Name	: _____
Date of Exam.	: _____
Duration	: **3 hours**
Max. Marks	: **70**
Study Centre	: _____

General Instructions:

1. There are 33 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.
3. All the sections are compulsory.
4. Section A contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, Section B contains five questions of two marks each, Section C contains seven questions of three marks each, Section D contains two case study-based questions of four marks each and Section E contains three long answer questions of five marks each.
5. There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C, and all three questions in Section E. You have to attempt only one of the choices in such questions.
6. Use of calculators is not allowed.
7. You may use the following values of physical constants where ever necessary
   i. $c = 3 \times 10^8$ m/s
   ii. $m_e = 9.1 \times 10^{-31}$ kg
   iii. $e = 1.6 \times 10^{-19}$C
   iv. $\mu_0 = 4\pi \times 10^{-7}$Tm^{-1}
   v. $h = 6.63 \times 10^{-34}$Js
   vi. $\varepsilon_0 = 8.854 \times 10^{-12} C^2 N^{-1} m^{-2}$
   vii. Avogadro's number $= 6.023 \times 10^{23}$ per gram mole

SECTION A

Q1. When a body is connected to the earth, then electrons from the earth, flow into the body. Then the body is_____.
(a) uncharged
(b) an insulator
(c) positively charged
(d) negatively charged

Q2. A hemisphere is uniformly charged positively. The electric field at a point on a diameter away from the center is directed
(a) perpendicular to the diameter
(b) parallel to the diameter
(c) at an angle tilted towards the diameter
(d) at an angle tilted away from the diameter

Q3. Polaroid glasses are used in sunglasses because_____.

(a) They are cheaper
(b) They have a good color
(c) They look fashionable
(d) They reduce the light intensity to half on account of polarization

Q4. Two capacitors of capacitance 6μF and 4μF are put in series across a 120 V battery. What is the potential difference across the 4μF capacitor?
(a) 72 V
(b) 60 V
(c) 48 V
(d) zero

Q5. By using which formula, we can find the work done in rotating the dipole in a uniform magnetic field from θ_1 to θ_2?
(a) $W = MB\left(\frac{\cos\theta_1}{\cos\theta_2}\right)$
(b) $W = MB(\cos\theta_1 + \cos\theta_2)$
(c) $W = MB(\cos\theta_1 - \cos\theta_2)$
(d) $W = M + B(\cos\theta_1 - \cos\theta_2)$

Q6 A concave mirror of focal length f produces an image n times the size of the object. If the image is real then the distance of the object is:
(a) $(n-1)f$
(b) $(n+1)f$
(c) $\left(\frac{n+1}{n}\right)f$
(d) $\left(\frac{n-1}{n}\right)f$

Q7. Threshold wavelength for a metal having work function W_0 is X. what is the threshold wavelength for the metal having work function $2W_0$.
(a) 4λ
(b) 2λ
(c) $\frac{2}{\lambda}$
(d) $\frac{\lambda}{4}$

Q8. Quantity which is not conserved in a nuclear reaction is
(a) momentum
(b) charge
(c) mass
(d) none of these

Q9. A silver wire has a resistance of 2.1 Ω at 27.5 °C, and a resistance of 2.7 Ω at 100 °C. What is the temperature coefficient of resistivity of silver?
(a) 0.0059
(b) 0.0039
(c) 0.0129
(d) 0.0159

Q10. According to Faraday's law of electromagnetic induction
(a) Electric field is produced by time varying magnetic flux
(b) Magnetic field is produced by time varying electric flux
(c) Magnetic field is associated with a moving charge.
(d) None of these

Q11. The resistance of an ammeter of range 1 ampere is 0.9 Ω. To increase its range to 10 amperes, the required shunt is
(a) 0.1 Ω
(b) 0.01 Ω
(c) 0.9 Ω
(d) 1 Ω

Q12. What happens to the inductive reactance when the frequency of the AC supply is increased?
(a) Increases
(b) Decreases
(c) Remains the same
(d) Decreases inversely

Q13. **Directions:** These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
Assertion- Two equivalent surfaces can be orthogonal.
Reason- Electric field lines are normal to the equipotential surface.

Q14. **Directions:** These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
Assertion- The poles of magnet cannot be separated by breaking into two pieces.
Reason- The magnetic moment will be reduced to half when a magnet is broken into two equal pieces.

Q15. **Directions:** These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
Assertion: The binding energy per nucleon, for nuclei with atomic mass number A > 100, decrease with A.
Reason: The forces are weak for heavier nuclei.

Q16. Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
Assertion: The mass number of a nucleus is always less than its atomic number.
Reason: Mass number of a nucleus may be equal to its atomic number.

SECTION B

Q17. What is the reason behind the electrostatic field lines not form closed loop.

Q18. The core of an electromagnet made of ferromagnetic materials. Why?

Q19. For household electrical wiring, one use Cu wire or Al wires. What consideration are kept in mind?

Q20. A glass lens of refractive index 1.45 disappears when immersed in a liquid. What is the value of refractive index of the liquid?

Q21. The mass of a H- atom is less than the sum of the masses of a proton and electron. Why?

OR

Consider two different hydrogen atoms. The electron in each atom is in an excited state. Is it possible for the electrons to have different energies but the same orbital angular momentum according to the Bohr model?

SECTION C

Q22. What is coherent source of light?
How does the resolving power of a compound microscope change when
(a) refractive index of medium the object and objective lens increases
(b) wavelength of radiation used is increased?

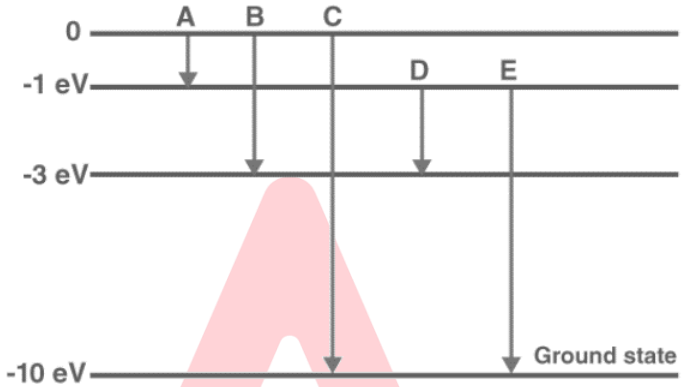
Q23. Prove that the instantaneous rate of change of the activity of a radioactive substance is in proportional to the square of its half-life.

Q24. Write the expression for the force on a charge moving in a magnetic field. By using this equation define the SI unit of the magnetic field.

Q25. The electrostatic force on a small sphere of charge 0.4μC due to another small sphere of charge -0.8μC in air is 0.2 N.
(a) What is the distance between the two spheres?
(b) What is the force on the second sphere due to the first?

Q26. In a single slit diffraction pattern, how does the angular width of central maximum changes when
(i) Slit width is decreased?
(ii) Distance between the slit and screen is increased?
(iii) Light of smaller visible wavelength is used? Justify your answer in each case.

Q27. The energy levels of an atom of element X are shown in the diagram. Which one of the level transitions will result in the emission of photons of wavelength 620 nm? Support your answer with mathematical calculations.



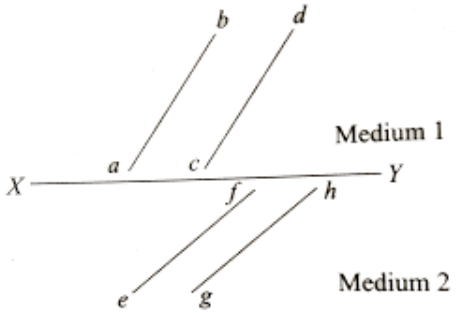
Q28. An optical instrument uses eye-lens of power 16 D and an objective lens of power 50 D and has a tube length of 16.25 cm. Name the optical instrument and calculate the magnifying power if it forms the final image at infinity.

OR

Q28. Show that the limiting value of the angle of prism is twice its critical angle? Hence define critical angle?

SECTION D

Q29. Read the following paragraph and answer the questions.
Wavefront is a locus of points which vibratic in same phase. A ray of light is perpendicular to the wavefront. According to Huygens principle, each point of the wavefront is the source of a secondary disturbance and the wavelets connecting from these points spread out in all directions with the speed of wave. The figure shows a surface XY separating two transparent media, medium-l and medium. The lines ab and cd represent wavefronts of a light wave travelling in medium- 1 and incident on XY. The lines ef and gh represent wavefronts of the light wave in medium -2 after refraction.



(i) The initial shape of the wavefront of the beam is
(a) planar

(b) convex
(c) concave
(d) convex near the axis and concave near the periphery

(ii) According to Huygens Principle, the surface of constant phase is_____.
(a) called an optical ray
(b) called a wave
(c) called a wavefront
(d) always linear in shape

(iii) As the beam enters the medium, it will
(a) travel as a cylindrical beam
(b) diverge
(c) converge
(d) diverge near tile axis and converge near the periphery.

(iv) Which of the following phenomena support the wave theory of light?
(a) Scattering
(b) Interference
(c) Diffraction
(d) Dispersion

Q30. Read the following paragraph and answer the questions.
A charged particle moving in a magnetic field experiences a force that is proportional to the strength of the magnetic field, the component of the velocity that is perpendicular to the magnetic field and the charge of the particle. This force is given by $\vec{F} = q(\vec{v} \times \vec{B})$ where q is the electric charge of the particle, v is the instantaneous velocity of the particle, and B is the magnetic field (in tesla). The direction of force is determined by the rules of cross product of two vectors. Force is perpendicular to both velocity and magnetic field. Its direction is same as $\vec{v} \times \vec{B}$ if q is positive and opposite of $\vec{v} \times \vec{B}$ if q is negative the force is always perpendicular to both the velocity of the particle and the magnetic field that created it. Because the magnetic force is always perpendicular to the motion, the magnetic field can do no work on an isolated charge. It can only do work indirectly, via the electric field generated by a changing magnetic field.

(i) When a magnetic field is applied on a stationary electron, it
(a) remains stationary
(b) spins about its axis
(c) moves in the direction of the magnetic field
(d) moves perpendicular to the direction of the magnetic field.

(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.

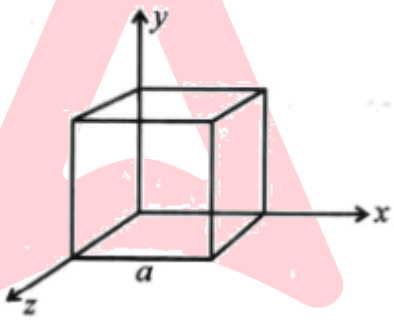
(b) The particle is moving and magnetic field is perpendicular to the velocity
(c) The particle is stationary and magnetic field is parallel
(d) The particle is moving and magnetic field is parallel to velocity

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

SECTION E

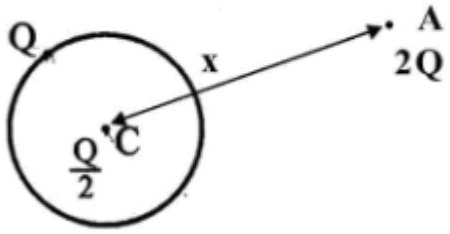
Q31. (a) An electric dipole of dipole moment $\vec{p}$ consists of point charges +q and −q separated by a distance 2a apart. Deduce the expression for the electric field $\vec{E}$ due to the dipole at a distance x from the centre of the dipole on its axial line in terms of the dipole moment $\vec{p}$. Hence show that in the limit x ≫ a, $\vec{E} \to 2\vec{p}/(4\pi\varepsilon_0 x^3)$.

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



OR

(a) Explain, using suitable diagrams, the difference in the behavior of a (i) conductor and (ii) dielectric in the presence of an external electric field. Define the terms polarization of a dielectric and write its relation with susceptibility.
(b) A thin metallic spherical shell of radius R carries a charge Q on its surface. A point charge $\frac{Q}{2}$ is placed at its centre C and another charge $+2Q$ is placed outside the shell at a distance x from the centre as shown in the figure. Find (i) the force on the charge at the centre of shell and at the point A and (ii) the electric flux through the shell.



Q32. A P-N-P transistor is used in common - emitter mode in an amplifier circuit. A change of 40μA in the base current brings a change of 2 mA in collector current and 0.04 V in base - emitter voltage. Find (i) input resistance (ii) current amplification factor (β). If a load resistance of 6kΩ is used, then find voltage gain?

OR

Q32. (a) With the help of a diagram, show the biasing of a light emitting diode (LED). Give its two advantages over conventional incandescent lamps?
(b) Draw the symbol for Zener diode? Zener diodes have higher dopant densities as compared to ordinary p-n junction diodes. How does it affect the width of the depletion layer?

Q33. (a) Draw the ray diagram of an astronomical telescope when the final image is formed at infinity. Write the expression for the resolving power of the telescope.
(b) An astronomical telescope has an objective lens of focal length 20 m and eyepiece of focal length 1 cm.
(i) Find the angular magnification of the telescope.
(ii) If this telescope is used to view the Moon, find the diameter of the image formed by the objective lens. Given the diameter of the Moon is 3.5×10^6 m and radius of lunar orbit is 3.8×10^8 m.

OR

Q33. (a) An object is placed in front of a concave mirror. It is observed that a virtual image is formed. Draw the ray diagram to show the image formation and hence derive the mirror equation $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$.
(b) An object is placed 30 cm in front of a plano-convex lens with its spherical surface of radius of curvature 20 cm. If the refractive index of the material of the lens is 1.5, find the position and nature of the image formed.

SOLUTION
SECTION A

S1. Ans. (c)
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
Sol. 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)
Sol. Polaroid glasses are used in sunglasses because they reduce the light intensity to half on polarization.
S4. Ans. (a)
Sol. Here, the net capacitance is

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

Now, net charge in circuit:

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

Now, potential difference across 4 μF capacitor:

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

So, potential difference across the 4 μF capacitor is 72 Volts.
S5. Ans. (c)
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)
Sol. Energy equivalent to mass detect is released.
S9. Ans. (b)
Sol. Here we have, $T_1 = 27.5\,°C, R_1 = 2.1\Omega, T_2 = 100°C, R_1 = 2.7\,\Omega$

We know that, 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

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

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

$9x = 0.9$

$\Rightarrow x = 0.1$

S12. Ans (a)
Sol. The inductive reactance of the AC supply increases with the frequency of the AC supply.
S13. Ans. (d)
Sol. Two equipotential surfaces never intersect each other so they cannot be orthogonal.
S14. Ans. (b)
Sol. As we know every atom of a magnet acts as a dipole, So poles cannot be separated. When magnet is broken into two equal pieces, magnetic moment of each part will be half of the original magnet.
S15. Ans. (c)
Sol. Nuclear force is nearly same for all nucleus.
S16. Ans. (d)
Sol. In case of hydrogen atom mass number and atomic number are equal.

SECTION B

S17. Ans. 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.
S18. Ans. Ferromagnetic material has high retentivity. Soon passing current through windings it gains sufficient magnetism immediately.
S19. Ans. 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.
S20. Ans. 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.
S21. Ans. 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.

OR

S21. Ans. 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

S22. Ans. 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 $\propto 1/\lambda$.

S23. Ans. 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, $\frac{dR}{dt}\propto\frac{1}{T_{1/2}^2}$

S24. Ans. 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.

S25. Ans. (a) Electrostatic force on the first sphere,

$F = 0.2$ N

Charge on this sphere, $q_1 = 0.4\mu C = 0.4\times10^{-5}$C

Charge on the second sphere, $q_2 = -0.8\mu C = -0.8\times10^{-6}$C

Electrostatic force between the spheres is given by the relation,

$$F=\frac{q_1q_2}{4\pi\epsilon_0 r^2}\ \text{And}\ \frac{1}{4\pi\epsilon_0}=9\times10^9\text{Nm}^2\text{C}^{-2}$$

Were, ϵ_0 = Permittivity of free space

$$\text{And},\frac{1}{4\pi\epsilon_0}=9\times10^9\text{Nm}^{-2}\text{C}^{-2}$$

$$r^2=\frac{q_1q_2}{4\pi\epsilon_0 F}$$

$$=144\times10^{-4}$$

$$r=\sqrt{144\times10^{-4}}=0.12\text{ m}$$

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.

S26. Ans. 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 $2\theta\propto\lambda$.

S27. Ans.

$$E = hc/\lambda = 6.6.\times 10^{-34} \times 3 \times 10^{8}/620 \times 10^{-9}$$
$$= 3.2 \times 10^{-19}\ \text{J}$$
$$= 3.2 \times 10^{-19}/1.6 \times 10^{-19} = 2\text{eV}$$

This corresponds to the transition "D"

S28. Ans.

$$P_e = 16D \Rightarrow f_e = \frac{1}{P_e} = \frac{1}{16}m = \frac{100}{16}\ \text{cm} = \frac{25}{4}\ \text{cm}$$
$$P_0 = 50D \Rightarrow f_0 = \frac{1}{P_d} = \frac{1}{50}m = \frac{100}{50}\ \text{cm} = 2\ \text{cm}$$
$$f_e = \frac{25}{4}\ \text{cm and } f_0 = 2\ \text{cm}$$

$f_e = \frac{25}{4}$ cm and $f_0 = 2$ cm

length of tube $= l = 16.25$ cm

Optical instrument is compound microscope.

$$M = \frac{L}{f_0} \times \frac{D}{f_e} = \frac{16.25}{2} \times \frac{25}{25} = 16.25 \times 2$$
$$M = 32.5$$

OR

S28. Ans. Angle of the prism $(A) = r_1 + r_2$

For limiting $A_{\max} = (r_1)_{\max} + (r_2)_{\max}$ (Maximum)

Value of angle of prism for $(r_1)_{\max}$ means $i = 90°$

But when $i = 90°(r_1)_{\max} = \text{C}$

$$A_{\max} = C + C$$
$$\text{A}_{\max} = 2\text{C}$$

The angle of incidence for which angle of refraction is 90° is called critical angle.

SECTION D

S29. 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) converge

(iv) (c) Diffraction

S30. Ans. (i) (a) For stationary electron, $\vec{v} = 0 \therefore$ Force on the electron is $\vec{F}_{\text{m}} = -e(\vec{v} \times \vec{B}) = 0$

(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

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

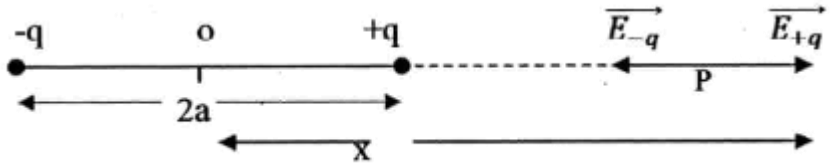
where θ is the angle between $\vec{v}$ and $\vec{B}$ Out of the given cases, only in case (b) it will experience the force while in other cases it will experience no force

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

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

SECTION E

S31. Ans. (a)



Electric field intensity at point P due to charge $-q$

$$\overrightarrow{E_{-q}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{(x+a)^2}(\hat{x})$$

Due to charge $+q$

$$\overrightarrow{E_{+q}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{(x-a)^2}(\hat{x})$$

Net electric field at point P

$$\vec{E} = \overrightarrow{E_{-q}} + \overrightarrow{E_{+q}}$$

$$= \frac{q}{4\pi\varepsilon_0} \times \left[\frac{1}{(x-a)^2} - \frac{1}{(x+a)^2}\right](\hat{x})$$

$$= \frac{q}{4\pi\varepsilon_0} \times \left[\frac{4aqx}{(x^2-a^2)^2}\right](\hat{x})$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{(q \times 2a)2x}{(x^2-a^2)^2}(\hat{x})$$

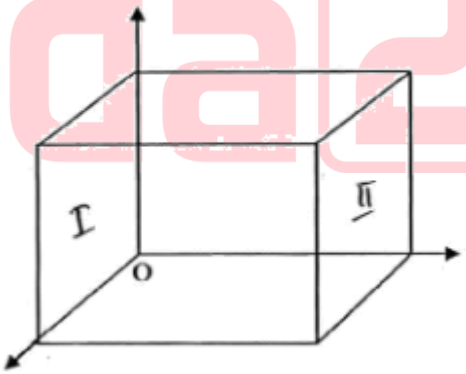
$$\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{2px}{(x^2-a^2)^2}(\hat{x})$$

For $x \gg a$

$$(x^2-a^2)^2 \simeq x^4$$

$$\vec{E} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2p}{x^3}\hat{x}$$

(b) Only the faces perpendicular to the direction of x-axis, contribute to the electric flux. The remaining faces of the cube give zero contribution.



Total flux ϕ $= \phi_I + \phi_{II}$

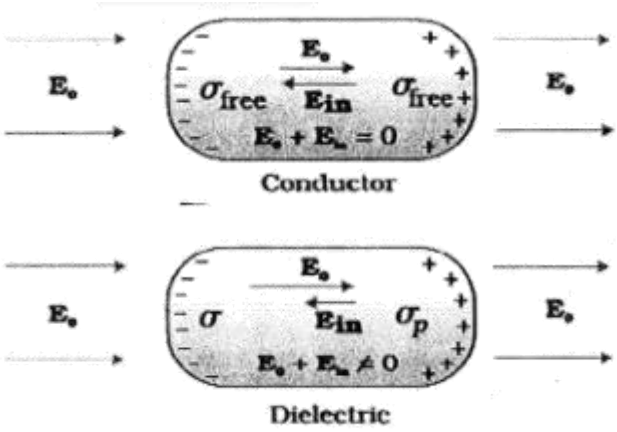
$= \oint_{\text{I}} \vec{E} \cdot \overrightarrow{ds} + \oint_{\text{II}} \vec{E} \cdot \overrightarrow{ds}$

$= 0 + 2(a) \cdot a^2$

$\therefore \phi = 2a^3$

OR

S31. Ans. (a)



In the presence of electric field, the free charge carriers, in a conductor, move the charge distribution in the conductor readjusts itself so that the net electric field within the conductor becomes zero.

In a dielectric, the external electric field induces a net dipole moment, by stretching/reorienting the molecules. The electric field, due to this induced dipole moment, opposes, but does not exactly cancel, the external electric field.

Polarization: Induced dipole moment, per unit volume, is called the polarization. For linear isotropic dielectrics having a susceptibility X_c, we have

$$P = X_e E$$

(b) (i) Net Force on the charge $\frac{Q}{2}$, placed at the centre of the shell, is zero.

Force on charge ' $2Q$ ' kept at point A

$$F = E \times 2Q = \frac{1\left(\frac{3Q}{2}\right)2Q}{4\pi\varepsilon_0 r^2} = \frac{(K)3Q^2}{r^2}$$

Electric flux through the shell

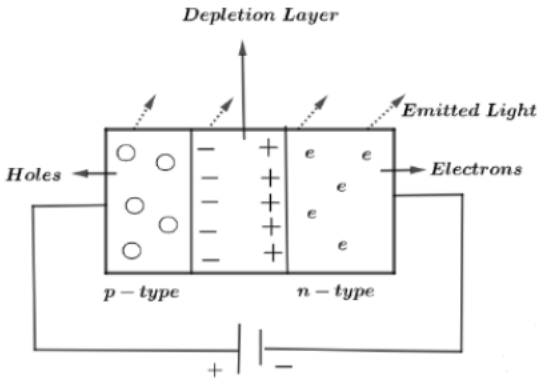
$$\phi = \frac{Q}{\varepsilon_0}$$

S32. Ans.

$$\Delta I_B = 40\mu A = 40 \times 10^{-6}\ \text{A}$$
$$\Delta I_C = 2\ \text{mA} = 2 \times 10^{-3}\ \text{A}$$
$$\Delta V_{BE} = 0.04\ \text{V}$$
$$R_L = 6\text{k}\Omega = 6 \times 10^3\Omega$$
$$\text{Rin} = \frac{\Delta V_{BE}}{\Delta I_B} = \frac{0.04}{40 \times 10^{-6}} = 1 \times 10^3\Omega = 1\text{k}\Omega$$
$$\beta = \frac{\Delta v_C}{\Delta I_B} = \frac{2 \times 10^{-3}}{40 \times 10^{-6}} = 50$$
$$\text{Voltage gain } = \beta\frac{RL}{\text{Ri}} = \frac{50 \times 6 \times 10^3}{1 \times 10^3} = 300$$

OR

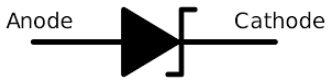
S32. Ans. (a) Light emitting diode is forward biased i.e. energy is released at the junction.



I n p-type region Holes are present and in n-type region there are electrons and when battery is connected in forward biasing such that positive terminal of battery connected to p-type region and negative terminal of battery connected with n-type region, this is called forward biasing. The thickness of the depletion layer becomes narrow and light is emitted through the semiconductor device.

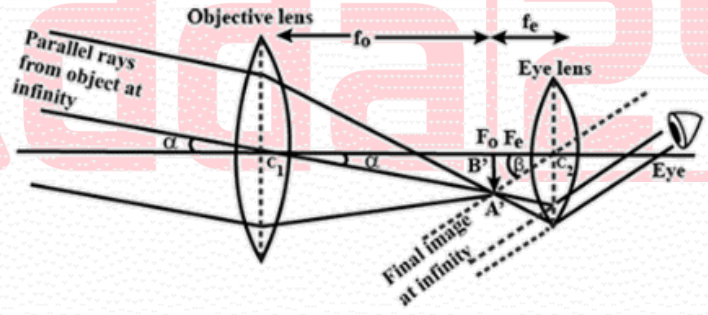
Advantages of LED

(1) They are used in numerical displays as compact in size.
(2) It works at low voltage and has longer life than incandescent bulbs.
(b) Symbol for Zener diode



Width of the depletion layer of Zener diode becomes very small due to heavy doping of p and n-regions.

S33. Ans. (a) Ray diagram of an astronomical telescope when the final image is formed at infinity



Expression for the resolving power of the telescope-

Magnifying power of telescope is defined as the ratio of angle subtended by image on eye (β) to angle subtended by object on eye (α)

Magnifying power of telescope $m = -\frac{\beta}{\alpha}$

From figure, $\beta = \tan\beta = \frac{A'B'}{f_e}$

Also, $\alpha = \tan\alpha = \frac{A'B'}{f_0}$

$$\Rightarrow \frac{\beta}{\alpha} = \frac{f_0}{f_e}$$

$$\Rightarrow m = -\frac{f_0}{f_e}$$

(b) (i) Angular magnification $m = \frac{\beta}{\alpha} = \frac{f_o}{f_e} = \frac{20m}{10^{-2}m} = 2000$

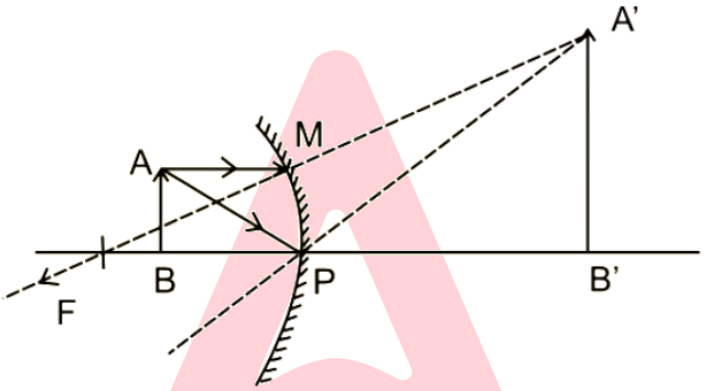
(ii)

$$\frac{D}{d} = \frac{x}{f_0}$$

$$d = \frac{Df_0}{x} = \frac{3.5 \times 10^6 \times 20}{3.8 \times 10^8} = .18 \text{ m}$$

OR

S33. Ans. (a)



From $\Delta A'B'F$ and MFP by similarity criteria.

$$\frac{A'B:}{MP} = \frac{B'F}{FP} \text{ or } \frac{A'B'}{AB} = \frac{B'F}{FP} \ (P.M = BA)$$

Similarly, from

$\Delta A'B'P$ and ABP

$$\frac{B'A}{BA} = \frac{B'P}{BP}$$

$$\frac{B'F}{FP} = \frac{B'P}{BP}$$

$$B'F = v + f$$

$$BP = u$$

$$\therefore \frac{u+f}{f} = \frac{v}{u}$$

$$1 + \frac{v}{f} = \frac{v}{u}$$

Dividing throughout by v and applying sign convention

$$\frac{1}{v} - \frac{1}{f} = \frac{-1}{u}$$

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

is the mirror equation.

For plano-convex lens,

$$R_1 = \infty$$
$$R_2 = -20 \text{ cm}$$

By lens maker's formula,

$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$
$$\frac{1}{f} = (1.5 - 1)\left[\frac{1}{\infty} - \frac{1}{(-20)}\right] = \frac{1}{40}$$
$$f = 40 \text{ cm}$$

Object distance, $u = -30$ cm By Lens formula;

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$
$$\frac{1}{v} - \frac{1}{(-30)} = \frac{1}{40}$$
$$\frac{1}{v} + \frac{1}{30} = \frac{1}{40}$$
$$\frac{1}{v} = \frac{1}{40} - \frac{1}{30} = -\frac{1}{120}$$
$$v = -120 \text{ cm}$$

-ve sign indicates that image is virtual.