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	1(1)	2(4)	–	1(5)	**7(16)**
2.	Current Electricity	1(1)	1(2)	1(3)	–	
3.	Magnetic Effects of Current and Magnetism	1(1)	2(4)	1(3)	–	**8(17)**
4.	Electromagnetic Induction and Alternating Current	3(6)	–	1(3)	–	
5.	Electromagnetic Waves	1(1)	–	1(3)	–	**8(18)**
6.	Optics	4(7)	1(2)	–	1(5)	
7.	Dual Nature of Radiation and Matter	2(2)	1(2)	–	–	**6(12)**
8.	Atoms and Nuclei	1(1)	1(2)	–	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***

General Instructions :

(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. Under what condition does a biconvex lens of glass having a certain refractive index act as a plane glass sheet when immersed in a liquid?

2. Define capacitive reactance. Write its S.I. units.

3. Define atomic mass unit (amu). Write the energy equivalent of atomic mass unit in MeV.

OR

What is the difference between an electron and a β-particle?

4. Two beams of light having intensities I and $4I$ interfere to produce a fringe pattern on a screen. The phase difference between the beams is $\pi/2$ at point A and π at point B. What is the difference between the resultant intensities at A and B?

5. A vector needs three quantities for its specification. Name the three independent quantities conventionally used to specify the earth's magnetic field.

6. Draw a plot showing the variation of de-Broglie wavelength of electron as a function of its K.E.

OR

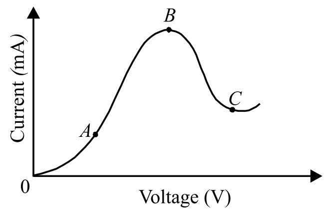
Define intensity of radiation in photon picture of light.

7. On what factors does the magnitude of the emf induced in the circuit due to magnetic flux depend?

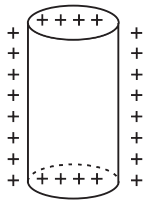
8. An LED is constructed from a *p-n* junction based on a certain semiconducting material whose energy gap is 1.9 eV. Find the wavelength of the emitted light.

OR

The graph shown in the figure represents a plot of current versus voltage for a given semiconductor. Identify the region, if any, over which the semiconductor has a negative resistance.



9. Sketch the electric field lines for a uniformly charged hollow cylinder shown in figure.



OR

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

10. In photoelectric effect, why should the photoelectric current increase as the intensity of monochromatic radiation incident on a photosensitive surface is increased? Explain.

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) : The average thermal velocity of the electrons in a conductor is zero.

Reason (R) : Direction of motion of electrons are randomly oriented.

12. Assertion (A) : We cannot get diffraction pattern from a wide slit illuminated by monochromatic light.

Reason (R) : In diffraction pattern, all the bright bands are not of the same intensity.

13. Assertion (A) : Diamond behaves like an insulator.

Reason (R) : There is a large energy gap between valence band and conduction band of diamond.

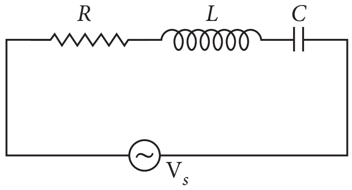
14. Assertion (A) : Light can travel in vacuum whereas sound cannot do so.

Reason (R) : Light has an electromagnetic wave nature whereas sound is mechanical wave.

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. When a resistor, inductor and capacitor are connected in series with the supply voltage, then the circuit so formed is called a series LCR circuit.



An alternating potential of 100 volts and 50 hertz is applied across a series circuit having an inductance of 5 henry, a resistance of 100 ohm and a variable capacitance.

(i) At what value of capacitance will the current in the circuit be in phase with the applied voltage?

(a) 2 μF (b) 4 μF (c) 6 μF (d) 8 μF

(ii) Calculate the current in this condition.

(a) 5 A (b) 1 A (c) 3 A (d) 6 A

(iii) What will be the potential difference across the resistance?

(a) 110 V (b) 200 V (c) 100 V (d) 50 V

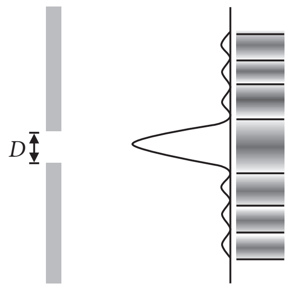
(iv) What will be the potential difference across the inductor?

(a) 1570 V (b) 1590 V (c) 100 V (d) 1000 V

(v) What will be the potential difference across the capacitance?

(a) 200 V (b) 150 V (c) 1260 V (d) 1570 V

16. Diffraction refers to various phenomena that occur when a wave encounters an obstacle or opening. It is defined as the bending of waves around the corners of an obstacle or through an aperture into the region of geometrical shadow of the obstacle / aperture.



(i) Diffraction effect can be observed in

(a) only sound waves (b) only light waves

(c) only ultrasonic waves (d) sound as well in light waves.

(ii) The width of the diffraction band varies

(a) inversely as the wavelength (b) directly as the width of the slit

(c) directly as the distance between the slit and the screen

(d) inversely as the size of the source from which the slit is illuminated.

(iii) When a beam of light is used to determine the position of an object, the maximum accuracy is achieved if the light is

(a) of low intensity (b) of longer wavelength

(c) of shorter wavelength (d) of high intensity.

(iv) Angular width of central maximum in the Fraunhofer diffraction pattern of a slit is measured. The slit is illuminated by light of wavelength 6000 Å. When the slit is illuminated by light of another wavelength, the angular width decreases by 30%. Calculate the wavelength of this light.

(a) 4000 Å (b) 4200 Å (c) 3800 Å (d) 1000 Å

(v) When the angular width decreases by 30% if the original apparatus is immersed in a liquid, then what is the refractive index of the liquid?

(a) 1 (b) 0.5 (c) 1.29 (d) 1.43

SECTION - C

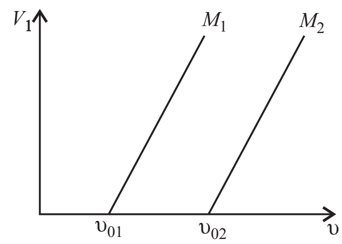
All questions are compulsory. In case of internal choices, attempt anyone.

17. Explain the following :

(i) Why do magnetic lines of force form continuous closed loops?

(ii) The horizontal component of the earth's magnetic field at a place is B and angle of dip is 60°. What is the value of vertical component of earth's magnetic field at equator?

18. The given graphs show the variation of the stopping potential V_s with the frequency (υ) of the incident radiations for two different photosensitive materials M_1 and M_2. The values of the stopping potential for M_1 and M_2 for a frequency υ_3 ($> \upsilon_{02}$) of the incident radiations are V_1 and V_2 respectively. Show that the slope of the lines equals $\dfrac{V_1 - V_2}{\upsilon_{02} - \upsilon_{01}}$.



19. What do you mean by current sensitivity of a moving coil galvanometer. On what factors does it depend?

OR

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

20. A cell of emf ε and internal resistance r is connected across a variable resistor R. Plot a graph showing the variation of terminal potential V with resistance R. Predict from the graph, the condition under which V becomes equal to ε.

21. 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 shadow of the obstacle. Explain why?

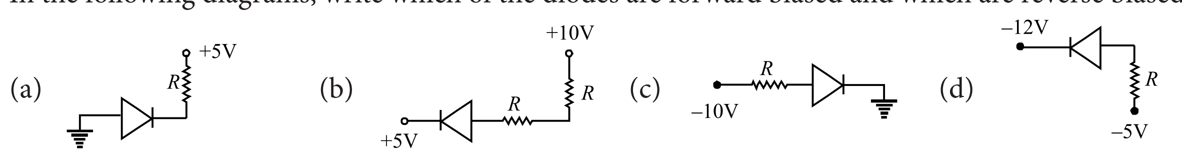
OR

Ray optics is based on the assumption that light travels in a straight line. Diffraction effects (observed when light propagates through small apertures/slits or around small obstacles) disprove this assumption. Yet the ray optics assumption is so commonly used in understanding location and several other properties of images in optical instruments. What is the justification?

22. Distinguish between an intrinsic semiconductor and p-type semiconductor. Give reason, why, a p-type semiconductor crystal is electrically neutral, although $n_h >> n_e$?

OR

In the following diagrams, write which of the diodes are forward biased and which are reverse biased.



23. Plot a graph showing the variation of coulomb force (F) versus $\left(\dfrac{1}{r^2}\right)$, where r is the distance between the two charges of each pair of charges : (1μC, 2μC) and (2μC, – 3μC), interpret the graphs obtained.

24. Why are electric field lines perpendicular at a point on an equipotential surface of a conductor?

25. Complete the following nuclear reactions.

(a) $^{10}_{5}\text{B} + ^{1}_{0}n \rightarrow ^{4}_{2}\text{He} + ...$

(b) $^{94}_{42}\text{Mo} + ^{2}_{1}\text{H} \rightarrow ^{95}_{43}\text{Te} + ...$

SECTION - D

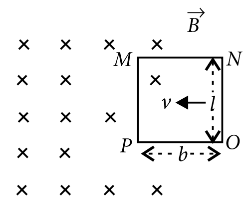
All questions are compulsory. In case of internal choices, attempt any one.

26. Name the device for converting solar energy into electrical energy. Draw its *V-I* characteristics curve. Why Si and GaAs are preferred for its construction?

27. State Lenz's law. Using this law indicate the direction of the current in a closed loop when a bar magnet with north pole in brought close to it. Explain briefly how the direction of the current predicted wrongly results in the violation of the law of conservation of energy.

OR

The figure shows a rectangular conducting frame *MNOP* of resistance *R* placed partly in a perpendicular magnetic field $\vec{B}$ and moved with velocity $\vec{v}$ as shown in the figure. Obtain the expression for the



(a) force acting on the arm '*ON*' and its direction.

(b) power required to move the frame to get a steady emf induced between the arms *MN* and *PO*.

28. A non-conducting thin disc of radius *R* charged uniformly over one side with surface density σ rotates about its axis with an angular velocity ω. Find

(i) the magnetic induction at the centre of the disc;

(ii) the magnetic moment of the disc.

29. Two identical heater wires are first connected in series and then in parallel. Find the ratio of heat produced in the two cases.

30. An EM wave of intensity *I* falls on a surface kept in vacuum and exerts radiation pressure *p* on it. Show that

(i) Radiation pressure is I/c if the wave is totally absorbed.

(ii) Radiation pressure is $2I/c$ if the wave is totally reflected.

(iii) Radiation pressure is in the range $I/c < p < 2I/c$ for real surfaces.

OR

What happens to the intensity of light from a bulb if the distance from the bulb is doubled? As a laser beam travels across the length of a room, its intensity essentially remains constant. What geometrical characteristic of LASER beam is responsible for the constant intensity which is missing in the case of light from the bulb?

SECTION - E

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

31. **(a)** Write two important limitations of Rutherford model which could not explain the observed features of atomic spectra. How were these explained in Bohr's model of hydrogen atom?

(b) Using Bohr's postulates, obtain the expression for the radius of the n^{th} orbit in hydrogen atom.

OR

(a) Write the general expression for total energy of hydrogen atom. Use this equation to find Rydberg's formula.

(b) What is the maximum possible number of spectral lines observed when the hydrogen atom is in its second excited state? Justify your answer. Calculate the ratio of the maximum and minimum wavelengths of the radiations emitted in this process.

32. (i) Show that the effective capacitance C of a series combination of three capacitors C_1, C_2 and C_3 is given by

$$C = \frac{C_1C_2C_3}{(C_1C_2 + C_2C_3 + C_3C_1)}$$

(ii) A parallel plate capacitor of capacitance C is charged to a potential V. It is then connected to another uncharged capacitor having the same capacitance. Find out the ratio of the energy stored in the combined system to that stored initially in the single capacitor.

OR

Obtain the expression for the energy stored per unit volume in a charged parallel plate capacitor.

33. Draw a graph to show variation in the angle of deviation δ with the variation of angle of incidence i for a monochromatic ray of light passing through a prism of refracting angle A. Deduce the relation

$$\mu = \frac{\sin \frac{A + \delta_m}{2}}{\sin \frac{A}{2}}.$$

OR

Answer the following questions :

(a) The angle subtended at the eye by an object is equal to the angle subtended at the eye by the virtual image produced by a magnifying glass. In what sense then does a magnifying glass provide angular magnification?

(b) In viewing through a magnifying glass, one usually positions one's eye very close to the lens. Does angular magnification change if the eye is moved back?

(c) Magnifying power of a simple microscope is inversely proportional to the focal length of the lens. What then stops us from using a convex lens of smaller focal length and achieving greater magnifying power?

(d) Why must both the objective and eyepiece of a compound microscope have short focal lengths?

(e) When viewing through a compound microscope, our eyes should be positioned not on the eye-piece but a short distance away from it for best viewing. Why? How much should be that short distance between the eye and eyepiece?

SOLUTIONS

1. When the refractive index of the biconvex lens is equal to the refractive index of the liquid in which lens is immersed then the biconvex lens behaves as a plane glass sheet. In this case, $\frac{1}{f} = 0$ or $f \to \infty$.

2. Capacitive reactance is the resistance offered by a capacitor to the flow of ac through it. It is denoted by X_C.
Mathematically,

$$X_C = \frac{1}{2\pi\upsilon C}$$

where υ = frequency of ac source
C = capacitance of the capacitor.
Ohm (Ω) is the SI unit of capacitive reactance.

3. One atomic mass unit (amu) is defined as 1/12th of the actual mass of carbon–12 atom.
Also, 1 amu = 931.5 MeV

OR

The main difference between them is that β-particle is an electron of nuclear origin whereas an electron is a subatomic particle.

4. Here, $I_1 = I$, $I_2 = 4I$, $\phi_1 = \frac{\pi}{2}$, $\phi_2 = \pi$

$$I_A = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi_1 = I + 4I + 2\sqrt{I \times 4I}\cos\frac{\pi}{2} = 5I$$

$$I_B = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi_2 = I + 4I + 2\sqrt{I \times 4I}\cos\pi = 5I - 4I = I$$

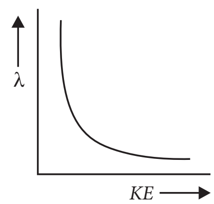
$\therefore\ I_A - I_B = 5I - I = 4I$

5. Angle of declination (magnetic declamatory) θ, angle of dip δ, horizontal component of earth's magnetic field B_H are the quantities which are considered as elements of earth's magnetic field.

6. de-Broglie wavelength

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mKE}}$$

$$\Rightarrow\ \lambda \propto \frac{1}{\sqrt{KE}}$$



OR

The amount of light energy or photon energy, incident per unit area per unit time is called intensity of radiation.
SI Unit : W m^{-2} or J m^{-2} s^{-1}.

7. The magnitude of the emf induced in the circuit due to magnetic flux depends on the rate of change of magnetic flux with time through the circuit.

$$|\varepsilon| = \frac{\Delta\phi}{\Delta t}$$

8. The wavelength of the emitted light is $\lambda = \frac{hc}{E_g}$

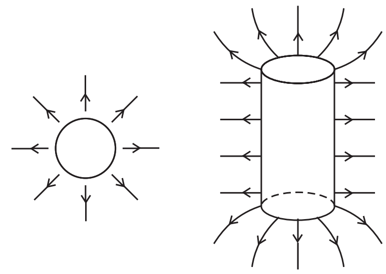
where h is the Planck's constant, c is the velocity of light in vacuum and E_g is the energy gap.
Here,
$E_g = 1.9$ eV $= 1.9 \times 1.6 \times 10^{-19}$ J
$h = 6.63 \times 10^{-34}$ J s, $c = 3 \times 10^8$ m s^{-1}

$$\therefore\ \lambda = \frac{(6.63\times10^{-34}\ \text{J s})(3\times10^8\ \text{m s}^{-1})}{(1.9\times1.6\times10^{-19}\ \text{J})} = 6.54\times10^{-7}\text{m}$$

OR

Region BC of the graph has a negative slope, hence in region BC semiconductor has a negative resistance.

9. For a uniformly charged hollow cylinder, the electric field lines are as shown.

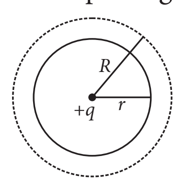


Top view Side view

OR

According to Gauss's law, the electric flux passing through a closed surface is given by

$$\oint \vec{E}\cdot d\vec{s} = \frac{q_{\text{enclosed}}}{\varepsilon_0}$$



When radius of spherical Gaussian surface is increased, its surface area will be increased but point charge enclosed in the sphere remains same. Hence there will be no change in the electric flux.

10. Since photoelectric current is directly proportional to the number of photoelectrons emitted per second, on increasing intensity, more photoelectrons will emit.

11. (a) : In normal conductor, the direction of electrons are randomly oriented such that the total sum of their velocities is equal to zero.

12. (b) : When slit is wide (*i.e.* $a >> \lambda$), bending of light becomes so small that it cannot be detected upto a certain distance of screen from the slit. Hence, practically, no diffraction occurs.

13. (a) : In insulator, the forbidden energy gap is quite large. When electric field is applied to such a solid, the electron find it difficult to acquire such a large amount of energy. Thus no electron flow occurs.

14. (a) : Light being electromagnetic wave do not require any material medium for its propagation. Hence light can travel in vacuum. On the other hand sound is a mechanical wave and requires a material medium for its propagation. Hence sound cannot travel in vacuum.

15. (i) (a) : For resonance, $\omega L = \frac{1}{\omega C}$ or $C = \frac{1}{\omega^2 L}$

Here, $\omega = 2\pi\nu = 100\pi$, $L = 5$ H

$$\therefore \quad C = \frac{1}{(100\pi)^2 \times 5} = 2 \times 10^{-6} \text{ farad} = 2\ \mu\text{F}$$

(ii) (b) : The current at resonance $= I_{rms} = \frac{E_{rms}}{R}$

$$= \frac{100}{100} = 1.0\ \text{A}$$

(iii) (c) : P.D. across $R = I_{rms} \times R = 1.0 \times 100 = 100$ volt

(iv) (a) : P.D. across $L = I_{rms} \times X_L = 1.0 \times (100\pi) \times 50$
$= 1570$ volt

(v) (d) : During resonance the voltage across capacitor will be equal to that across the inductor but they are 180° out of phase. Thus the magnitude of voltage across the capacitor is same as that of inductor, *i.e.*, 1570 V.

16. (i) (d)

(ii) (c) : Bandwidth, $\beta = \frac{\lambda d}{D}$, where λ is the wavelength of light used, d is the distance between slit and screen, D is the width of the slit.

(iii) (c)

(iv) (b) : $\beta = \frac{\lambda d}{D}$, *i.e.*, $\beta \propto \lambda$

$$\therefore \quad \frac{6000}{\lambda} = \frac{100}{70} \Rightarrow \lambda = 4200\ \text{Å}$$

(v) (d) : The same change in angular width of the central maximum will be obtained on immersing the apparatus in a liquid, if the refractive index μ of the liquid is such that

$$\mu = \frac{\lambda_{vacuum}}{\lambda_{medium}} \quad \text{or} \quad \mu = \frac{6000}{4200} = 1.43$$

17. (i) Magnetic lines of force form continuous closed loops because a magnet is always a dipole and as a result, the net magnetic flux of a magnet is always zero.

(ii) At equator the value of vertical component of earth's magnetic field is zero.

18. For metal M_1, $eV_1 = h\upsilon_3 - h\upsilon_{01}$

or $eV_1 + h\upsilon_{01} = h\upsilon_3$ ...(i)

For metal M_2, $eV_2 = h\upsilon_3 - h\upsilon_{02}$

or $eV_2 + h\upsilon_{02} = h\upsilon_3$ ...(ii)

By equations (i) and (ii)

$$eV_1 + h\upsilon_{01} = eV_2 + h\upsilon_{02}$$

or $e(V_1 - V_2) = h(\upsilon_{02} - \upsilon_{01})$

or $\frac{h}{e} = \frac{(V_1 - V_2)}{(\upsilon_{02} - \upsilon_{01})}$ or Slope $= \frac{V_1 - V_2}{\upsilon_{02} - \upsilon_{01}}$

19. Current sensitivity of moving coil galvanometer is defined as the deflection of coil per unit current flowing in it

i.e. $S_I = \left(\frac{\theta}{I}\right) = \frac{NAB}{C}$

Current sensitivity of galvanometer depends on

(i) Number of turns N : It increases with increase of number of turns.

(ii) Area of coil A : It increases with increase of area of coil.

(iii) Strength of magnetic poles B : It increases with increase of strength of poles.

(iv) Torsional rigidity of suspension C : It increases with decrease of torsional rigidity of suspension.

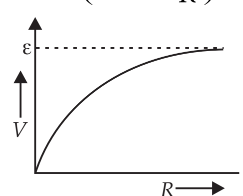
OR

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.

20. As, $V = \varepsilon - Ir = \varepsilon - \frac{V}{R}r$ $\quad \left(\because \ I = \frac{V}{R}\right)$

or $V\left[1 + \frac{r}{R}\right] = \varepsilon$

or $V = \frac{\varepsilon}{\left(1 + \frac{r}{R}\right)}$



A graph between V and R is as shown in the figure.

When $R = \infty$, then $V = \frac{\varepsilon}{1+0} = \varepsilon$.

So, V becomes equal to ε, when $R = \infty$

i.e., the graph becomes parallel to resistance axis.

21. Waves from the distant source are diffracted by the edge of the circular obstacle and these waves superimpose constructively at the centre of obstacle's shadow producing a bright spot.

OR

In optical instruments, the sizes of apertures are much larger as compared to wavelength of light. So the diffraction effects are negligibly small. Hence, the assumption that light travels in straight lines is used in the optical instruments.

22. p-type semiconductor is electrically neutral, because the holes in p-type semiconductor are not positive charges, instead they are only the missing electrons in the covalent bonds or vacancies in the covalent bonds of semi-conductor atoms produced by doping the semi-conductor with trivalent impurity atoms.

OR

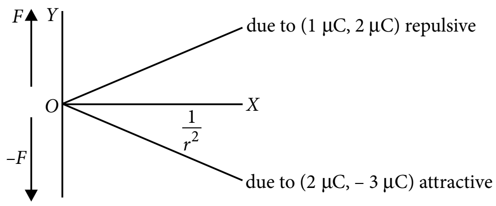
(a) $V_A - V_B = 0 - 5 = -5\ V$ Reverse Biased

(b) $V_A - V_B = 10 - 5 = +5$ V Forward Biased

(c) $V_A - V_B = -10 - 0 = -10$ V Reverse Biased

(d) $V_A - V_B = -5 + 12 = +7$ V Forward Biased.

23.



(i) Pair (1 μC, 2 μC) : From upper graph it is clear that the force of repulsion increases with the reducing distance between two charges.

(ii) Pair (2 μC, –3 μC) : From lower graph it is clear that the force of attraction increases as the distance between two charges reduces.

24. If the field were not normal to the equipotential surface, it would have a non zero component along the surface. So to move a test charge against this component, a work would have to be done. But there is no potential difference between any two points on an equipotential surface and consequently no work is required to move a test charge on the surface. Hence, the electric field must be normal to the equipotential surface at every point.

25. (a) ${}^{10}_{5}B + {}^{1}_{0}n \rightarrow {}^{4}_{2}He + {}^{7}_{3}Li$

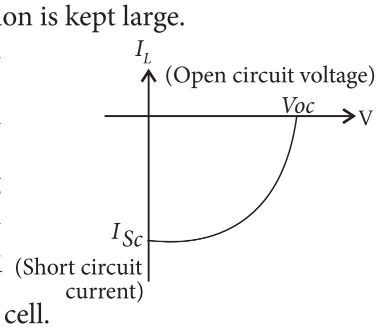
$$10 + 1 = 4 + A$$
$$A = 11 - 4 = 7$$
$$5 + 0 = 2 + Z$$
$$Z = 5 - 2 = 3$$
$$\therefore\ A = 7, Z = 3$$

(b) ${}^{94}_{42}Mo + {}^{2}_{1}H \rightarrow {}^{95}_{43}Te + {}_{0}n^{1}$

$$94 + 2 = 95 + A$$
$$A = 96 - 95 = 1$$
$$42 + 1 = 43 + Z$$
$$Z = 43 - 43 = 0$$

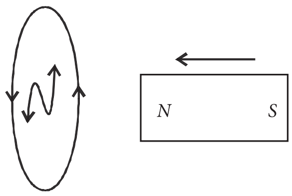
26. Solar cell converts solar energy into electrical energy. A solar cell is basically a p–n junction which generates emf when solar radiation falls on the p–n junction. It works on the principle of photovoltaic effect as photodiode, except that no external bias is applied and the junction is kept large.

The curve plotted between the photo-voltage, V developed across the solar cell, and current I_L flowing through external resistance connected across it, is called V–I characteristic of solar cell.



The materials most commonly used for solar cells are silicon (Si) and gallium arsenide (GaAs). Solar intensity received is maximum near 1.5 eV. As, for photo excitation $h\upsilon > E_g$, so semiconductor with bandgap energy $E_g \sim 1.5$ eV or lower gives better solar energy. Since, Si has $E_g \sim 1.1$ eV and for GaAs has $E_g \sim 1.53$ eV. So they have relatively higher absorption co-efficient then other material like CdS or CdSe. This is why Si and GaAs are preferred materials for solar cell.

27. Lenz's law states that the direction of the induced emf and the direction of induced current are such that they oppose the cause which produces them.



When the N pole of a magnet is moved towards a coil, the induced current in the coil flows in anticlockwise direction on the side of magnet, so as to acquire north polarity and oppose the motion of the magnet towards the coil, by applying repulsive force on it.

In order to continue the change in magnetic flux linked with the circuit, some work is to be done or some energy is to be spent against the opposition offered by induced EMF. This energy spent by the external source ultimately appears in the circuit in the form of electrical energy.

Suppose that the Lenz's law is not valid. Then the induced current flows through the coil in a direction opposite to one dictated by Lenz's law. The resulting force on the magnet makes it move faster and faster, *i.e.*, the magnet gains speed and hence kinetic energy without expending an equivalent amount of energy. This sets up a perpetual motion machine, violating the law of conservation of energy. Thus Lenz's law is valid and is a consequence of the law of conservation of energy.

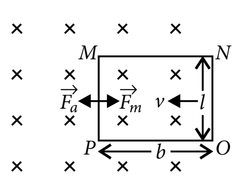
OR

(a) As the rod is moving with a constant velocity, the applied force $\vec{F}_a$ must balance the magnetic force $F_m = IlB$ on the rod when it is carrying the induced current I.

$$I = \frac{\varepsilon}{R} = \frac{vBl}{R}$$

Thus force acting on arm 'ON' is

$$F_{ON} = \frac{l^2B^2v}{R}$$, if loop is partially in the magnetic field.



But $F_{ON} = 0$ inside the magnetic field.

(b) Now, power required to move frame to get a steady emf induced between the arms MN and PO is,

$$\therefore\quad P = F_a v = \frac{B^2l^2v^2}{R}$$

28. (i) Let us take a ring element of radius r and thickness dr, then charge on the ring element, $dq = \sigma 2\pi\, r\, dr$ and current, due to this element,

$$di = \frac{(\sigma 2\pi r\, dr)\omega}{2\pi} = \sigma\omega r\, dr$$

So, magnetic induction at the centre, due to this element

$$dB = \frac{\mu_0}{2}\frac{di}{r}$$

and hence, from symmetry

$$B = \int dB = \int_0^R \frac{\mu_0 \sigma\omega\, r\, dr}{2r} = \frac{\mu_0}{2}\sigma\omega R$$

(ii) Magnetic moment of the element, considered
$dp_m = (di)\pi r^2 = (\sigma\omega r dr)(\pi r^2) = \sigma\pi\omega r^3\, dr$
Hence, the sought magnetic moment,

$$p_m = \int dp_m = \int_0^R \sigma\pi\omega r^3 dr = \sigma\omega\pi\frac{R^4}{4}$$

29. Let R be the resistance of each heater wire. Total resistance in series, $R_1 = R + R = 2R$

Total resistance in parallel, $R_2 = \dfrac{R\times R}{R+R} = \dfrac{R^2}{2R} = \dfrac{R}{2}$

For a given potential difference heat produced,

$$H \propto \frac{1}{R} \quad \therefore \quad \frac{H_1}{H_2} = \frac{R_2}{R_1} = \frac{R/2}{2R} = \frac{1}{4}$$

30. (i) When wave is fully absorbed,

Radiation Pressure $(p) = \dfrac{\Delta I}{c} = \dfrac{I-0}{c} = \dfrac{I}{c}$

(when wave is fully absorbed by surface, momentum of reflected wave per unit time per area = 0).
(ii) When wave is fully reflected, momentum per unit time per unit area = $-I/c$,

Radiation pressure $(p) = \dfrac{I}{c} - \left(\dfrac{-I}{c}\right) = \dfrac{2I}{c}$

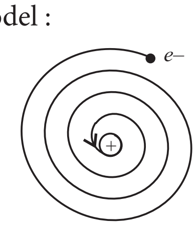
(iii) Radiation pressure (p) lies between I/c and $2I/c$ for real surfaces.

OR

Intensity becomes $\left(\dfrac{1}{4}\right)^{th}$ when r becomes double. $\left(\because\ I \propto \dfrac{1}{r^2}\right)$

This is due to the reason that a light beam spreads as it propagates into spherical region of area $4\pi r^2$. Whereas laser beam does not spread as it travels across the length of a room, its intensity remains constant.

31. (a) Limitation of Rutherford's model :
(i) Rutherford's atomic model is inconsistent with classical physics. According to electromagnetic theory, an electron is a charged particle moving in the circular orbit around the nucleus and is accelerated, so it should emit radiation continuously and thereby loose energy. Due to this, radius of the electron would decrease continuously and also the atom should then produce continuous spectrum, and ultimately electron will fall into the nucleus and atom will collapse in 10^{-8} s. But the atom is fairly stable and it emits line spectrum.



(ii) Rutherford's model is not able to explain the spectrum of even most simplest H-spectrum.
Bohr's postulates to resolve observed features of atomic spectrum :
(i) Quantum condition: Of all the possible circular orbits allowed by the classical theory, the electrons are permitted to circulate only in those orbits in which the angular momentum of an electron is an integral multiple of $\dfrac{h}{2\pi}$, h being Planck's constant. Therefore, for any permitted orbit,

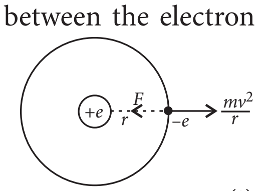
$$L = mvr = \frac{nh}{2\pi}, \quad n = 1, 2, 3...,$$

where n is called the principal quantum number, and this equation is called Bohr's quantisation condition.
(ii) Stationary orbits: While resolving in the permissible orbits, an electron does not radiate energy. These non-radiating orbits are called stationary orbits.
(iii) Frequency condition: An atom can emit or absorb radiation in the form of discrete energy photons only when an electron jumps from a higher to a lower orbit or from a lower to a higher orbit, respectively.

$$h\upsilon = E_i - E_f$$

where υ is frequency of radiation emitted, E_i and E_f are the energies associated with stationary orbits of principal quantum number n_i and n_f respectively (where $n_i > n_f$).
(b) Radius of n^{th} orbit of hydrogen atom : In H-atom, an electron having charge $-e$ revolves around the nucleus of charge $+e$ in a circular orbit of radius r, such that necessary centripetal force is provided by the electrostatic force of attraction between the electron and nucleus.

i.e., $$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e.e}{r^2}$$



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

From Bohr's quantization condition

$$mvr = \frac{nh}{2\pi} \quad \text{or} \quad v = \frac{nh}{2\pi mr} \qquad ...(ii)$$

Using equation (ii) in (i), we get

$$m\left(\frac{nh}{2\pi mr}\right)^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r} \quad \text{or} \quad \frac{mn^2h^2}{4\pi^2m^2r^2} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

$$\text{or} \quad r = \frac{n^2h^2\varepsilon_0}{\pi me^2} \qquad ...(iii)$$

where $n = 1, 2, 3, \ldots$ is principal quantum number.
Equation (iii), gives the radius of n^{th} orbit of H-atom. So the radii of the orbits increase proportionally with n^2 *i.e.*, $[r \propto n^2]$. Radius of first orbit of H-atom is called Bohr radius a_0 and is given by $a_0 = \frac{h^2\varepsilon_0}{\pi m e^2}$ for $n = 1$ or $a_0 = 0.529$ Å

So, radius of n^{th} orbit of H-atom then becomes $r = n^2 \times 0.529$ Å

OR

(a) Total energy of the hydrogen atoms is given by

$$E_n = \frac{1}{2}mv_n^2 - \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n} = \frac{1}{8\pi\varepsilon_0}\frac{e^2}{r_n} - \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n}$$

$$E_n = -\frac{1}{8\pi\varepsilon_0}\frac{e^2}{r_n} = -\frac{1}{8\varepsilon_0^2}\frac{me^4}{h^2n^2} \qquad \left[\because r_n = \frac{n^2h^2\varepsilon_0}{\pi me^2}\right]$$

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

where Rydberg constant $R = \frac{me^4}{8\varepsilon_0^2 h^3 c}$

Now, energy emitted $\Delta E = E_i - E_f$ by electron when it jumps from initial state i to final state f, then

$$\Delta E = Rhc\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

But $\Delta E = h\upsilon$

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

This is known as Rydberg's formula.

(b) In second excited state *i.e.*, $n = 3$, three spectral lines can be obtained corresponding to transition of electron from $n = 3$ to $n = 1$, $n = 3$ to $n = 2$ and $n = 2$ to $n = 1$.

For Lyman series, $n = 3$ to $n = 1$, for minimum wavelength, $\frac{1}{\lambda_{min}} = R\left[\frac{1}{1^2} - \frac{1}{3^2}\right] = \frac{8R}{9}$ ...(i)

For Balmer series, $n = 3$ to $n = 2$, for maximum wavelength, $\frac{1}{\lambda_{max}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5}{36}R$ ...(ii)

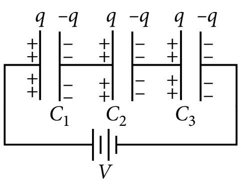
Dividing eq. (i) by (ii), we get

$$\frac{\lambda_{max}}{\lambda_{min}} = \frac{8R/9}{5R/36} = \frac{32}{5}$$

$\lambda_{max} : \lambda_{min} = 32 : 5$

32. (i) Capacitors in series : Consider three capacitors C_1, C_2 and C_3 are connected in series. The left plate of C_1 and the right plate of C_3 are connected to two terminals of a battery and have charges q and $-q$ respectively.

The total potential drop V across the combination is the sum of the potential drops V_1, V_2 and V_3 across C_1, C_2 and C_3 respectively.



$\therefore \quad V = V_1 + V_2 + V_3$

$$= \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$$

$$\therefore \quad \frac{V}{q} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \qquad \text{...(i)}$$

The effective capacitance C of the combination is

$$C = \frac{q}{V} \Rightarrow \frac{1}{C} = \frac{V}{q} \qquad \text{...(ii)}$$

On comparing Eq (i) and (ii), we get

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{C_2C_3 + C_3C_1 + C_1C_2}{C_1C_2C_3}$$

$$\therefore \quad C = \frac{C_1C_2C_3}{C_1C_2 + C_2C_3 + C_3C_1}$$

(ii) Energy stored in a capacitor

$$= \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$$

Capacitance of the (parallel) combination $= C + C = 2C$

Here, total charge Q, remains the same.

$\therefore$ Initial energy (Single capacitor) $= \frac{1}{2}\frac{Q^2}{C}$

and final energy (Combined capacitor) $= \frac{1}{2}\frac{Q^2}{2C}$

$$\therefore \quad \frac{\text{Final energy}}{\text{Initial energy}} = \frac{1}{2}$$

OR

Energy stored in a charged capacitor :

If q is the charge and V is the potential difference across a capacitor at any instant during its charging, then small work done in storing an additional small charge dq against the repulsion of charge q already stored on it is

$dW = V.dq = (q/C)dq$

So, the total amount of work done in storing the maximum charge Q on capacitor is

$$W = \int_0^Q \frac{q}{C}\cdot dq = \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q = \frac{1}{2}\frac{Q^2}{C}$$

which gets stored in the capacitor in the form of electrostatic energy. So the energy stored in capacitor is

$$U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

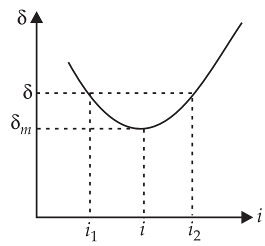
whereas the energy density *i.e.*, energy stored per unit volume in a charged parallel plate capacitor is given by

$$\text{Energy density} = \frac{\text{Total energy within plates}}{\text{Volume within plates}}$$

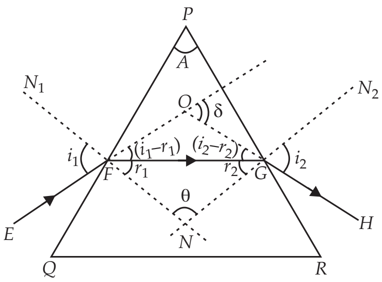
$$= \frac{\frac{1}{2}CV^2}{Ad} = \frac{\frac{1}{2}\frac{\varepsilon_0 A}{d}\cdot E^2d^2}{A\cdot d}$$

Energy density $= \frac{1}{2}\varepsilon_0 E^2$

33. Graph of deviation δ and angle of incidence i If we determine experimentally, the angles of deviation corresponding to different angles of incidence and then plot i (on X-axis) and δ (on Y-axis), we get a curve as shown in figure above. Clearly if angle of incidence is gradually increased, from a small value, the angle of deviation first decreases, becomes minimum for a particular angle of incidence and the begins to increase. Obviously for one angle of deviation (δ), there are two angles of incidences i_1 and i_2, but for one and only one particular value of angle of incidence i, for which angle of emergence is equal to angle of incidence, the angle of deviation is the minimum. This minimum angle of deviation is represented by δ_m.



To deduce relation between μ and δ_m using a prism :



Let PQR be the principal section of the prism. The refracting angle of the prism is A.

A ray of monochromatic light EF is incident on face PQ at angle of incidence i_1. The refractive index of material of prism is μ. This ray enters from rarer to denser medium and so is deviated towards the normal FN and gets refracted along the direction FG. The angle of refraction for this face is r_1. The refracted ray FG becomes incident on face PR and is refracted away from the normal GN_2 and emerges in the direction GH. The angle of incidence on this face is r_2 (into prism) and angle of refraction (into air) is i_2. The incident ray EF and emergent ray GH when produced meet at O. The angle between these two rays is called angle of deviation 'δ'.

$\angle OFG = i_1 - r_1$ and $\angle OGF = i_2 - r_2$

In ΔFOG, δ is exterior angle

$$\delta = \angle OFG + \angle OGF = (i_1 - r_1) + (i_2 - r_2)$$

$$= (i_1 + i_2) - (r_1 + r_2) \quad ...(i)$$

From geometry

$$r_1 + r_2 = A \quad ...(ii)$$

Substituting this value in (i), we get

$$\delta = i_1 + i_2 - A \quad ...(iii)$$

or $\quad i_1 + i_2 = A + \delta \quad ...(iv)$

From Snell's law, $\mu = \frac{\sin i_1}{\sin r_1} = \frac{\sin i_2}{\sin r_2} \quad ...(v)$

Minimum deviation : From equation (iii), it is clear that the angle of deviation depends upon the angle of incidence i_1. As the path of light is reversible, therefore if angle of incidence be i_2, then angle of emergence will be i_1. Thus for two angles of incidence i_1 and i_2, there will be one angle of deviation.

For minimum deviation i_1 and i_2 become coincident, *i.e.* $i_1 = i_2 = i$ (say)

So from equation (v), $r_1 = r_2 = r$ (say)

Hence from equation (iv) and (ii), we get

$$r + r = A \quad \text{or} \quad r = A/2$$

and $\quad i + i = A + \delta_m \quad$ or $\quad i = \frac{A + \delta_m}{2}$

Hence from Snell's law,

$$\mu = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

OR

(a) Without a magnifying glass, the object cannot be seen directly at distance less than 25 cm. The lens enables the eye in seeing objects from much closer distances. It produces linear magnification by increasing the visual angle from that angle which the object would have subtended at the eye when seen directly at the least distance of distinct vision.

(b) The angular magnification decreases a little because the angle subtended by the image at the eye is slightly less than the angle subtended at the lens. The effect is almost negligible if the image is at a much larger distance.

(c) Focal length of a lens is given by,

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

When $\mu = 1.5$, $f = R$ (numerically, for $R_1 = R_2 = R$) with f too small, R will also be small and lens will have increased spherical aberration.

(d) The magnifying power of a compound microscope is given by, $M = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$. To have large M, both f_o and f_e must be small.

(e) The eye-piece makes a real image of the objective aperture at a short distance on the outer (eye) side. This is called "exit-pupil" or "eye-ring". Therefore, the eye must have its pupil on this exit-pupil for best viewing. It is only a few millimeters from the eye-piece.

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