(ii) A proton is projected with a uniform velocity v along the axis of a current carrying solenoid, then
(a) the proton will be accelerated along the axis
(b) the proton path will be circular about the axis
(c) the proton moves along helical path
(d) the proton will continue to move with velocity v along the axis.

(iii) A charged particle experiences magnetic force in the presence of magnetic field. Which of the following statement is correct?
(a) The particle is stationary and magnetic field is perpendicular.
(b) The particle is moving and magnetic field is perpendicular to the velocity
(c) The particle is stationary and magnetic field is parallel
(d) The particle is moving and magnetic field is parallel to velocity

(iv) A charge q moves with a velocity $2\ \mathrm{ms}^{-1}$ along x-axis in a uniform magnetic field $\vec{B} = (\hat{\imath} + 2\hat{\jmath} + 3\hat{k})\mathrm{T}$ then charge will experience a force
(a) in $z \cdot y$ plane
(b) along y-axis
(c) along $+z$ axis
(d) along z axis

SOLUTION

SECTION A

S1. Ans. (c) positively charged

Sol. when a positively charged, body is connected to the earth, then electrons from the earth flow into the body.

S2. Ans. (a) perpendicular to the diameter

If the point is on a diameter away from the center and a uniformly positive charged hemisphere is there, the electric field component parallel to diameter will be canceled out. And perpendicular components will remain. So, an electric field will be perpendicular to the diameter at a point away from the center on diameter.

S3. Ans. (d) They reduce the light intensity to half on account of polarization

Sol. Polaroid glasses are used in sunglasses because they reduce the light intensity to half on polarization.

S4. Ans. (a) 72 V

Sol. Net capacitance is:

$$C = \frac{4 \times 6}{4 + 6} = 2.4\mu F$$

Now, net charge in circuit:

$$q = C \times V$$
$$\Rightarrow q = 2.4 \times 120$$
$$\Rightarrow q = 288\mu C$$

Now, potential difference across 4 μF capacitor:

$$V = \frac{q}{C_{4\mu F}}$$
$$\Rightarrow V = \frac{288}{4}$$
$$\Rightarrow V = 72 \text{ Volt}$$

So, potential difference across the 4 μF capacitor is 72 Volts.

S5. Ans. (c) $\mathrm{W} = \mathrm{MB}(\cos\theta_1 - \cos\theta_2)$

Sol. The formula to find the work done in rotating the dipole in a uniform magnetic field from θ_1 to θ_2 is

$W = MB(\cos\,\theta_1 - \cos\,\theta_2)$.

S6. Ans. (c) $\left(\frac{n+1}{n}\right) f$

Sol. Focal length of the mirror $= f$ The size of the image is n times the size of the object. So, magnification, $m = -n$ [image is real]

Also, $m = \frac{f}{f-u}$

$\Rightarrow -\mathrm{n} = \frac{-\mathrm{f}}{-\mathrm{f}-(-\mathrm{u})}$

$\Rightarrow -n = \frac{-f}{-f+u}$

$\Rightarrow nf - nu = -f$

$\Rightarrow f(n+1) = nu$

$\Rightarrow u = \frac{f(n+1)}{n}$

Thus, the distance of the object from the mirror is $\frac{f(n+1)}{n}$

S7. Ans. (c)

Sol.

$$W_0 = h\frac{c}{\lambda}$$

$$2W_0 = h\frac{c}{\lambda_1}$$

$$2 = \frac{\lambda}{\lambda 1}\ or\ \lambda_1 = \frac{\lambda}{2}$$

S8. Ans. (c) mass

Sol. Energy equivalent to mass detect is released.

S9. Ans. (b) 0.0039

Sol. $T_1 = 27.5\,°C, R_1 = 2.1\Omega, T_2 = 100°C, R_1 = 2.7\ \Omega$

The temperature coefficient of resistivity is

$$\alpha = R_2 - \frac{R_1}{R_1(T_2 - T_2)} = 0.0039°C^{-1}$$

S10. Ans. (a)

Sol. Faradays law states that time varying magnetic flux can induce an emf.

S11. Ans. (a)

Sol. Let value of shunt be x

$\mathrm{Req} = \frac{0.9\times x}{0.9+x}$

$\frac{i_1}{i_2} = \frac{R_2}{R_1} = \frac{1}{10} = \frac{\frac{0.9x}{0.9+x}}{0.9}$

$9x = 0.9$

$\Rightarrow x = 0.1$

S12. Ans (a) increases

Sol. The inductive reactance of the AC supply increases with the frequency of the AC supply.

S13. Ans. (d)

Sol. The valency of semiconductor (Ge or Si) is four, hence it has 4 valence electrons in the outermost orbit of the Ge or Si-atom.

S14. Ans. (c)

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

$$\Delta E_\infty - E_2 = 0 + \frac{13.6}{2^2} = 3.4\text{eV}$$

S15. Ans. (b) π

Sol. The phase difference between electric and magnetic fields in an electromagnetic wave is π.

S16. Ans. (d)

Sol. Two equipotential surfaces never intersect each other so they cannot be orthogonal.

S17. Ans. (b)

S18. Ans. (c)

Sol. Nuclear force is nearly same for all nucleus.

SECTION B

S1. Electric field lines are starts from the positive charge and terminate at negative charge. If there is a single positive charge the field lines will start form the charge and terminates at infinity. So the electric field lines do not form closed loops.

S2. Ferromagnetic material has high retentivity. Soon passing current through windings it gains sufficient magnetism immediately.

S3. Two considerations are required that is, The cost of the metals and the good conductivity of the metal. Here the cost factor inhibits silver. Cu and Al are the next best conductors.

S4. The value of refractive index of the liquid should be 1.45 so that the glass lens of refractive index 1.45 disappears when immersed in a liquid.

S5. The value of the retarding potential at which the photo electric current becomes zero is called as the stopping potential for the given frequency of the incident radiation.

S6. According to mass energy equivalence established by Einstein, $E = mc^2$If B represents binding energy of hydrogen atom (= 13.6 eV), the equivalent mass of this energy = B/c^2.

Hence, mass of a H-atom $= m_p + m_n - B/c^2$ It is less than sum of the masses of a proton and an electron.

S7. In excited state of electrons of two H - atoms, electrons may be in orbit or energy level either $n = 2,3$ ..... And can have same energy but angular momentum by Bohr's model is $L = \frac{nh}{2\pi}$. As n for both may be different so both H - atom will have different angular momentum.

SECTION C

S1. Coherent source- The source which emits a light wave with the same frequency, wavelength and phase or having a constant phase difference is known as a coherent source.

(a) If the refractive index (n) of the medium between the object and objective lens increases, the resolving power increases because resolving power μ N.A.

(b) On increasing the wavelength of radiation used, the resolving power of microscope decreases because resolving power $\propto 1/\lambda$.

S2. Activity of a radioactive substance

$$R\left(= -\frac{dN}{dt}\right) = \lambda N$$

But we know, Rate of change of activity

$$\frac{dR}{dt} = \lambda\left(\frac{dN}{dt}\right) = \lambda \cdot (-\lambda N) = -\lambda^2 N$$
$$\lambda = \frac{\log_e\ 2}{T_{1/2}}\ \therefore\ \frac{dR}{dt} = -\left(\frac{\log_e\ 2}{T_{1/2}}\right)^2 N$$

Instantaneous activity, $\frac{dR}{dt} \propto \frac{1}{T_{1/2}^2}$

S3. Force on a charge (q) moving in a magnetic field N with velocity $\vec{v}$ making an angle θ with the direction of magnetic field $\vec{B}$ is given by,

$F_m = qvBsin\theta$

When $\theta = 90° \Rightarrow sin\theta = 1$, so

$F_m = qvB$

$B = \frac{F_m}{qv}$

If, $v = 1m/s, B = \frac{F_m}{q}\ newtons/coulomb$

SI unit of magnetic field is Tesla.

S4. (a) Electrostatic force on the first sphere, $F = 0.2$ N Charge on this sphere, $q^1 = 0.4\mu C = 0.4 \times 10^{-5}$C

Charge on the second sphere, $q^2 = -0.8\mu\text{C} = -0.8 \times 10^{-6}\text{C}$

Electrostatic force between the spheres is given by the relation,

$$F = \frac{q_1 q_2}{4\pi\epsilon_0 r^2} \text{ And } \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{Nm}^2\text{C}^{-2}$$

Were, ϵ_0 = Permittivity of free space

$$\text{And}, \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{Nm}^{-2}\text{C}^{-2}$$
$$r^2 = \frac{q_1 q_2}{4\pi\epsilon_0 F}$$
$$= 144 \times 10^{-4}$$
$$r = \sqrt{144 \times 10^{-4}} = 0.12 \text{ m}$$

The distance between the two spheres is 0.12 m. (b) Both the spheres attract each other with the same force. Therefore, the force on the second sphere due to the first is 0.2 N.

S5. We know that angular width of central maximum of diffraction pattern of a single slit is given by,

$$2\theta = \frac{2\lambda}{a}$$

(i) If slit width a is decreased, the angular width will increase because $2\theta \propto \frac{1}{a}$.

(ii) If the distance between the slit and the screen increases, then it does not affect the angular width of diffraction maxima.

(iii) If the light of smaller visible wavelength is used, the angular width is decreased because $2\theta \propto \lambda$.

SECTION D

S1. Statement The net-outward normal electric flux through any closed surface of any shape is equal to $1/\varepsilon_0$ times the total charge contained within that surface, i.e.,

$$\oint_S \vec{E} \cdot d\vec{S} = \frac{1}{\varepsilon_0}\sum q$$

Where, $\oint_S$ indicates the surface integral over the whole of the closed surface, $\sum q$ is the algebraic sum of all the charges (i.e., net charge in coulombs) enclosed by surface S and remain unchanged with the size and shape of the surface.
Let a point charge $+q$ be placed at centre O of a sphere S. Then S is a Gaussian surface. Electric field at any point on S is given by

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

The electric field and area element points radially outwards, so $\theta = 0^\circ$.

Flux through area $d\vec{S}$ is

$$d\phi = \vec{E} \cdot d\vec{S} = EdS\cos\ 0^\circ = EdS$$

Total flux through surface S is

$$\phi = \oint_S d\phi = \oint_S EdS = E\oint_S dS = E \times \text{ Area of Sphere}$$
$$\phi = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}4\pi r^2 \text{ or, } \phi = \frac{q}{\varepsilon_0}$$

Hence, Gauss's theorem has been proved.

S2. (a) Unpolarized Light: The light having vibrations of electric field vector in all possible directions perpendicular to the direction of wave propagation is called the ordinary (or unpolarized) light. Plane (or linearly)

Polarized Light: The light having vibrations of electric field vector in only one direction perpendicular to the direction of propagation of light is called plane (or linearly) polarized light. When unpolarized light wave is incident on a polaroid, then the electric vectors along the direction of its aligned molecules get absorbed; the electric vector oscillating along a direction perpendicular to the aligned molecules, pass through. This light is called linearly polarized light.

(b) When unpolarized light passes through a polarizer, vibrations perpendicular to the axis of the polaroid are blocked. Unpolarized light have vibrations in all directions. Hence, if the polarizer is rotated, the unblocked vibrations remain same with reference to the axis of polarizer. Hence for all positions of polaroid, half of the incident light always get transmitted. Hence, the intensity of the light does not change.

S3. (a) consider the case of n- type semiconductor. The majority carrier (electron) density is larger than the minority hole density that is, Consider the case of n-type semiconductor. The majority carrier (electron) density is larger than the minority hole density, i.e., $n >> p$. On illumination, the no. of both types of carriers would equally increase in number as $n' = n + \Delta n, p' = p + \Delta p$ But $\Delta n = \Delta p$ and $n >> p$ Hence, the fractional change in majority carrier, i.e., $\frac{\Delta n}{n} << \frac{\Delta p}{p}$ (fractional change in minority carrier)

Fractional change due to photo-effects on minority carrier dominated reverse bias current is more easily measurable than the fractional change in majority carrier dominated forward bias current. Hence photodiodes are used in reverse bias condition for measuring light intensity.

(b) LED is fabricated by heavy doping of both the p and n regions and providing a transparent cover so that light can come out.

Working: When the diode is forward biased, electrons are sent from n→ p and holes from p→ n. At the junction boundary, the excess minority carriers on either side of junction recombine with majority carriers. This releases energy in the form of photon

hv = Eg

GaAs (Gallium Arsenide): Band gap of semiconductors used to manufacture LEDs should be 1.8 eV to 3 eV. These materials have band gap which is suitable to produce desired visible light wavelengths.

Advantage-

i. Low operational voltage and less power consumption.
ii. Fast action and no warm-up time required.
iii. Long life and ruggedness.
iv. Fast on-off switching capability.

SECTION E

S1. Ans. (i) (a) as the beam is initially parallel the shape of wavefront is planar.

(ii). (c) according to Huygens principle the surface of constant phase is called a wavefront.

(iii) (c)

(iv) (c) Diffraction

S2. Ans. (i) (a) For stationary electron,$\vec{v} = 0$ ∴ Force on the electron is $\vec{F}_{\mathrm{m}} = -e(\vec{v} \times \vec{B}) = 0$

(ii) (d) Force on the proton $\vec{F}_B = e(\vec{v} \times \vec{B})$Since, $\vec{v}$ is parallel to $\vec{B}$

$$\therefore \ \vec{F}_B \doteq 0$$

Hence proton will continue to move with velocity v along the axis of solenoid.

(iii) (b) Magnetic force on the charged particle q is

$$\vec{F}_{\mathrm{m}} = q(\vec{v} \times \vec{B}) \text{ or } F_{\mathrm{m}} = qvB\sin\ \theta$$

where θ is the angle between $\vec{v}$ and $\vec{B}$ Out of the given cases, only in case (b) it will experience the force while in other cases it will experience no force

(iv) (a) $\vec{F} = q(\vec{v} \times \vec{B})$

$$= q[(2\hat{\imath} \times (\hat{\imath} + 2\hat{\jmath} + 3\hat{k})] = (4q)\hat{k} - (6q)\hat{\jmath}$$