inductance of a solenoid:

Consider a long solenoid of length l and number of turns N_1. At its central part, a coil of N_2 number of turns is wound. If I_1 is the current flowing in long solenoid, the magnetic field produced within the solenoid is $B_1 = \frac{N_1 I_1}{\ell}$

$\therefore$ Flux linked with each turn of secondary coil $= \phi_2 = B_1 A$, where A is the cross-sectional area of the solenoid.

$\therefore$ Total flux linked with secondary coil of N_2 number of turns $= \phi_2' = N_2\phi_2 = N_2 B_1 A$

$$= N_2\left(\frac{\mu_o N_1 I_1}{\ell}\right)A$$ (1 mark)

$$\therefore \phi_2' = \frac{\mu_0 N_1 N_2}{\ell} AI_1$$

$$\therefore \text{Mutual inductance} = M = \frac{\phi_2'}{I_1} = \frac{\mu_o N_1 N_2 A}{\ell}$$

(1 mark)

33. The magnifying power of a telescope is equal to the ratio of the visual angle subtended at the eye by final image formed at least distance of distinct vision to the visual angle subtended at naked eye by the object at infinity. (1 mark)

when final image is at D.

$$\text{Magnifying power } M = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$$

$$\text{In normal adjustment } M = -\frac{f_o}{f_e}$$ (1 mark)

Focal length of objective lens $f_o = 150$ cm

Focal length of eye lens $f_e = 5$ cm

When final image forms at $D = 25$ cm

$$\therefore \quad \text{Magnification } M = -\frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$$

$$= -\frac{150}{5}\left(1 + \frac{5}{25}\right) = -\frac{150}{5} \times \frac{6}{5}$$ (1 mark)

Let height of final image is h cm $\quad \therefore \tan\beta = \frac{h}{25}$

β = visual angle formed by final image at eye

α = visual angle substended by object at objective

$$\tan\alpha = \frac{100 \text{ m}}{3000 \text{ m}} = \frac{1}{30}$$

But $M = \frac{\tan\beta}{\tan\alpha}$ $-36 = \frac{\left(\frac{h}{25}\right)}{\left(\frac{1}{30}\right)} = \frac{h}{25} \times 30$

$-36 = \frac{6h}{5}$ (1 mark)

$h = -\frac{36 \times 5}{6} = -30$ cm (1 mark)

OR

(i) Given : $i = e = 3A/4$, $A = 60°$
From formula,
$i + e = A + \delta$
or, $3A/4 + 3A/4 = A + \delta$

$\Rightarrow \frac{A}{2} = \delta$ or $\frac{60°}{2} = \delta$

$\Rightarrow \delta = 30°$ (2½ marks)

(ii) Since i = e, the prism is in the minimum deviation position, therefore, the refractive index of the prism

$\mu = \frac{\sin(A + \delta_m)/2}{\text{Sin}A/2}$

$= \frac{\sin(60° + 30°)/2}{\sin(60°/2)}$

$= 0.707/0.5 = 1.414$ (2½ marks)

34. **(i)** The flux leakage in a transformer can be reduced by winding the primary and secondary coils one over the other. (1 mark)

(ii) The magnetisation of the core is repeatedly reversed by the alternating magnetic field which results in loss of energy as heat. (1 mark)

(iii) In steady current, the phenomenon of mutual induction does not take place. (2 marks)

OR

(iii) There are three assumptions:–

(i) The primary resistance and current are small.

(ii) The same flux links both the primary and the secondary as very little flux escapes from the core. (2 marks)

(iii) The secondary current is small.

35. **(i)** From lens formula,

$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\frac{1}{f_1} = (1.5 - 1)\left(\frac{1}{8} + \frac{1}{R}\right) \Rightarrow f_1 = 2R$

$\frac{1}{f_2} = (1.7 - 1)\left(\frac{1}{-R} - \frac{1}{R}\right) \Rightarrow f_2 = \frac{-5R}{7}$

$\frac{1}{f_3} = (1.5 - 1)\left(\frac{1}{R} + \frac{1}{8}\right) \Rightarrow f_3 = 2R$

$\frac{1}{f_{eq}} = \frac{1}{2R} - \frac{7}{5R} + \frac{1}{2R}$

$\Rightarrow F_{eq} = -2.5R = -50$ cm (2 marks)

(ii) Cutting a lens in transverse direction doubles their focal length i.e., 2f.

Using the formula of equivalent focal length.

$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \frac{1}{f_4}$

We get equivalent focal length as $\frac{f}{2}$. (1 mark)

(iii) $P = \frac{1}{f} = (\mu_1 - \mu_2)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

(μ_1 is refractive index of lens and μ_2 is of surrounding medium)

$\Rightarrow 1.25 = (1.5 - \mu_2)\left(\frac{1}{0.2} + \frac{1}{0.4}\right)$

$\Rightarrow \frac{1.25 \times 0.08}{0.6} = (1.5 - \mu_2) \Rightarrow \mu_2 = \frac{4}{3}$ (1 mark)

OR

(iii) We have power $P = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$= (1.5 - 1)\left(\frac{1}{20} - \frac{1}{-20}\right) \times \frac{1}{10^{-2}}$

$= 0.5 \times \frac{2}{20} \times 100 = +5$ D (1 mark)