General Instructions :

Read the following instructions very carefully and follow them:

(i) This question paper contains 33 questions. All questions are compulsory.
(ii) Question paper is divided into FIVE sections - Section A, B, C, D and **E**.
(iii) In Section A : Question number 1 to 16 are Multiple Choice (MCQ) type questions carrying 1 mark each.
(iv) In Section B : Question number 17 to 21 are Very Short Answer (VSA) type questions carrying 2 marks each.
(v) In Section C : Question number 22 to 28 are Short Answer (SA) type questions carrying 3 marks each.
(vi) In Section D : Question number 29 & 30 are Long Answer (LA) type questions carrying 4 marks each.
(vii) In Section E : Question number 31 to 33 are Case-Based questions carrying 5 marks each.
(viii) There is no overall choice. However, an internal choice has been provided in 1 question in Section-B, 1 question in Section-C, 2 questions in Section-D and 3 questions in Section-E.
(ix) Use of calculators is NOT allowed.

$c = 3 \times 10^8\ m/s$
$h = 6.63 \times 10^{-34} Js$
$e = 1.6 \times 10^{-19} C$
$\mu_0 = 4\pi \times 10^{-7}\ T\ m\ A^{-1}$
$\varepsilon_0 = 8.854 \times 10^{-12} C^2\ N^{-1}\ m^{-2}$
$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ N\ m^2 C^{-2}$
Mass of electron $(m_e) = 9.1 \times 10^{-31}$ kg
Mass of neutron $= 1.675 \times 10^{-27}$ kg
Mass of proton $= 1.673 \times 10^{-27}$ kg
Avogadro's number $= 6.023 \times 10^{23}$ per gram mole
Boltzmann constant $= 1.38 \times 10^{-23} JK^{-1}$

SECTION-A

1. A battery supplies 0.9 A current through a 2Ω resistor and 0.3 A current through a 7Ω resistor when connected one by one. The internal resistance of the battery is :
(a) 2Ω (b)1.2Ω
(c)1Ω (d)0.5Ω

2. A particle of mass m and charge q describes a circular path of radius R in a magnetic field. If its mass and charge were 2 m and $\frac{q}{2}$ respectively, the radius of its path would be
(a) $\frac{R}{4}$ (b)$\frac{R}{2}$
(c)2 R (d)4 R

3. Which of the following pairs is that of paramagnetic materials ?
(a) Copper and Aluminium
(b)Sodium and Calcium
(c)Lead and Iron
(d)Nickel and Cobalt

4. A galvanometer of resistance 50Ω is converted into a voltmeter of range $(0-2\ V)$ using a resistor of $1.0 k\Omega$. If it is to be converted into a voltmeter of range $(0-10\ V)$, the resistance required will be
(a) 4.8kΩ (b) 5.0kΩ
(c)5.2kΩ (d)5.4kΩ

5. Two coils are placed near each other. When the current in one coil is changed at the rate of 5 A/s, an emf of 2 mV is induced in the other. The mutual inductance of the two coils is
(a) 0.4 mH (b)2.5 mH
(c)10 mH (d)2.5 H

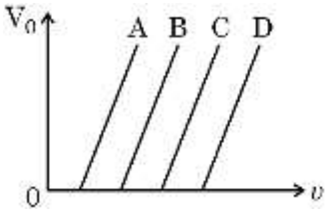
6. The electromagnetic waves used to purify water are
(a) Infrared rays (b)Ultraviolet rays
(c)X-rays (d)Gamma rays

7. The focal lengths of the objective and the eyepiece of a compound microscope are 1 cm and 2 cm respectively. If the tube length of the microscope is 10 cm , the magnification obtained by the microscope for most suitable viewing by relaxed eye is :

(a) 250 (b) 200

(c) 150 (d) 125

8. The variation of the stopping potential (V_0) with the frequency (v) of the incident radiation for four metals A, B, C and D is shown in the figure. For the same frequency of incident radiation producing photo-electrons in all metals, the kinetic energy of photo-electrons will be maximum for metal



(a) A (b) B

(c) C (d) D

9. The energy of an electron in the ground state of hydrogen atom is -13.6 eV . The kinetic and potential energy of the electron in the first excited state will be

(a) $-13.6\text{eV}, 27.2\text{eV}$ (b) $-6.8\text{eV}, 13.6\text{eV}$

(c) $3.4\text{eV}, -6.8\text{eV}$ (d) $6.8\text{eV}, -3.4\text{eV}$

10. A Young's double-slit experimental set up is kept in a medium of refractive index $\left(\frac{4}{3}\right)$. Which maximum in this case will coincide with the 6^{th} maximum obtained if the medium is replaced by air?

(a) 4^{th} (b) 6^{th}

(c) 8^{th} (d) 10^{th}

11. The potential energy between two nucleons inside a nucleus is minimum at a distance of about

(a) 0.8 fm (b) 1.6 fm

(c) 2.0 fm (d) 2.8 fm

12. A pure Si crystal having 5×10^{28} atoms m^{-3} is dopped with 1 ppm concentration of antimony. If the concentration of holes in the doped crystal is found to be $4.5 \times 10^9\ \text{m}^{-3}$, the concentration (in m^{-3}) of intrinsic charge carriers in Si crystal is about

(a) 1.2×10^{15} (b) 1.5×10^{16}

(c) 3.0×10^{15} (d) 2.0×10^{16}

For Questions 13 to 16, two statements are given - one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below.

(a) If both Assertion (A) and Reason (R) are true and Reason (R) is correct explanation of Assertion (A).

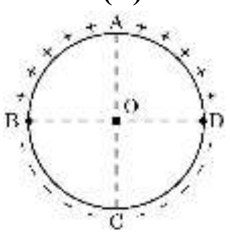
(b) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).

(c) If Assertion (A) is true but Reason (R) is false.

(d) If both Assertion (A) and Reason (R) are false.

13. Assertion (A) : Equal amount of positive and negative charges are distributed uniformly on two halves of a thin circular ring as shown in figure. The resultant electric field at the centre O of the ring is along OC .

Reason (R) : It is so because the net potential at O is not zero.



14. Assertion (A) : The energy of a charged particle moving in a magnetic field does not change.

Reason (R) : It is because the work done by the magnetic force on the charge moving in a magnetic field is zero.

15. Assertion (A) : In a Young's double-slit experiment, interference pattern is not observed when two coherent sources are infinitely close to each other.

Reason (R) : The fringe width is proportional to the separation between the two sources.

16. Assertion (A) : An alpha particle is moving towards a gold nucleus. The impact parameter is maximum for the scattering angle of 180°.

Reason (R) : The impact parameter in an alpha particle scattering experiment does not depend upon the atomic number of the target nucleus.

SECTION - B

17. (A) Four point charges of $1 \mu C, -2 \mu C, 1 \mu C$ and $-2 \mu C$ are placed at the corners A, B, C and D respectively, of a square of side 30 cm . Find the net force acting on a charge of $4 \mu C$ placed at the centre of the square.

OR

(B) Three point charges, 1 pC each, are kept at the vertices of an equilateral triangle of side 10 cm . Find the net electric field at the centroid of triangle.

18. Derive an expression for magnetic force $\vec{F}$ acting on a straight conductor of length L carrying current I in an external magnetic field $\vec{B}$. Is it valid when the conductor is in zig-zag form ? Justify.

19. A telescope has an objective lens of focal length 150 cm and an eyepiece of focal length 5 cm . Calculate its magnifying power in normal adjustment and the distance of the image formed by the objective.

20. (A) Two energy levels of an electron in hydrogen atom are separated by 2.55 eV . Find the wavelength of radiation emitted when the electron makes transition from the higher energy level to the lower energy level.

(B) In which series of hydrogen spectrum this line shall fall ?

21. The earth revolves around the sun in an orbit of radius 1.5×10^{11} m with orbital speed $30 \mathrm{~km/s}$. Find the quantum number that characterises its revolution using Bohr's model in this case (mass of earth $= 6.0 \times 10^{24}$ kg).

SECTION - C

22. (A) Write Einstein's photoelectric equation. How did Millikan prove the validity of this equation?

(B) Explain the existence of threshold frequency of incident radiation for photoelectric emission from a given surface.

23. (A) Define the term 'electric flux' and write its dimensions.

(B) A plane surface, in shape of a square of side 1 cm is placed in an electric field $\vec{E} = \left(100 \frac{N}{C}\right) \hat{\imath}$ such that the unit vector normal to the surface is given by $\hat{n} = 0.8 \hat{\imath} + 0.6 \hat{k}$. Find the electric flux through the surface.

24. (A) (i) State Lenz's Law. In a closed circuit, the induced current opposes the change in magnetic flux that produced it as per the law of conservation of energy. Justify.

(ii) A metal rod of length 2 m is rotated with a frequency $60 \mathrm{rev/s}$ about an axis passing through its centre and perpendicular to its length. A uniform magnetic field of 2T perpendicular to its plane of rotation is switched on in the region. Calculate the e.m.f. induced between the centre and the end of the rod.

OR

(B) (i) State and explain Ampere's circuital law.

(ii) Two long straight parallel wires separated by 20 cm , carry 5 A and 10 A current respectively, in the same direction. Find the magnitude and direction of the net magnetic field at a point midway between them.

25. An electron moving with a velocity $\vec{v} = (1.0 \times 10^{7} \mathrm{~m/s}) \hat{\imath} + (0.5 \times 10^{7} \mathrm{~m/s}) \hat{\jmath}$ enters a region of uniform magnetic field $\vec{B} = (0.5 \mathrm{mT}) \hat{\jmath}$. Find the radius of the circular path described by it. While rotating; does the electron trace a linear path too? If so, calculate the linear distance covered by it during the period of one revolution.

26. (A) Name the parts of the electromagnetic spectrum which are **(i)** also known as 'heat waves' and **(ii)** absorbed by ozone layer in the atmosphere.

(B) Write briefly one method each, of the production and detection of these radiations.

27. (A) Explain the characteristics of a $p-n$ junction diode that makes it suitable for its use as a rectifier.

(B) With the help of a circuit diagram, explain the working of a full wave rectifier.

28. Explain the following, giving reasons :

(A) A doped semiconductor is electrically neutral.

(B) In a p-n junction under equilibrium, there is no net current.
(C) In a diode, the reverse current is practically not dependent on the applied voltage.

SECTION-D

29. Dielectrics play an important role in design of capacitors. The molecules of a dielectric may be polar or non-polar. When a dielectric slab is placed in an external electric field, opposite charges appear on the two surfaces of the slab perpendicular to electric field. Due to this an electric field is established inside the dielectric.
The capacitance of a capacitor is determined by the dielectric constant of the material that fills the space between the plates. Consequently, the energy storage capacity of a capacitor is also affected. Like resistors, capacitors can also be arranged in series and/or parallel.

(i) Which of the following is a polar molecule?
(a) O_2 (b) H_2
(c) N_2 (d) HCl

(ii)Which of the following statements about dielectrics is correct?
(a) A polar dielectric has a net dipole moment in absence of an external electric field which gets modified due to the induced dipoles.
(b) The net dipole moments of induced dipoles is along the direction of the applied electric field.
(c) Dielectrics contain free charges.
(d) The electric field produced due to induced surface charges inside a dielectric is along the external electric field.

(iii) When a dielectric slab is inserted between the plates of an isolated charged capacitor, the energy stored in it :
(a) increases and the electric field inside it also increases.
(b) decreases and the electric field also decreases.
(c) decreases and the electric field increases.
(d) increases and the electric field decreases.

(iv) (A) An air-filled capacitor with plate area A and plate separation d has capacitance C_0. A slab of dielectric constant K , area A and thickness $\left(\frac{d}{5}\right)$ is inserted between the plates. The capacitance of the capacitor will become
(a) $\left[\frac{4K}{5K+1}\right]C_0$ (b) $\left[\frac{K+5}{4}\right]C_0$
(c) $\left[\frac{5K}{4K+1}\right]C_0$ (d) $\left[\frac{K+4}{5K}\right]C_0$

OR

(iv) (B) Two capacitors of capacitances $2C_0$ and $6C_0$ are first connected in series and then in parallel across the same battery. The ratio of energies stored in series combination to that in parallel is
(a) $\frac{1}{4}$ (b) $\frac{1}{6}$
(c) $\frac{2}{15}$ (d) $\frac{3}{16}$

30. A prism is an optical medium bounded by three refracting plane surfaces. A ray of light suffers successive refractions on passing through its two surfaces and deviates by a certain angle from its original path. The refractive index of the material of the prism is given by $\mu = \sin\left(\frac{A+\delta m}{2}\right)/\sin\frac{A}{2}$. If the angle of incidence on the second surface is greater than an angle called critical angle, the ray will not be refracted from the second surface and is totally internally reflected.

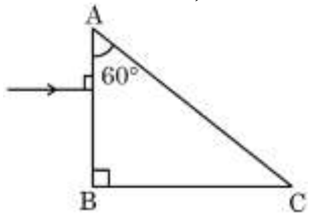
(i) The critical angle for glass is θ_1 and that for water is θ_2. The critical angle for glass-water surface would be (given $_a\mu_g = 1.5$, $_a\mu_w = 1.33$)
(a) less than θ_2 (b) between θ_1 and θ_2
(c) greater than θ_2 (d) less than θ_1

(ii) When a ray of light of wavelength λ and frequency v is refracted into a denser medium
(a) λ and v both increase.
(b) λ increases but v is unchanged.

(c) λ decreases but v is unchanged.
(d) λ and v both decrease.
(iii) (A) The critical angle for a ray of light passing from glass to water is minimum for
(a) red colour (b) blue colour
(c) yellow colour (d) violet colour

OR

(iii) (B) Three beams of red, yellow and violet colours are passed through a prism, one by one under the same condition. When the prism is in the position of minimum deviation, the angles of refraction from the second surface are r_R, r_Y and r_V respectively.
Then
(a) $r_V < r_Y < r_R$ (b) $r_Y < r_R < r_V$
(c) $r_R < r_Y < r_V$ (d) $r_R = r_Y = r_V$
(iv) A ray of light is incident normally on a prism ABC of refractive index $\sqrt{2}$, as shown in figure. After it strikes face AC, it will



(a) go straight undeviated
(b) just graze along the face AC
(c) refract and go out of the prism
(d) undergo total internal reflection

SECTION-E

31. (A) (i) Draw equipotential surfaces for an electric dipole.
(ii) Two point charges q_1 and q_2 are located at $\vec{r}_1$ and $\vec{r}_2$ respectively in an external electric field $\vec{E}$. Obtain an expression for the potential energy of the system.
(iii) The dipole moment of a molecule is 10^{-30}Cm. It is placed in an electric field $\vec{E}$ of 10^5 V/m such that its axis is along the electric field. The direction of $\vec{E}$ is suddenly changed by 60° at an instant. Find the change in the potential energy of the dipole, at that instant.

OR

(B) (i) A thin spherical shell of radius R has a uniform surface charge density σ. Using Gauss' law, deduce an expression for electric field (i) outside and (ii) inside the shell.
(ii) Two long straight thin wires AB and CD have linear charge densities $10\mu C/m$ and $-20\mu C/m$, respectively. They are kept parallel to each other at a distance 1 m . Find magnitude and direction of the net electric field at a point midway between them.

32. (A) (i) You are given three circuit elements X, Y and Z . They are connected one by one across a given ac source. It is found that V and I are in phase for element X. V leads I by $\left(\frac{\pi}{4}\right)$ for element Y while I leads V by $\left(\frac{\pi}{4}\right)$ for element Z. Identify elements X, Y and Z.
(ii) Establish the expression for impedance of circuit when elements X, Y and Z are connected in series to an ac source. Show the variation of current in the circuit with the frequency of the applied ac source.
(iii) In a series LCR circuit, obtain the conditions under which **(a)** impedance is minimum and **(b)** wattless current flows in the circuit.

OR

(B)(i) Describe the construction and working of a transformer and hence obtain the relation for $\left(\frac{v_s}{v_p}\right)$ in terms of number of turns of primary and secondary.
(ii) Discuss four main causes of energy loss in a real transformer.

33. (A) (i) A plane light wave propagating from a rarer into a denser medium, is incident at an angle i on the surface separating two media. Using Huygen's principle, draw the refracted wave and hence verify Snell's law of refraction.

(ii) In a Young's double slit experiment, the slits are separated by 0.30 mm and the screen is kept 1.5 m away. The wavelength of light used is 600 nm . Calculate the distance between the central bright fringe and the 4^{th} dark fringe.

OR

(B) (i) Discuss briefly diffraction of light from a single slit and draw the shape of the diffraction pattern.
(ii) An object is placed between the pole and the focus of a concave mirror. Using mirror formula, prove mathematically that it produces a virtual and an enlarged image.

General Instructions :

Read the following instructions very carefully and follow them:

(i) This question paper contains 33 questions. All questions are compulsory.
(ii) Question paper is divided into FIVE sections - Section A, B, C, D and **E**.
(iii) Section A - Question number 1 to 16 are Multiple Choice (MCQ) type questions. Each question carries 1 mark.
(iv) Section B - Question number 17 to 21 are Very Short Answer type questions. Each question carries 2 mark.
(v) Section C-Question number 22 to 28 are Short Answer type questions. Each question carries 3 mark.
(vi) Section D : Question number 29 and 30 are Case-Based questions. Each question carries 4 mark.
(vii) Section **E** - Question number 31 to 33 are Long Answer type questions. Each question carries 5 mark.
(viii) There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the Sections except Section-A.
(ix) Kindly note that there is a separate question paper for Visually Impaired candidates.
(x) Use of calculators is NOT allowed.

You may use the following values of physical constants wherever necessary :

$c = 3 \times 10^8 \text{ m/s}$
$h = 6.63 \times 10^{-34} \text{Js}$
$e = 1.6 \times 10^{-19} \text{C}$
$\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$
$\varepsilon_0 = 8.854 \times 10^{-12} \text{C}^2 \text{ N}^{-1} \text{ m}^{-2}$
$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N m}^2\text{C}^{-2}$
Mass of electron $(m_e) = 9.1 \times 10^{-31}$ kg
Mass of neutron $= 1.675 \times 10^{-27}$ kg
Mass of proton $= 1.673 \times 10^{-27}$ kg
Avogadro's number $= 6.023 \times 10^{23}$ per gram mole
Boltzmann constant $= 1.38 \times 10^{-23} \text{JK}^{-1}$

SECTION-A

34. Two charges +q each are kept ' 2a ' distance apart. A third charge −2q is placed midway between them. The potential energy of the system is -

(a) $\frac{q^2}{8\pi\varepsilon_0 a}$ (b) $-\frac{6q^2}{8\pi\varepsilon_0 a}$
(c) $\frac{-7q^2}{8\pi\varepsilon_0 a^a}$ (d) $\frac{9q^2}{8\pi\varepsilon_0 a}$

35. Two identical small conducting balls B_1 and B_2 are given -7 pC and +4 pC charges respectively. They are brought in contact with a third identical ball B_3 and then separated. If the final charge on each ball is -2 pC , the initial charge on B_3 was

(a) -2 pC (b) -3 pC
(c) -5 pC (d) -15 pC

36. The quantum nature of light explains the observations on photoelectric effect as -

(a) there is a minimum frequency of incident radiation below which no electrons are emitted.
(b) the maximum kinetic energy of photoelectrons depends only on the frequency of incident radiation.
(c) when the metal surface is illuminated, electrons are ejected from the surface after sometime.
(d) the photoelectric current is independent of the intensity of incident radiation.

37. The radius (r_n) of n^{th} orbit in Bohr model of hydrogen atom varies with n as

(a) $r_n \propto n$ (b) $r_n \propto \frac{1}{n}$

(c) $r_n \propto n^2$ (d) $r_n \propto \frac{1}{n^2}$

38. A straight wire is kept horizontally along east-west direction. If a steady current flows in wire from east to west, the magnetic field at a point above the wire will point towards

(a) East (b) West

(c) North (d) South

39. The magnetic susceptibility for a diamagnetic material is

(a) small and negative

(b) small and positive

(c) large and negative

(d) large and positive

40. A galvanometer of resistance 100Ω is converted into an ammeter of range $(0 - 1\ A)$ using a resistance of 0.1Ω. The ammeter will show full scale deflection for a current of about

(a) 0.1 mA (b) 1 mA

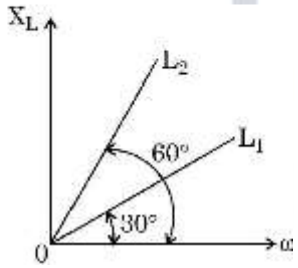
(c) 10 mA (d) 0.1 A

41. A circular loop A of radius R carries a current I. Another circular loop B of radius r $\left(= \frac{R}{20}\right)$ is placed concentrically in the plane of A. The magnetic flux linked with loop B is proportional to

(a) R (b) $\sqrt{R}$

(c) $R^{\frac{3}{2}}$ (d) R^2

42. Figure shows the variation of inductive reactance X_L of two ideal inductors of inductance L_1 and L_2, with angular frequency ω. The value of $\frac{L_1}{L_2}$ is



(a) $\sqrt{3}$ (b) $\frac{1}{\sqrt{3}}$

(c) 3 (d) $\frac{1}{3}$

43. The phase difference between electric field $\vec{E}$ and magnetic field $\vec{B}$ in an electromagnetic wave propagating along z -axis is -

(a) zero (b) π

(c) $\frac{\pi}{2}$ (d) $\frac{\pi}{4}$

44. A coil of N turns is placed in a magnetic field $\vec{B}$ such that $\vec{B}$ is perpendicular to the plane of the coil. B changes with time as $B = B_0 \cos\left(\frac{2\pi}{T} t\right)$ where T is time period. The magnitude of emf induced in the coil will be maximum at Here, $n = 1, 2, 3, 4, \ldots$

(a) $t = \frac{nT}{8}$ (b) $t = \frac{nT}{4}$

(c) $t = \frac{nT}{2}$ (d) $t = nT$

45. In Balmer series of hydrogen atom, as the wavelength of spectral lines decreases, they appear

(a) equally spaced and equally intense.

(b) further apart and stronger in intensity.

(c) closer together and stronger in intensity.

(d) closer together and weaker in intensity.

Note : For questions number 13 to 16 , 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) If both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
(b) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).
(c) If Assertion (A) is true and Reason (R) is false.
(d) If both Assertion (A) and Reason (R) are false.

46. Assertion (A) : Electrons are ejected from the surface of zinc when it is irradiated by yellow light.
Reason (R) : Energy associated with a photon of yellow light is more than the work function of zinc.

47. Assertion (A) : The temperature coefficient of resistance is positive for metals and negative for p -type semiconductors.
Reason (R) : The charge carriers in metals are negatively charged, whereas the majority charge carriers in p-type semiconductors are positively charged.

48. Assertion (A) : When electrons drift in a conductor, it does not mean that all free electrons in the conductor are moving in the same direction.
Reason (R) : The drift velocity is superposed over large random velocities of electrons.

49. Assertion (A) : In interference and diffraction of light, light energy reduces in one region producing a dark fringe. It increases in another region and produces a bright fringe.
Reason (R) : This happens because energy is not conserved in the phenomena of interference and diffraction.

SECTION-B

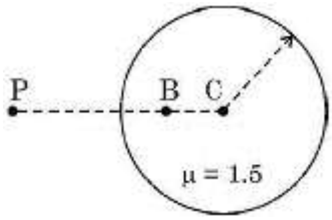
50. Draw the circuit diagram of a $p-n$ junction diode in (i) forward biasing and (ii) reverse biasing. Also draw its I V characteristics in the two cases.

51. A proton and α-particle are accelerated through different potentials V_1 and V_2 respectively so that they have the same de Broglie wavelengths. Find $\frac{V_1}{V_2}$.

52. A ray of light is incident normally on one face of an equilateral glass prism of refractive index μ. When the prism is completely immersed in a transparent medium, it is observed that the emergent ray just grazes the adjacent face. Find the refractive index of the medium.

53. Two electric heaters have power ratings P_1 and P_2, at voltage V . They are connected in series to a dc source of voltage V. Find the power consumed by the combination. Will they consume the same power if connected in parallel across the same source ?

54. (A) An air bubble is trapped at point $B(CB = 20\text{ cm})$ in a glass sphere of radius 40 cm and refractive index 1.5 as shown in figure. Find the nature and position of the image of the bubble as seen by an observer at point P .



OR

(B) In normal adjustment, for a refracting telescope, the distance between objective and eye piece lens is 1.00 m. If the magnifying power of the telescope is 19, find the focal length of the objective and the eyepiece lens.

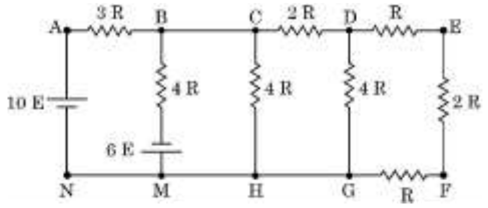
SECTION-C

55. (A) Differentiate between nuclear fission and fusion.
(B) The fission properties of ${}_{94}Pu^{239}$ are very similar to those of ${}_{92}U^{235}$. How much energy (in MeV), is released if all the atoms in 1 g of pure ${}_{94}Pu^{239}$ undergo fission? The average energy released per fission is 180 MeV.

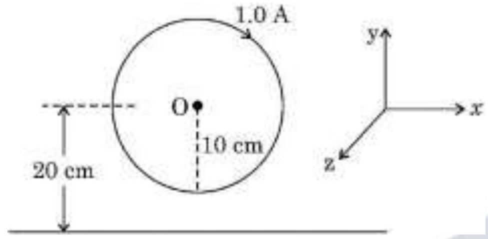
56. The electric field in a region is given by $\vec{E} = (10x + 4)\hat{i}$
where x is in m and E is in N/C. Calculate the amount of work done in taking a unit charge from
(i) $(5\text{ m}, 0)$ to $(10\text{ m}, 0)$
(ii) $(5\text{ m}, 0)$ to $(5\text{ m}, 10\text{ m})$

57. Draw the graph showing variation of scattered particles detected (N) with the scattering angle (θ) in Geiger-Marsden experiment. Write two conclusions that you can draw from this graph. Obtain the expression for the distance of closest approach in this experiment.

58. Find the current in branch BM in the network shown :



59. A circular loop of radius 10 cm carrying current of 1.0 A lies in $x-y$ plane. A long straight wire lies in the same plane parallel to x axis at a distance of 20 cm as shown in figure.



Find the direction and value of current that has to be maintained in the wire so that the net magnetic field at O is zero.

60. Name the electromagnetic waves with their wavelength range which are used for

(i) FM radio broadcast

(ii) detection of fracture in bones

(iii) treatment of muscular strain

61. (A) (i) Define mutual inductance. Write its SI unit.

(ii) Derive an expression for the mutual inductance of a system of two long coaxial solenoids of same length l, having turns N_1 and N_2 and of radii r_1 and $r_2 (> r_1)$.

OR

(B) What are ferromagnetic materials ? Explain ferromagnetism with the help of suitable diagrams, using the concept of magnetic domain.

SECTION-D

Note : Questions number 29 to 30 are Case Study based questions. Read the following paragraph and answer the questions that follow.

62. A pure semiconductor like Ge or Si , when doped with a small amount of suitable impurity, becomes an extrinsic semiconductor. In thermal equilibrium, the electron and hole concentration in it are related to the concentration of intrinsic charge carriers. A p-type or n-type semiconductor can be converted into a p · n junction by doping it with suitable impurity. Two processes, diffusion and drift take place during formation of a p · n junction. A semiconductor diode is basically a p · n junction with metallic contacts provided at the ends for the application of an external voltage. A p-n junction diode allows currents to pass only in one direction when it is forward biased. Due to this property, a diode is widely used to rectify alternating voltages, in half-wave or full wave configuration.

(i) When Ge is doped with pentavalent impurity, the energy required to free the weakly bound electron from the dopant is about

(a) 0.001 eV (b) 0.01 eV

(c) 0.72 eV (d) 1.1 eV

(ii) At a given temperature, the number of intrinsic charge carriers in a semiconductor is 2.0×10^{10} cm^{-3}. It is doped with pentavalent impurity atoms. As a result, the number of holes in it becomes 8×10^{3} cm^{-3}. The number of electrons in the semiconductor is

(a) 2×10^{24} m^{-3} (b) 4×10^{23} m^{-3}

(c) 1×10^{22} m^{-3} (d) 5×10^{22} m^{-3}

(iii)(A) During the formation of a p-n junction -

(a) electrons diffuse from p-region into n-region and holes diffuse from n -region into p -region.

(b) both electrons and holes diffuse from n -region into p -region.
(c) electrons diffuse from n-region into p-region and holes diffuse from p-region into n-region.
(d) both electrons and holes diffuse from p-region into n-region.

OR

(iii)(B)Initially during the formation of a p-n junction -
(a) diffusion current is large and drift current is small.
(b) diffusion current is small and drift current is large.
(c) both the diffusion and the drift currents are large.
(d) both the diffusion and the drift currents are small.

(iv) An ac voltage $V = 0.5\sin(100\pi t)$ volt is applied, in turn, across a half-wave rectifier and a full-wave rectifier. The frequency of the output voltage across them respectively will be
(a) 25 Hz, 50 Hz (b) 25 Hz, 100 Hz
(c) 50 Hz, 50 Hz (d) 50 Hz, 100 Hz

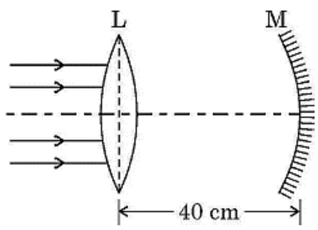
63. A lens is a transparent optical medium bounded by two surfaces; at least one of which should be spherical. Applying the formula of image formation by a single spherical surface successively at the two surfaces of a thin lens, a formula known as lens maker's formula and hence the basic lens formula can be obtained. The focal length (or power) of a lens depends on the radii of its surfaces and the refractive index of its material with respect to the surrounding medium. The refractive index of a material depends on the wavelength of light used. Combination of lenses helps us to obtain diverging or converging lenses of desired power and magnification.

(i) A thin converging lens of focal length 20 cm and a thin diverging lens of focal length 15 cm are placed coaxially in contact. The power of the combination is
(a) $\frac{-5}{6}$ D (b) $\frac{-5}{3}$ D
(c) $\frac{4}{3}$ D (d) $\frac{3}{2}$ D

(ii) The radii of curvature of two surfaces of a convex lens are R and 2R. If the focal length of this lens is $\left(\frac{4}{3}\right)$ R, the refractive index of the material of the lens is :
(a) $\frac{5}{3}$ (b) $\frac{4}{3}$
(c) $\frac{3}{2}$ (d) $\frac{7}{5}$

(iii) The focal length of an equiconvex lens
(a) increases when the lens is dipped in water.
(b) increases when the wavelength of incident light decreases.
(c) increases with decrease in radius of curvature of its surface.
(d) decreases when the lens is cut into two identical parts along its principal axis.

(iv) (A) A thin convex lens L of focal length 10 cm and a concave mirror M of focal length 15 cm are placed coaxially 40 cm apart as shown in figure. A beam of light coming parallel to the principal axis is incident on the lens. The final image will be formed at a distance of



(a) 10 cm , left of lens
(b) 10 cm , right of lens
(c) 20 cm , left of lens
(d) 20 cm , right of lens

OR

(B) A beam of light coming parallel to the principal axis of a convex lens L_1 of focal length 16 cm is incident on it. Another convex lens L_2 of focal length 12 cm is placed coaxially at a distance 40 cm from L_1. The nature and distance of the final image from L_2 will be

(a) real, 24 cm (b) virtual, 12 cm
(c) real, 32 cm (d) virtual, 18 cm

SECTION-E

64. (A)(i) Draw a ray diagram for the formation of the image of an object by a convex mirror. Hence, obtain the mirror equation.

(ii) Why are multi-component lenses used for both the objective and the eyepiece in optical instruments?

(iii) The magnification of a small object produced by a compound microscope is 200 . The focal length of the eyepiece is 2 cm and the final image is formed at infinity. Find the magnification produced by the objective.

OR

(B) (i) Differentiate between a wavefront and a ray.

(ii) State Huygen's principle and verify laws of reflection using suitable diagram.

(iii) In Young's double slit experiment, the slits S_1 and S_2 are 3 mm apart and the screen is placed 1.0 m away from the slits. It is observed that the fourth bright fringe is at a distance of 5 mm from the second dark fringe. Find the wavelength of light used.

65. (A) (i) A dielectric slab of dielectric constant ' K ' and thickness ' t ' is inserted between plates of a parallel plate capacitor of plate separation d and plate area A . Obtain an expression for its capacitance.

(ii) Two capacitors of different capacitances are connected first (1) in series and then (2) in parallel across a dc source of 100 V . If the total energy stored in the combination in the two cases are 40 mJ and 250 mJ respectively, find the capacitance of the capacitors.

OR

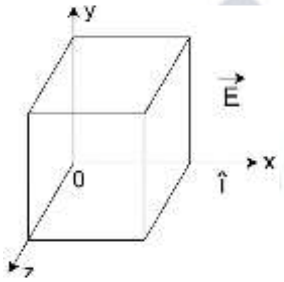
(B) (i) Using Gauss's law, show that the electric field E at a point due to a uniformly charged infinite plane sheet is given by $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$ where symbols have their usual meanings.

(ii) Electric field $\vec{E}$ in a region is given by

$\vec{E} = (5x^2 + 2)\hat{i}$

where E is in N/C and x is in meters.

A cube of side 10 cm is placed in the region as shown in figure.



Calculate (1) the electric flux through the cube, and (2) the net charge enclosed by the cube.

66. (A) (i) Mention the factors on which the resonant frequency of a series LCR circuit depends. Plot a graph showing variation of impedance of a series LCR circuit with the frequency of the applied a.c. source.

(ii) With the help of a suitable diagram, explain the working of a step-up transformer.

(iii) Write two causes of energy loss in a real transformer.

OR

(B) (i) With the help of a diagram, briefly explain the construction and working of ac generator.

(ii) An electron is revolving around a proton in an orbit of radius r with a speed v. Obtain expression for magnetic moment associated with the electron.

General Instructions :

Read the following instructions very carefully and follow them:

(i) This question paper contains 33 questions. All questions are compulsory.

(ii) Question paper is divided into FIVE sections - Section A, B, C, D and **E**.

(iii) Section A - Question number 1 to 16 are Multiple Choice (MCQ) type questions. Each question carries 1 mark.

(iv) Section B - Question number 17 to 21 are Very Short Answer type questions. Each question carries 2 mark.

(v) Section C-Question number 22 to 28 are Short Answer type questions. Each question carries 3 mark.

(vi) Section D : Question number 29 and 30 are Case-Based questions. Each question carries 4 mark.

(vii) Section **E** - Question number 31 to 33 are Long Answer type questions. Each question carries 5 mark.

(viii) There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the Sections except Section-A.
(ix) Kindly note that there is a separate question paper for Visually Impaired candidates.
(x) Use of calculators is NOT allowed.
You may use the following values of physical constants wherever necessary :
$c = 3 \times 10^8$ m/s
$h = 6.63 \times 10^{-34}$Js
$e = 1.6 \times 10^{-19}$C
$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}
$\varepsilon_0 = 8.854 \times 10^{-12} C^2 N^{-1} m^{-2}$
$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 N m^2 C^{-2}$
Mass of electron $(m_e) = 9.1 \times 10^{-31}$ kg
Mass of neutron $= 1.675 \times 10^{-27}$ kg
Mass of proton $= 1.673 \times 10^{-27}$ kg
Avogadro's number $= 6.023 \times 10^{23}$ per gram mole
Boltzmann constant $= 1.38 \times 10^{-23} JK^{-1}$

SECTION A

67. Two charged particles P and Q, having the same charge but different masses m_P and m_Q, start from rest and travel equal distances in a uniform electric field $\vec{E}$ in time t_P and t_Q respectively. Neglecting the effect of gravity, the ratio $\left(\frac{t_P}{t_Q}\right)$ is :

(a) $\frac{m_P}{m_Q}$ (b) $\frac{m_Q}{m_P}$
(c) $\sqrt{\frac{m_P}{m_Q}}$ (d) $\sqrt{\frac{m_Q}{m_P}}$

68. Electrons drift with speed v_d in a conductor with potential difference V across its ends. If V is reduced to $\left(\frac{V}{2}\right)$, their drift speed will become :

(a) $\frac{v_d}{2}$ (b) v_d
(c) $2v_d$ (d) $4v_d$

69. A wire of length 4.4 m is bent round in the shape of a circular loop and carries a current of 1.0 A . The magnetic moment of the loop will be :

(a) $0.7 Am^2$ (b) $1.54 Am^2$
(c) $2 \cdot 10 Am^2$ (d) $3.5 Am^2$

70. A circular coil of radius 10 cm is placed in a magnetic field $\vec{B} = (1.0\hat{i} + 0.5\hat{j})$mT such that the outward unit vector normal to the surface of the coil is $(0.6\hat{\imath} + 0.8\hat{\jmath})$. The magnetic flux linked with the coil is :

(a) 0.314μ Wb (b) $3 \cdot 14\mu$ Wb
(c) $31 \cdot 4\mu$ Wb (d) 1.256μ Wb

71. Which of the following quantity/quantities remains same in primary and secondary coils of an ideal transformer?
Current, Voltage, Power, Magnetic flux

(a) Current only (b) Voltage only
(c) Power only (d) Magnetic flux and Power both

72. A resistor and an ideal inductor are connected in series to a $100\sqrt{2}$ V, 50 Hz ac source. When a voltmeter is connected across the resistor or the inductor, it shows the same reading. The reading of the voltmeter is :

(a) $100\sqrt{2}$ V (b) 100 V
(c) $50\sqrt{2}$ V (d) 50 V

73. Electromagnetic waves with wavelength 10 nm are called :

(a) Infrared waves (b) Ultraviolet rays
(c) Gamma rays (d) X-rays

74. The work function for a photosensitive surface is $3 \cdot 315$eV. The cut-off wavelength for photoemission of electrons from this surface is :

(a) 150 nm (b) 200 nm

(c) 375 nm (d) 500 nm

75. Energy levels A, B and C of an atom correspond to increasing values of energy i.e. $E_A < E_B < E_C$. Let λ_1, λ_2 and λ_3 be the wavelengths of radiation corresponding to the transitions C to B, B to A and C to A , respectively. The correct relation between λ_1, λ_2 and λ_3 is:

(a) $\lambda_1^2 + \lambda_2^2 = \lambda_3^2$ (b) $\frac{1}{\lambda_1} + \frac{1}{\lambda_2} = \frac{1}{\lambda_3}$

(c) $\lambda_1 + \lambda_2 + \lambda_3 = 0$ (d) $\lambda_1 + \lambda_2 = \lambda_3$

76. An alpha particle approaches a gold nucleus in Geiger-Marsden experiment with kinetic energy K . It momentarily stops at a distance d from the nucleus and reverses its direction. Then d is proportional to :

(a) $\frac{1}{\sqrt{K}}$ (b) $\sqrt{K}$

(c) $\frac{1}{K}$ (d) K

77. An n-type semiconducting Si is obtained by doping intrinsic Si with :

(a) Al (b) B

(c) P (d) In

78. When a p-n junction diode is subjected to reverse biasing :

(a) the barrier height decreases and the depletion region widens.

(b) the barrier height increases and the depletion region widens.

(c) the barrier height decreases and the depletion region shrinks.

(d) the barrier height increases and the depletion region shrinks.

Questions number 13 to 16 are Assertion (A) and Reason (R) type questions. Two statements are given - one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (a), (b), (c) and (d) as given below.

(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(c) Assertion (A) is true, but Reason (R) is false.

(d) Assertion (A) is false and Reason (R) is also false.

79. Assertion (A) : Photoelectric current increases with an increase in intensity of incident radiation, for a given frequency of incident radiation and the accelerating potential.

Reason (*R*) : Increase in the intensity of incident radiation results in an increase in the number of photoelectrons emitted per second and hence an increase in the photocurrent.

80. Assertion (A) : Lenz's law is a consequence of the law of conservation of energy.

Reason (*R*) : There is no power loss in an ideal inductor.

81. Assertion (A) : An electron and a proton enter with the same momentum $\vec{p}$ in a magnetic field $\vec{B}$ such that $\vec{p} \perp \vec{B}$. Then both describe a circular path of the same radius.

Reason (*R*) : The radius of the circular path described by the charged particle (charge q , mass m) moving in the magnetic field $\vec{B}$ is given by $r = \frac{mv}{qB}$.

82. Assertion (A) : The magnifying power of a compound microscope is negative.

Reason (*R*) : The final image formed is erect with respect to the object.

SECTION B

83. Define resistivity of a conductor. How does the resistivity of a conductor depend upon the following:

(A) Number density of free electrons in the conductor (n)

(B) Their relaxation time (τ)

84. (A) Two waves, each of amplitude ' a ' and frequency ' ω ' emanating from two coherent sources of light superpose at a point. If the phase difference between the two waves is ϕ, obtain an expression for the resultant intensity at that point.

OR

(B) What is the effect on the interference pattern in Young's double-slit experiment when **(i)** the source slit is moved closer to the plane of the slits, and **(ii)** the separation between the two slits is increased? Justify your answers.

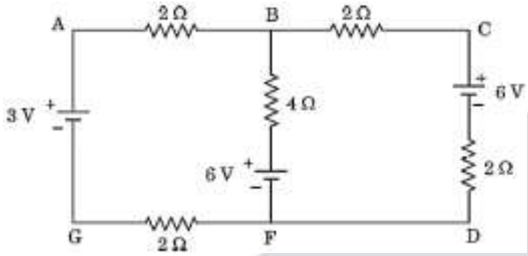
85. A convex lens ($n = 1.52$) has a focal length of 15.0 cm in air. Find its focal length when it is immersed in liquid of refractive index 1.65 . What will be the nature of the lens?

86. The carbon isotope ${}_{6}^{12}C$ has a nuclear mass of $12 - 000000u$. Calculate the binding energy of its nucleus. Given $m_p = 1.007825u; m_n = 1.008665u$.

87. How does the energy gap of an intrinsic semiconductor effectively change when doped with a **(a)** trivalent impurity, and **(b)** pentavalent impurity?
Justify your answer in each case.

SECTION C

88. The figure shows a circuit with three ideal batteries. Find the magnitude and direction of currents in the branches AG, BF and CD.



89. **(A)** On what factors does the speed of an electromagnetic wave in a medium depend?
(B) How is an electromagnetic wave produced ?
(C) Sketch a schematic diagram depicting the electric and magnetic fields for an electromagnetic wave propagating along z-axis.

90. A 100 -turn coil of radius 1.6 cm and resistance 5.0Ω is co-axial with a solenoid of 250 turns /cm and radius 1.8 cm . The solenoid current drops from 1.5 A to zero in 25 ms . Calculate the current induced in the coil in this duration. (Take $\pi^2 = 10$)

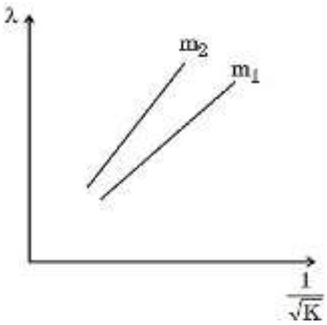
91. **(A)** Two long, straight, parallel conductors carry steady currents in opposite directions. Explain the nature of the force of interaction between them. Obtain an expression for the magnitude of the force between the two conductors. Hence define one ampere.

OR

(B) Obtain an expression for the torque $\vec{\tau}$ acting on a current carrying loop in a uniform magnetic field $\vec{B}$. Draw the necessary diagram.

92. Using Bohr's postulates, derive the expression for the radius of the n^{th} orbit of an electron in a hydrogen atom. Also find the numerical value of Bohr's radius a_0.

93. de Broglie wavelength λ as a function of $\frac{1}{\sqrt{K}}$, for two particles of masses m_1 and m_2 are shown in the figure. Here, K is the energy of the moving particles.



(A) What does the slope of a line represent ?
(B) Which of the two particles is heavier?
(C) Is this graph also valid for a photon?
Justify your answer in each case.

94. With the help of a circuit diagram, explain the working of a p-n junction diode as a full wave rectifier. Draw its input and output waveforms.

SECTION D

Case Study Based Questions

Questions number 29 and 30 are case study based questions. Read the following paragraphs and answer the questions that follow.

95. When the terminals of a cell are connected to a conductor of resistance R , an electric current flows through the circuit. The electrolyte of the cell also offers some resistance in the path of the current, like the conductor. This resistance offered by the electrolyte is called internal resistance of the cell (r). It depends upon the nature of the electrolyte, the area of the electrodes immersed in the electrolyte and the temperature. Due to internal resistance, a part of the energy supplied by the cell is wasted in the form of heat.

When no current is drawn from the cell, the potential difference between the two electrodes in known as emf of the cell (ε).With a current drawn from the cell, the potential difference between the two electrodes is termed as terminal potential difference (V).

(i)Choose the incorrect statement:

(a) The potential difference (V) between the two terminals of a cell in a closed circuit is always less than its emf (ε), during discharge of the cell.

(b) The internal resistance of a cell decreases with the decrease in temperature of the electrolyte.

(c) When current is drawn from the cell then $V = \varepsilon - Ir$.

(d) The graph between potential difference between the two terminals of the cell (V) and the current (I) through it is a straight line with a negative slope.

(ii) Two cells of emfs 2.0 V and 6.0 V and internal resistances 0.1Ω and 0.4Ω respectively, are connected in parallel. The equivalent emf of the combination will be :

(a) 2.0 V (b) $2 \cdot 8$ V

(c) 6.0 V (d) 8.0 V

(iii) Dipped in the solution, the electrode exchanges charges with the electrolyte. The positive electrode develops a potential $V_+ (V_+ > 0)$, and the negative electrode develops a potential $-(V_-)(V_- \geq 0)$, relative to the electrolyte adjacent to it. When no current is drawn from the cell then :

(a) $\varepsilon = V_+ + V_- > 0$ (b) $\varepsilon = V_+ - V_- > 0$

(c) $\varepsilon = V_+ + V_- < 0$ (d) $\varepsilon = V_+ + V_- = 0$

(iv) (A) Five identical cells, each of emf 2 V and internal resistance $0 - 1\Omega$ are connected in parallel. This combination in turn is connected to an external resistor of 9.98Ω. The current flowing through the resistor is :

(a) 0.05 A (b) 0.1 A

(c) 0.15 A (d) 0.2 A

OR

(B) Potential difference across a cell in the open circuit is 6 V . It becomes 4 V when a current of 2 A is drawn from it. The internal resistance of the cell is :

(a) 1.0Ω (b) 1.5Ω

(c) 2.0Ω (d) 2.5Ω

96. When a ray of light propagates from a denser medium to a rarer medium, it bends away from the normal. When the incident angle is increased, the refracted ray deviates more from the normal. For a particular angle of incidence in the denser medium, the refracted ray just grazes the interface of the two surfaces. This angle of incidence is called the critical angle for the pair of media involved.

(i) For a ray incident at the critical angle, the angle of reflection is :

(a) 0° (b) $< 90^\circ$

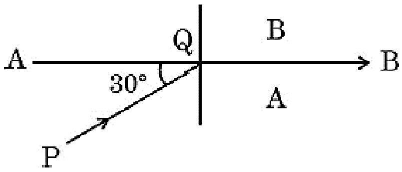
(c) $> 90^\circ$ (d) 90°

(ii) A ray of light of wavelength 600 nm is incident in water $\left(n = \frac{4}{3}\right)$ on the water-air interface at an angle less than the critical angle. The wavelength associated with the refracted ray is :

(a) 400 nm (b) 450 nm

(c) 600 nm (d) 800 nm

(iii)(A) The interface AB between the two media A and B is shown in the figure. In the denser medium A , the incident ray PQ makes an angle of 30° with the horizontal. The refracted ray is parallel to the interface. The refractive index of medium B w.r.t. medium A is :



(a) $\frac{\sqrt{3}}{2}$ (b) $\frac{\sqrt{5}}{2}$

(c) $\frac{4}{\sqrt{3}}$ (d) $\frac{2}{\sqrt{3}}$

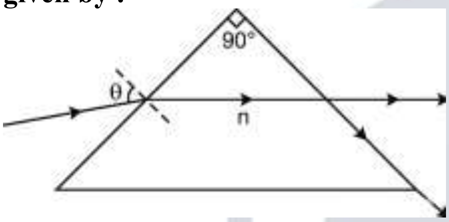
OR

(B) Two media A and B are separated by a plane boundary. The speed of light in medium A and B is $2 \times 10^8\ ms^{-1}$ and $2.5 \times 10^8\ ms^{-1}$ respectively. The critical angle for a ray of light going from medium A to medium B is :

(a) $\sin^{-1}\frac{1}{2}$ (b) $\sin^{-1}\frac{4}{5}$

(c) $\sin^{-1}\frac{3}{5}$ (d) $\sin^{-1}\frac{2}{5}$

(iv) The figure shows the path of a light ray through a triangular prism. In this phenomenon, the angle θ is given by :



(a) $\sin^{-1}\sqrt{n^2-1}$ (b) $\sin^{-1}(n^2-1)$

(c) $\sin^{-1}\left[\frac{1}{\sqrt{n^2-1}}\right]$ (d) $\sin^{-1}\left[\frac{1}{(n^2-1)}\right]$

SECTION E

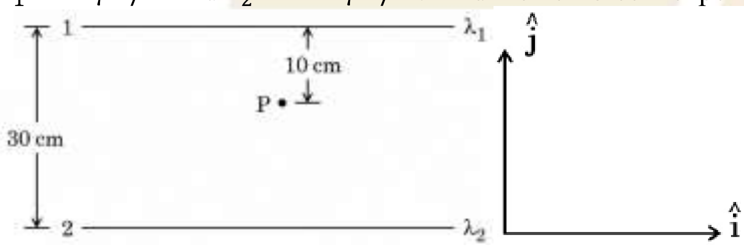
97. (A) (i) Obtain an expression for the electric potential due to a small dipole of dipole moment $\vec{p}$, at a point $\vec{r}$ from its centre, for much larger distances compared to the size of the dipole.

(ii) Three point charges q, 2q and nq are placed at the vertices of an equilateral triangle. If the potential energy of the system is zero, find the value of n .

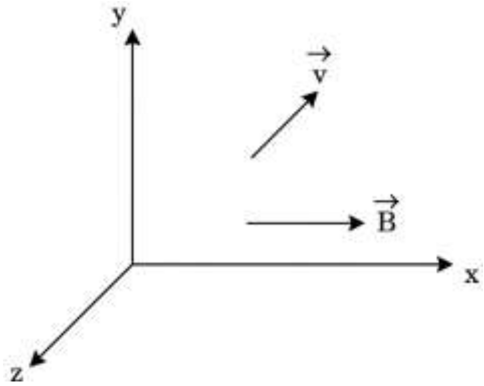
OR

(B) (i) State Gauss's Law in electrostatics. Apply this to obtain the electric field $\vec{E}$ at a point near a uniformly charged infinite plane sheet.

(ii) Two long straight wires 1 and 2 are kept as shown in the figure. The linear charge density of the two wires are $\lambda_1 = 10\mu C/m$ and $\lambda_2 = -20\mu C/m$. Find the net force $\vec{F}$ experienced by an electron held at point P.



98. (A) (i) A particle of mass m and charge q is moving with a velocity $\vec{v}$ in a magnetic field $\vec{B}$ as shown in the figure. Show that it follows a helical path. Hence, obtain its frequency of revolution



(ii) In a hydrogen atom, the electron moves in an orbit of radius 2Å making 8×10^{14} revolutions per second. Find the magnetic moment associated with the orbital motion of the electron.

OR

(B) (i) What is current sensitivity of a galvanometer? Show how the current sensitivity of a galvanometer may be increased. "Increasing the current sensitivity of a galvanometer may not necessarily increase its voltage sensitivity." Explain.

(ii) A moving coil galvanometer has a resistance 15Ω and takes 20 mA to produce full scale deflection. How can this galvanometer be converted into a voltmeter of range 0 to 100 V ?

99. (A) (i) Give any two differences between the interference pattern obtained in Young's double-slit experiment and a diffraction pattern due to a single slit.

(ii) Draw an intensity distribution graph in case of a double-slit interference pattern.

(iii) In Young's double-slit experiment using monochromatic light of wavelength λ, the intensity of light at a point on the screen, where path difference is λ, is K units. Find the intensity of light at a point on the screen where the path difference is $\frac{\lambda}{6}$.

OR

(B) (i) Draw a labelled ray diagram of a compound microscope showing image formation at least distance of distinct vision. Derive an expression for its magnifying power.

(ii) A telescope consists of two lenses of focal length 100 cm and 5 cm . Find the magnifying power when the final image is formed at infinity.

General Instructions :

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(iii) In Section A : Question number 1 to 16 are Multiple Choice (MCQ) type questions carrying 1 mark each.

(iv) In Section B : Question number 17 to 21 are Very Short Answer (VSA) type questions carrying 2 marks each.

(v) In Section C : Question number 22 to 28 are Short Answer (SA) type questions carrying 3 marks each.

(vi) In Section D : Question number 29 & 30 are Long Answer (LA) type questions carrying 4 marks each.

(vii) In Section E : Question number 31 to 33 are Case-Based questions carrying 5 marks each.

(viii) There is no overall choice. However, an internal choice has been provided in 1 question in Section-B, 1 question in Section-C, 2 questions in Section-D and 3 questions in Section-E.

(ix) Use of calculators is NOT allowed.

$c = 3 \times 10^8$ m/s

$h = 6.63 \times 10^{-34}$ Js

$e = 1.6 \times 10^{-19}$ C

$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}

$\varepsilon_0 = 8.854 \times 10^{-12} C^2 N^{-1} m^{-2}$

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N $m^2 C^{-2}$

Mass of electron $(m_e) = 9.1 \times 10^{-31}$ kg

Mass of neutron $= 1.675 \times 10^{-27}$ kg

Mass of proton $= 1.673 \times 10^{-27}$ kg

Avogadro's number $= 6.023 \times 10^{23}$ per gram mole

Boltzmann constant $= 1.38 \times 10^{-23} \mathrm{JK}^{-1}$

SECTION A

100. Consider a group of charges $q_1, q_2, q_8 \ldots$ such that $\Sigma q \neq 0$. Then equipotentials at a large distance, due to this group are approximately :

(a) Plane (b) Spherical surface

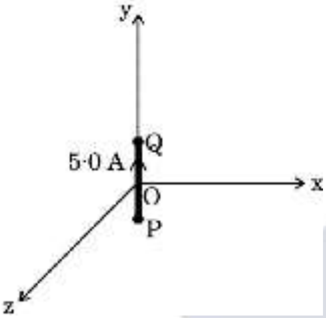
(c) Paraboloidal surface (d) Ellipsoidal surface

101. A proton is taken from point P_1 to point P_2, both located in an electric field. The potentials at points P_1 and P_2 are -5 V and +5 V respectively. Assuming that kinetic energies of the proton at points P_1 and P_2 are zero, the work done on the proton is :

(a) -1.6×10^{-18} J (b) 1.6×10^{-18} J

(c) Zero (d) 0.8×10^{-18} J

102. A 2.0 cm segment of wire, carrying 5.0 A current in positive y-direction lies along y-axis, as shown in the figure. The magnetic field at a point $(3 \mathbf{~m}, 4 \mathbf{~m}, 0)$ due to this segment (part of a circuit) is :



(a) $(0-12 \mathrm{nT}) \hat{\jmath}$ (b) $-(0 \cdot 10 \mathrm{nT}) \hat{\jmath}$

(c) $-(0.24 \mathrm{nT}) \hat{k}$ (d) $(0.24 \mathrm{nT}) \hat{k}$

103. A circular loop of wire, carrying a current ' T ' is lying in xy-plane with its centre coinciding with the origin. It is subjected to a uniform magnetic field pointing along +z-axis. The loop will :

(a) move along X-axis (b) move along -Y-axis

(c) move along Z-axis (d) remain stationary

104. A current carrying circular loop of magnetic moment $\vec{M}$ is suspended in a vertical plane in an external magnetic field $\vec{B}$ such that its plane is normal to $\vec{B}$. The work done in rotating this loop by 45° about an axis perpendicular to $\vec{B}$ is closest to :

(a) -0.3 MB (b) 0.3MB

(c) -1.7MB (d) 1.7 MB

105. The current in a coil of 15 mH increases uniformly from zero to 4 A in 0.004 s . The emf induced in the coil will be :

(a) 22.5 V (b) 17.5 V

(c) 15.0 V (d) 12.5 V

106. Consider a solenoid of length l and area of cross-section A with fixed number of turns. The self-inductance of the solenoid will increase if :

(a) both l and A are increased

(b) l is decreased and A is increased

(c) l is increased and A is decreased

(d) both l and A are decreased

107. Which one of the following has the highest frequency ?

(a) Infrared rays (b) Gamma rays

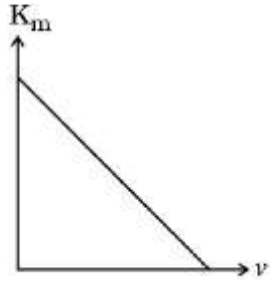
(c) Radio waves (d) Microwaves

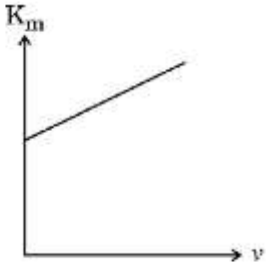
108. A proton and an alpha particle having equal velocities approach a target nucleus. They come momentarily to rest and then reverse their directions. The ratio of the distance of closest approach of the proton to that of the alpha particle will be :

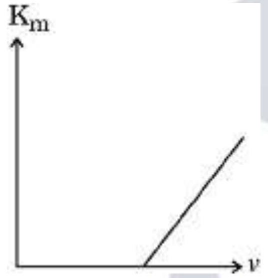
(a) $\frac{1}{2}$ (b) 2

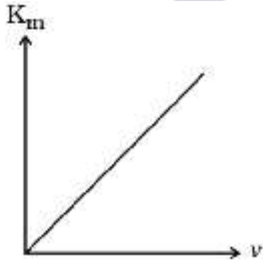
(c) $\frac{1}{4}$ (d) 4

109. Which one of the following is the correct graph between the maximum kinetic energy (K_m) of the emitted photoelectrons and the frequency of incident radiation (v) for a given photosensitive surface ?

(a)


(b)


(c)


(d)


110. An electron makes a transition from $n = 2$ level to $n = 1$ level in the Bohr model of a hydrogen atom. Its period of revolution :

(a) increases by 87.5%
(b) decreases by 87.5%
(c) increases by 43.75%
(d) decreases by 43 · 75%

111. Si is doped with a pentavalent element. The energy required to set the additional electron free is about :

(a) 0.01 e (b) 0.05 eV

(c) 0.72 eV (d) 1.1 eV

Questions number 13 to 16 are Assertion (A) and Reason (R) type questions. Two statements are given - one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (a), (b), (c) and (d) as given below.

(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
(c) Assertion (A) is true, but Reason (R) is false.
(d) Assertion (A) is false and Reason (R) is also false.

112. **Assertion (A) :** In a semiconductor, the electrons in the conduction band have lesser energy than those in the valence band.

Reason (R) : Donor energy level is just above the valence band in a semiconductor.

113. **Assertion (A) :** Photoelectric effect demonstrates the particle nature of light.

Reason (R) : Photoelectric current is proportional to frequency of incident radiation.

114. **Assertion (A) :** A proton and an electron enter a uniform magnetic field $\vec{B}$ with the same momentum $\vec{p}$ such that $\vec{p}$ is perpendicular to $\vec{B}$. They describe circular paths of the same radius.

Reason (R) : In a magnetic field, orbital radius r is equal to $\frac{p}{qB}$.

115. **Assertion (A) :** A convex lens, when immersed in a liquid, disappears.

Reason (R): The refractive indices of material of the lens and the liquid are equal.

SECTION B

116. **(A)** What is meant by 'relaxation time' of free electrons in a conductor? Show that the resistance of a conductor can be expressed by $R = \frac{ml}{ne^2\tau A}$, where symbols have their usual meanings.

OR

(B) Draw the circuit diagram of a Wheatstone bridge. Obtain the condition when no current flows through the galvanometer in it.

117. The magnifying power of an astronomical telescope is 24 . In normal adjustment, distance between its two lenses is 150 cm . Find the focal length of the objective lens.

118. **Explain the following :**

(A) For a simple microscope, the angular size of the object equals the angular size of the image. Yet it offers magnification.

(B) Both plane and convex mirrors produce virtual images of objects. Can they produce real images under some circumstances?

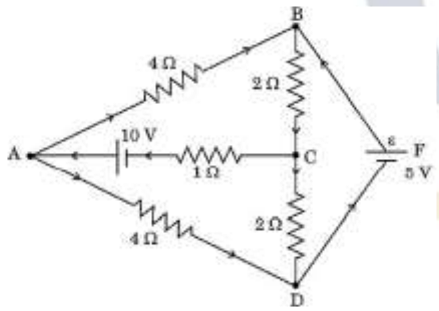
119. The minimum intensity of white light that our eyes can perceive is about $0.1 \mathrm{nWm}^{-2}$. Calculate the number of photons of this light entering our pupil (area $0.4 \mathrm{~cm}^2$) per second.

(Take average wavelength of white light $= 500$ nm and Planck's constant $= 6.6 \times 10^{-84}$Js)

120. Suppose a pure Si crystal has 5×10^{28} atoms m^{-9}. It is doped by 1 ppm concentration of boron. Calculate the concentration of holes and electrons, given that $n_i = 1.5 \times 10^{16} \mathrm{~m}^{-3}$. Is the doped crystal n-type or p-type ?

SECTION C

121. Determine the current in branches AB, AC and BC of the network shown in figure.



122. Two long straight parallel conductors carrying currents, exert a force on each other. Why ? Derive an expression for the force per unit length between two long straight parallel conductors carrying currents in opposite directions. Explain the nature of the force between these conductors.

123. A sinusoidal voltage is applied to an electric circuit containing a circuit element ' X ' in which the current leads the voltage by $\frac{\pi}{2}$.

(A) Identify the circuit element ' X ' in the circuit.

(B) Write the formula for its reactance.

(C) Show graphically the variation of this reactance with frequency of ac voltage.

(D) Explain the behaviour of this element when it is used in (i) an ac circuit, and (ii) a de circuit.

124. The electric field in an electromagnetic wave in vacuum is given by :

$\vec{E} = (6.3\ N/C)[\cos(1.5 rad/m)y + (4.5 \times 10^8 rad/s)t]\hat{i}$
(A) Find the wavelength and frequency of the wave.
(B) What is the amplitude of the magnetic field of the wave ?
(C) Write an expression for the magnetic field of this wave.

125. State Bohr's first and second postulates. Use them to derive an expression for the radius of the n^{th} orbit in a hydrogen atom.

126. **(A)** Define atomic mass unit (u).
(B) Calculate the energy required to separate a deuteron into its constituent parts (a proton and a neutron). Given :
$m(D) = 2.014102u$
$m_H = 1.007825u$
$m_n = 1.008665u$

127. **(A)** Draw the circuit diagrams for obtaining the $V - I$ characteristics of a p-n junction diode. Explain briefly the salient features of the V-I characteristics in **(i)** forward biasing, and **(ii)** reverse biasing.

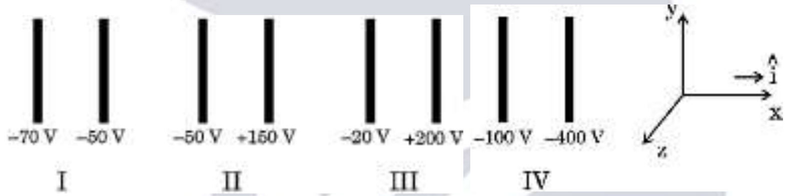
OR

(B) On the basis of energy band diagrams, distinguish between **(i)** an insulator, **(ii)** a semiconductor, and **(iii)** a conductor.

SECTION D

Case Study Based Questions
Questions number 29 and 30 are case study based questions. Read the following paragraphs and answer the questions that follow.

128. The figure shows four pairs of parallel identical conducting plates, separated by the same distance 2.0 cm and arranged perpendicular to x-axis. The electric potential of each plate is mentioned. The electric field between a pair of plates is uniform and normal to the plates.



(i) For which pair of the plates is the electric field $\vec{E}$ along $\hat{i}$?
(a) I (b) II
(c) III (d) IV

(ii) An electron is released midway between the plates of pair IV. It will :
(a) move along $\hat{i}$ at constant speed
(b) move along $-\hat{i}$ at constant speed
(c) accelerate along $\hat{i}$
(d) accelerate along $-\hat{i}$

(iii) Let V_0 be the potential at the left plate of any set, taken to be at $x = 0$ m. Then potential V at any point ($0 \leq x \leq 2$ cm) between the plates of that set can be expressed as:
where α is a constant, positive or negative.
(a) $V = V_0 + \alpha x$ (b) $V = V_0 + \alpha x^2$
(c) $V = V_0 + \alpha x^{1/2}$ (d) $V = V_0 + \alpha x^{3/2}$

(iv) (A) Let E_1, E_2, E_8 and E_4 be the magnitudes of the electric field between the pairs of plates, I, II, III and IV respectively. Then :
(a) $E_1 > E_2 > E_3 > E_4$ (b) $E_3 > E_4 > E_1 > E_2$
(c) $E_4 > E_3 > E_2 > E_1$ (d) $E_2 > E_8 > E_4 > E_1$

OR

(B) An electron is projected from the right plate of set I directly towards its left plate. It just comes to rest at the plate. The speed with which it was projected is about :
(Take (e/m) = 1.76×10^{11} C/kg)
(a) 1.3×10^5 m/s (b) 2.6×10^6 m/s
(c) 6.5×10^5 m/s (d) 5.2×10^7 m/s

129. Diffraction and interference are closely related phenomena that occur together. Diffraction is the phenomenon of bending of light around the edges of the obstacle, while interference is the combination of waves that results in a new wave pattern. In order to get interference, there must be at least two waves that are diffracting. So while diffraction can occur without interference, interference cannot occur without diffraction.

Two slits of width 2μ m each in an opaque material are separated by a distance of 6μ m. Monochromatic light of wavelength 450 nm is incident normally on the slits. One finds a combined interference and diffraction pattern on the screen.

(i) The number of peaks of the interference fringes formed within the central peak of the envelope of the diffraction pattern will be :

(a) 2 (b) 3
(c) 4 (d) 6

(ii) The number of peaks of the interference formed if the slit width is doubled while keeping the distance between the slits same will be :

(a) 1 (b) 2
(c) 3 (d) 4

(iii)(A) If instead of 450 nm light, another light of wavelength 680 nm is used, number of peaks of the interference formed in the central peak of the envelope of the diffraction pattern will be :

(a) 2 (b) 4
(c) 6 (d) 9

OR

(B) Consider the diffraction of light by a single slit described in this case study. The first minimum falls at an angle θ equal to :

(a) $\sin^{-1}(0.12)$ (b) $\sin^{-1}(0.225)$
(c) $\sin^{-1}(0.32)$ (d) $\sin^{-1}(0.45)$

(iv) The number of bright fringes formed due to interference on 1 m of screen placed at $\frac{4}{3}$ m away from the slits is:

(a) 2 (b) 3
(c) 6 (d) 10

SECTION E

130. **(A) (i)** Obtain the expression for the capacitance of a parallel plate capacitor with a dielectric medium between its plates.

(ii) A charge of 6μC is given to a hollow metallic sphere of radius 0.2 m . Find the potential at (a) the surface and (b) the centre of the sphere.

OR

(B) (i) A charge +Q is placed on a thin conducting spherical shell of radius R . Use Gauss's theorem to derive an expression for the electric field at a point **lying (a) inside and (b)** outside the shell.

(ii) Show that the electric field for same charge density (σ) is twice in case of a conducting plate or surface than in a nonconducting sheet.

131. **(A) (I) (1)** What is meant by current sensitivity of a galvanometer ? Mention the factors on which it depends.

(2) A galvanometer of resistance G is converted into a voltmeter of range ($0-V$) by using a resistance R. Find the resistance, in terms of R and G , required to convert it into a voltmeter of range $\left(0-\frac{V}{2}\right)$.

(II) The magnetic flux through a coil of resistance 5Ω increases with time as :

$\phi=(2.0t^3+5.0t^2+6.0t)\mathrm{mWb}$

Find the magnitude of induced current through the coil at $t=2$ s.

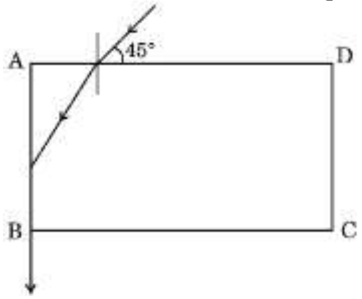
OR

(B) (i) A rectangular coil of N turns and area of cross-section A is rotated at a steady angular speed ω in a uniform magnetic field. Obtain an expression for the emf induced in the coil at any instant of time.

(ii) Two coplanar and concentric circular loops L_1 and L_2 are placed coaxially with their centres coinciding. The radii of L_1 and L_2 are 1 cm and 100 cm respectively. Calculate the mutual inductance of the loops. (Take $\pi^2=10$)

132. **(A) (i)** Trace the path of a ray of light showing refraction through a triangular prism and hence obtain an expression for angle of deviation (δ) in terms of A, i and e, where symbols have their usual meanings. Draw a graph showing the variation of angle of deviation with the angle of incidence.

(ii) In the figure, a ray of light is incident on a transparent liquid contained in a thin glass box at an angle of 45° with its one face. The emergent ray passes along the face AB . Find the refractive index of the liquid.



OR

(B) (i) The displacement of two light waves, each of amplitude ' a ' and frequency ω, emanating from two coherent sources of light, are given by $y_1 = a\cos\omega t$ and $y_2 = a\cos(\omega t + \phi)$. ϕ is the phase difference between the two waves. These light waves superpose at a point. Obtain the expression for the resultant intensity at that point.

(ii) In Young's double slit experiment, find the ratio of intensities at two points on a screen when waves emanating from two slits reaching these points have path differences (a) $\frac{\lambda}{6}$ and (b) $\frac{\lambda}{12}$.

General Instructions :

Read the following instructions very carefully and follow them:

(i) This question paper contains 33 questions. All questions are compulsory.
(ii) Question paper is divided into FIVE sections - Section A, B, C, D and **E**.
(iii) In Section A : Question number 1 to 16 are Multiple Choice (MCQ) type questions carrying 1 mark each.
(iv) In Section B : Question number 17 to 21 are Very Short Answer (VSA) type questions carrying 2 marks each.
(v) In Section C : Question number 22 to 28 are Short Answer (SA) type questions carrying 3 marks each.
(vi) In Section D : Question number 29 & 30 are Long Answer (LA) type questions carrying 4 marks each.
(vii) In Section E : Question number 31 to 33 are Case-Based questions carrying 5 marks each.
(viii) There is no overall choice. However, an internal choice has been provided in 1 question in Section-B, 1 question in Section-C, 2 questions in Section-D and 3 questions in Section-E.
(ix) Use of calculators is NOT allowed.

$c = 3 \times 10^8$ m/s
$h = 6.63 \times 10^{-34}$ Js
$e = 1.6 \times 10^{-19}$ C
$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}
$\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}
$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^{2}C^{-2}
Mass of electron $(m_e) = 9.1 \times 10^{-31}$ kg
Mass of neutron $= 1.675 \times 10^{-27}$ kg
Mass of proton $= 1.673 \times 10^{-27}$ kg
Avogadro's number $= 6.023 \times 10^{23}$ per gram mole
Boltzmann constant $= 1.38 \times 10^{-23}$ JK^{-1}

SECTION A

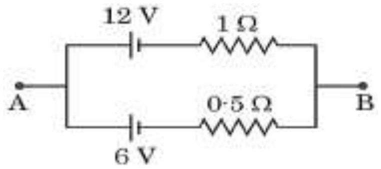
133. A thin plastic rod is bent into a circular ring of radius R . It is uniformly charged with charge density λ. The magnitude of the electric field at its centre is :

(a) $\frac{\lambda}{2\varepsilon_0 R}$ (b) Zero
(c) $\frac{\lambda}{4\pi\varepsilon_0 R}$ (d) $\frac{\lambda}{4\varepsilon_0 R}$

134. Ten capacitors, each of capacitance 1μ F, are connected in parallel to a source of 100 V . The total energy stored in the system is equal to :

(a) 10^{-2} J (b) 10^{-3} J
(c) 0.5×10^{-3} J (d) 5.0×10^{-2} J

135. Consider the circuit shown in the figure. The potential difference between points A and B is :



(a) 6 V (b) 8 V
(c) 9 V (d) 12 V

136. A loop carrying a current I clockwise is placed in x − y plane, in a uniform magnetic field directed along z -axis. The tendency of the loop will be to :

(a) move along x-axis (b) move along y -axis
(c) shrink (d) expand

137. A 10 cm long wire lies along y -axis. It carries a current of 1.0 A in positive y-direction. A magnetic field $\vec{B} = (5mT)\hat{j} - (8mT)\hat{k}$ exists in the region. The force on the wire is :

(a) $(0.8mN)\hat{i}$ (b) $-(0.8mN)\hat{i}$
(c) $(80mN)\hat{i}$ (d) $-(80mN)\hat{i}$

138. A galvanometer of resistance GΩ is converted into an ammeter of range 0 to IA. If the current through the galvanometer is 0. 1% of IA, the resistance of the ammeter is :

(a) $\frac{G}{999}\Omega$ (b) $\frac{G}{1000}\Omega$
(c) $\frac{G}{1001}\Omega$ (d) $\frac{G}{100\cdot1}\Omega$

139. The reactance of a capacitor of capacitance C connected to an ac source of frequency ω is ' X '. If the capacitance of the capacitor is doubled and the frequency of the source is tripled, the reactance will become :

(a) $\frac{X}{6}$ (b) 6 X
(c) $\frac{2}{3}X$ (d) $\frac{3}{2}X$

140. In the four regions, I, II, III and IV, the electric fields are described as :
The displacement current will exist in the region :
Region I : $E_x = E_0 \sin(kz - \omega t)$
Region II : $E_x = E_0$
Region III : $E_x = E_0 \sin kz$
Region IV : $E_x = E_0 \cos kz$
(a) I (b) IV
(c) II (d) III

141. The transition of electron that gives rise to the formation of the second spectral line of the Balmer series in the spectrum of hydrogen atom corresponds to :

(a) $n_f = 2$ and $n_i = 3$
(b) $n_f = 3$ and $n_i = 4$
(c) $n_f = 2$ and $n_i = 4$
(d) $n_f = 2$ and $n_i = \infty$

142. Ge is doped with As. Due to doping,

(a) the structure of Ge lattice is distorted.
(b) the number of conduction electrons increases.
(c) the number of holes increases.
(d) the number of conduction electrons decreases.

143. Two beams, A and B whose photon energies are $3 \cdot 3$eV and $11 \cdot 3$eV respectively, illuminate a metallic surface (work function $2 \cdot 3$eV) successively. The ratio of maximum speed of electrons emitted due to beam A to that due to beam B is :

(a) 3 (b) 9

(c) $\frac{1}{3}$ (d) $\frac{1}{9}$

144. The waves associated with a moving electron and a moving proton have the same wavelength λ. It implies that they have the same :

(a) momentum (b) angular momentum

(c) speed (d) energy

Questions number 13 to 16 are Assertion (A) and Reason (R) type questions. Two statements are given - one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (a), (b), (c) and (d) as given below.

(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(c) Assertion (A) is true, but Reason (R) is false.

(d) Assertion (A) is false and Reason (R) is also false.

145. Assertion (A) : In photoelectric effect, the kinetic energy of the emitted photoelectrons increases with increase in the intensity of the incident light.

Reason (R) : Photoelectric current depends on the wavelength of the incident light.

146. Assertion (A) : The mutual inductance between two coils is maximum when the coils are wound on each other.

Reason (R) : The flux linkage between two coils is maximum when they are wound on each other.

147. Assertion (A) : Two long parallel wires, freely suspended and connected in series to a battery, move apart.

Reason (R) : Two wires carrying current in opposite directions repel each other.

148. Assertion (A) : Plane and convex mirrors cannot produce real images under any circumstance.

Reason (R) : A virtual image cannot serve as an object to produce a real image.

SECTION B

149. Find the temperature at which the resistance of a wire made of silver will be twice its resistance at $20^{\circ}\mathrm{C}$. Take $20^{\circ}\mathrm{C}$ as the reference temperature and temperature coefficient of resistance of silver at $20^{\circ}\mathrm{C} = 4.0 \times 10^{-3}\ \mathrm{K}^{-1}$.

150. (A) Monochromatic light of frequency 5.0×10^{14} Hz passes from air into a medium of refractive index $1 \cdot 5$. Find the wavelength of the light (i) reflected, and (ii) refracted at the interface of the two media.

OR

(B) A plano-convex lens of focal length 16 cm is made of a material of refractive index 1.4 . Calculate the radius of the curved surface of the lens.

151. An object is placed 30 cm in front of a concave mirror of radius of curvature 40 cm . Find the (i) position of the image formed and (ii) magnification of the image.

152. Consider a neutron (mass m) of kinetic energy E and a photon of the same energy. Let λ_n and λ_p be the de Broglie wavelength of neutron and the wavelength of photon respectively. Obtain an expression for $\frac{\lambda_n}{\lambda_p}$.

153. Plot a graph showing the variation of current with voltage for the material GaAs. On the graph, mark the region where :

(A) resistance is negative, and

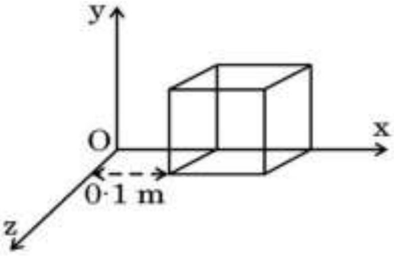
(B) Ohm's law is obeyed.

SECTION C

154. A cube of side $0 \cdot 1$ m is placed, as shown in the figure, in a region where electric field $\vec{E} = 500 \times \hat{\imath}$ exists. Here x is in meters and E in NC^{-1}. Calculate :

(A) the flux passing through the cube, and

(B) the charge within the cube.



155. **(A)** Define 'current density'. Is it a scalar or a vector ? An electric field $\vec{E}$ is maintained in a metallic conductor. If n be the number of electrons (mass m , charge -e) per unit volume in the conductor and τ its relaxation time, show that the current density $\vec{j} = \alpha\vec{E}$, where $\alpha = \left(\frac{ne^2}{m}\right)\tau$.

OR

(B) What is a Wheatstone bridge ? Obtain the necessary conditions under which the Wheatstone bridge is balanced.

156. **A proton with kinetic energy 1.3384×10^{-14} J moving horizontally from north to south, enters a uniform magnetic field B of $2 \cdot 0$mT directed eastward. Calculate :**

(A) the speed of the proton

(B) the magnitude of acceleration of the proton

(C) the radius of the path traced by the proton

[Take (q/m) for proton $= 1.0 \times 10^8$ C/kg]

157. An inductor, a capacitor and a resistor are connected in series with an ac source $v = v_m \sin \omega t$. Derive an expression for the average power dissipated in the circuit. Also obtain the expression for the resonant frequency of the circuit.

158. **(A)** "The wavelength of the electromagnetic wave is often correlated with the characteristic size of the system that radiates." Give two examples to justify this statement.

(B) (i) Long distance radio broadcasts use short-wave bands. Why ?

(ii) Optical and radio telescopes are built on the ground, but X-ray astronomy is possible only from satellites orbiting the Earth. Why ?

159. Write the drawbacks of Rutherford's atomic model. How did Bohr remove them? Show that different orbits in Bohr's atom are not equally spaced.

160. **(A)** State any two properties of a nucleus.

(B) Why is the density of a nucleus much more than that of an atom?

(C) Show that the density of the nuclear matter is the same for all nuclei.

SECTION D

Questions number 29 and 30 are case study-based questions. Read the following paragraphs and answer the questions that follow.

161. A lens is a transparent medium bounded by two surfaces, with one or both surfaces being spherical. The focal length of a lens is determined by the radii of curvature of its two surfaces and the refractive index of its medium with respect to that of the surrounding medium. The power of a lens is reciprocal of its focal length. If a number of lenses are kept in contact, the power of the combination is the algebraic sum of the powers of the individual lenses.

(i) A double-convex lens, with each face having same radius of curvature R , is made of glass of refractive index n . Its power is :

(a) $\frac{2(n-1)}{R}$ (b) $\frac{(2n-1)}{R}$

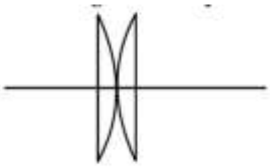
(c) $\frac{(n-1)}{2R}$ (d) $\frac{(2n-1)}{2R}$

(ii) A double-convex lens of power P , with each face having same radius of curvature, is cut into two equal parts perpendicular to its principal axis. The power of one part of the lens will be :

(a) 2P (b) P

(c) 4 P (d) $\frac{P}{2}$

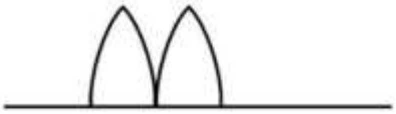
(iii) The above two parts are kept in contact with each other as shown in the figure. The power of the combination will be :



(a) $\frac{P}{2}$ (b) P

(c) 2 P (d) $\frac{P}{4}$

(iv) (A) A double-convex lens of power P , with each face having same radius of curvature, is cut along its principal axis. The two parts are arranged as shown in the figure. The power of the combination will be :



(a) Zero (b) P

(c) 2P (d) $\frac{P}{2}$

OR

(B) Two convex lenses of focal lengths 60 cm and 20 cm are held coaxially in contact with each other. The power of the combination is :

(a) $6 \cdot 6$D (b) 15 D

(c) $\frac{1}{15}$D (d) $\frac{1}{80}$D

162. Junction Diode as a Rectifier :

The process of conversion of an ac voltage into a dc voltage is called rectification and the device which performs this conversion is called a rectifier. The characteristics of a $p-n$ junction diode reveal that when a $p-n$ junction diode is forward biased, it offers a low resistance and when it is reverse biased, it offers a high resistance. Hence, a p-n junction diode conducts only when it is forward biased. This property of a $p-n$ junction diode makes it suitable for its use as a rectifier.

Thus, when an ac voltage is applied across a $p-n$ junction, it conducts only during those alternate half cycles for which it is forward biased. A rectifier which rectifies only half cycle of an ac voltage is called a half-wave rectifier and one that rectifies both the half cycles is known as a full-wave rectifier.

(i) The root mean square value of an alternating voltage applied to a full-wave rectifier is $\frac{V_0}{\sqrt{2}}$. Then the root mean square value of the rectified output voltage is :

(a) $\frac{V_0}{\sqrt{2}}$ (b) $\frac{V_0^2}{\sqrt{2}}$

(c) $\frac{2\,V_0}{\sqrt{2}}$ (d) $\frac{V_0}{2\sqrt{2}}$

(ii) In a full-wave rectifier, the current in each of the diodes flows for :

(a) Complete cycle of the input signal

(b) Half cycle of the input signal

(c) Less than half cycle of the input signal

(d) Only for the positive half cycle of the input signal

(iii) In a full-wave rectifier :

(a) Both diodes are forward biased at the same time.

(b) Both diodes are reverse biased at the same time.

(c) One is forward biased and the other is reverse biased at the same time.

(d) Both are forward biased in the first half of the cycle and reverse biased in the second half of the cycle.

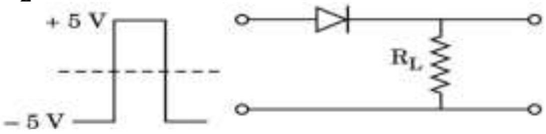
(iv) (A) An alternating voltage of frequency of 50 Hz is applied to a half-wave rectifier. Then the ripple frequency of the output will be :

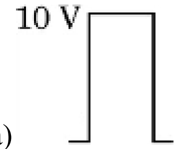
(a) 100 Hz (b) 50 Hz

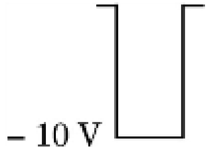
(c) 25 Hz (d) 150 Hz

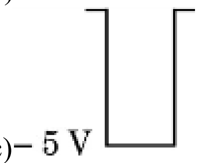
OR

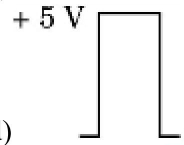
(B) A signal, as shown in the figure, is applied to a p-n junction diode. Identify the output across resistance R_L :



(a) 

(b) 

(c) 

(d) 

SECTION E

163. **(A)(i)** Derive an expression for potential energy of an electric dipole $\vec{p}$ in an external uniform electric field $\vec{E}$. When is the potential energy of the dipole (1) maximum, and (2) minimum ?

(ii) An electric dipole consists of point charges - 1.0 pC and $+1 \cdot 0$pC located at (0,0) and (3 mm, 4 mm) respectively in $x - y$ plane. An electric field $\vec{E} = \left(\frac{1000\ V}{m}\right)\hat{i}$ is switched on in the region. Find the torque $\vec{\tau}$ acting on the dipole.

OR

(B) (i) An electric dipole (dipole moment $\vec{p} = p\hat{i}$), consisting of charges -q and q , separated by distance 2 a , is placed along the x-axis, with its centre at the origin. Show that the potential V , due to this dipole, at a point x, $(x \gg a)$ is equal to $\frac{1}{4\pi\varepsilon_0} \cdot \frac{\vec{p}\cdot\hat{i}}{x^2}$.

(ii) Two isolated metallic spheres S_1 and S_2 of radii 1 cm and 3 cm respectively are charged such that both have the same charge density $\left(\frac{2}{\pi} \times 10^{-9}\right) C/m^2$. They are placed far away from each other and connected by a thin wire. Calculate the new charge on sphere S_1.

164. **(A) (i)** A resistor and a capacitor are connected in series to an ac source $v = v_m \sin \omega t$. Derive an expression for the impedance of the circuit.

(ii) When does an inductor act as a conductor in a circuit ? Give reason for it.

OR

(B) (i) Draw a labelled diagram of a step-up transformer and describe its working principle. Explain any three causes for energy losses in a real transformer.

(ii) A step-up transformer converts a low voltage into high voltage. Does it violate the principle of conservation of energy? Explain.

(iii) A step-up transformer has 200 and 3000 turns in its primary and secondary coils respectively. The input voltage given to the primary coil is 90 V . Calculate :

(1) The output voltage across the secondary coil

(2) The current in the primary coil if the current in the secondary coil is $2 \cdot 0$ A.

165. **(A) (i)** A ray of light passes through a triangular prism. Show graphically, how the angle of deviation varies with the angle of incidence ? Hence define the angle of minimum deviation.

(ii) A ray of light is incident normally on a refracting face of a prism of prism angle A and suffers a deviation of angle δ. Prove that the refractive index n of the material of the prism is given by $n = \frac{\sin(A+\delta)}{\sin A}$.

(iii) The refractive index of the material of a prism is $\sqrt{2}$. If the refracting angle of the prism is 60°, find the

(1) Angle of minimum deviation, and

(2) Angle of incidence.

OR

(B) (i) State Huygens' principle. A plane wave is incident at an angle i on a reflecting surface. Construct the corresponding reflected wavefront. Using this diagram, prove that the angle of reflection is equal to the angle of incidence.

(ii) What are the coherent sources of light ? Can two independent sodium lamps act like coherent sources ? Explain.

(iii) A beam of light consisting of a known wavelength 520 nm and an unknown wavelength λ, used in Young's double slit experiment produces two interference patterns such that the fourth bright fringe of unknown wavelength coincides with the fifth bright fringe of known wavelength. Find the value of λ.

General Instructions :

Read the following instructions very carefully and follow them:

(i) This question paper contains 33 questions. All questions are compulsory.

(ii) Question paper is divided into FIVE sections - Section A, B, C, D and **E**.

(iii) Section A - Question number 1 to 16 are Multiple Choice (MCQ) type questions. Each question carries 1 mark.

(iv) Section B - Question number 17 to 21 are Very Short Answer type questions. Each question carries 2 mark.

(v) Section C-Question number 22 to 28 are Short Answer type questions. Each question carries 3 mark.

(vi) Section D : Question number 29 and 30 are Case-Based questions. Each question carries 4 mark.

(vii) Section **E** - Question number 31 to 33 are Long Answer type questions. Each question carries 5 mark.

(viii) There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the Sections except Section-A.

(ix) Kindly note that there is a separate question paper for Visually Impaired candidates.

(x) Use of calculators is NOT allowed.

You may use the following values of physical constants wherever necessary :

$c = 3 \times 10^8$ m/s

$h = 6.63 \times 10^{-34}$ Js

$e = 1.6 \times 10^{-19}$ C

$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}

$\varepsilon_0 = 8.854 \times 10^{-12} C^2 N^{-1} m^{-2}$

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 N m^2 C^{-2}$

Mass of electron $(m_e) = 9.1 \times 10^{-31}$ kg

Mass of neutron $= 1.675 \times 10^{-27}$ kg

Mass of proton $= 1.673 \times 10^{-27}$ kg

Avogadro's number $= 6.023 \times 10^{23}$ per gram mole

Boltzmann constant $= 1.38 \times 10^{-23} JK^{-1}$

SECTION A

166. When a glass rod is rubbed with a silk cloth, it acquires a positive charge of 4.8×10^{-17}C. In the process, the number of electrons and protons transferred are respectively :

(a) 0,300 (b) 0,225

(c) 150,150 (d) 300,0

167. The emf and internal resistance of a cell are 3 V and $0 - 2\Omega$ respectively. It is connected to an external resistor of $5 \cdot 8\Omega$. The potential difference across the cell will be :

(a) 1.2 V (b) 2.0 V

(c) 2.9 V (d) 3.2 V

168. The magnetic field due to a current carrying circular coil at a point far off on its axis at a distance ' r ' from the centre of the coil is proportional to :

(a) $\frac{1}{r}$ (b) $\frac{1}{r^2}$
(c) $\frac{1}{r^{3/2}}$ (d) $\frac{1}{r^3}$

169. The magnetic field B within the solenoid of length L having N turns and carrying current I will be :
(a) μ_0 NIL (b) $\frac{\mu_0 NI}{L}$
(c) $\frac{\mu_0 NI}{4\pi L}$ (d) μ_0NI

170. A circular loop of radius 'a' carries a current 3I through it. Another concentric circular loop of radius 2a carrying a current I is placed perpendicular to the first loop. The dipole moment of the equivalent magnetic dipole for the system is:
(a) πIa^2 (b) 5 Ia
(c) $5\pi Ia^2$ (d) $7\pi Ia^2$

171. The magnetic flux ϕ (in Wb) through a closed loop of resistance $3 \cdot 0\Omega$ varies with time $t(s)$ as $\phi = 6t^2 + 3 \cdot 0t + 5$. The value of the induced current in the loop at $t = 1.0$ s is :
(a) 15.0 A (b) 3.0 A
(c) 4.0 A (d) 5.0 A

172. The frequencies of ultraviolet rays, gamma-rays and microwaves are v_1, v_2 and v_3 respectively. Then:
(a) $v_1 = v_2 = v_3$ (b) $v_1 > v_2 > v_3$
(c) $v_2 > v_1 > v_3$ (d) $v_3 > v_2 > v_1$

173. In the photoelectric effect, electrons are emitted from a given metal surface when the incident radiation has a certain minimum value of :
(a) frequency (b) intensity
(c) wavelength (d) angle of incidence

174. In Bohr model of a hydrogen atom, the increase in the angular momentum of the electron, when it is excited from n = 1 to n = 3 orbit, is :
(a) $\frac{h}{2\pi}$ (b) $\frac{2h}{\pi}$
(c) $\frac{3h}{2\pi}$ (d) $\frac{h}{\pi}$

175. A positively charged particle of mass m , moving with velocity v is bombarded on a heavy nucleus of charge Ze . Its distance of closest approach from the nucleus is proportional to :
(a) $\frac{Z}{mv^2}$ (b) $\frac{v^2}{Zm}$
(c) v^2 (d) $\frac{Zv^2}{m}$

176. The effect on width of depletion layer and height of the potential barrier of a p-n junction, when it is forward biased, are respectively :
(a) decreases, decreases
(b) increases, increases
(c) decreases, increases
(d) increases, decreases

177. The doping of a semiconductor with donor impurity results in :
(a) formation of a p-type semiconductor
(b) formation of a new energy level just above the filled valence band
(c) decrease in the concentration of electrons
(d) formation of a new energy level just below the conduction band

Questions number 13 to 16 are Assertion (A) and Reason (R) type questions. Two statements are given - one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (a), (b), (c) and (d) as given below.
(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(c) Assertion (A) is true, but Reason (R) is false.
(d) Assertion (A) is false and Reason (R) is also false.

178. **Assertion (A) :** Work functions of different metals are different.
Reason (R) : Metals differ in their conductivity.

179. **Assertion (A)** : The capacitive reactance increases with the increase of the frequency (ω) of applied ac voltage.
Reason (R) : The value of capacitive reactance (X_C) is ωC.

180. **Assertion (A) :** When current is passed through a spring, two adjacent turns move towards each other.
Reason (R) : There is a force between any two adjacent turns of a current carrying spring.

181. **Assertion (A) :** Signals through an optical fibre can be transmitted without any appreciable loss of energy.
Reason (R) : An optical fibre works on the principle of total internal reflection.

SECTION B

182. Two identical cells, each of emf E and internal resistance r , are connected in series with a resistor of 8Ω. A current of 1.5 A flows in the circuit. When these cells are connected in parallel, they send 1.0 A current through the same resistor. Calculate the internal resistance, r and emf, E of the cell.

183. **(A)** Name the factors on which focal length of a lens depends. How will a thin biconvex glass lens submerged in water behave? Give reason for your answer.

OR

(B) How will the fringe width be affected in a Young's double slit experiment with light of wavelength λ if :
(i) the separation between the slits is reduced to half, keeping the distance of the screen from the slits constant?
(ii) the distance of the screen from the slits is reduced to half, keeping the separation between the slits constant?

184. The power of the combination of two thin convex lenses L_1 and L_2, kept coaxially in contact, is +10 D . If the focal length of L_1 is four times that of L_2, find their focal lengths.

185. Differentiate between mass defect and binding energy per nucleon. The binding energy per nucleon is nearly constant in the range $30 < A < 170$. Why?

186. What are the important considerations for choosing dopants for silicon or germanium? Justify your answer.

SECTION C

187. **(A)** Define the terms - 'temperature coefficient of resistance' and 'electrical conductivity' of a conductor. Why are constantan and manganin used for making standard resistances? Explain.

OR

(B) Define 'drift velocity'. Show that resistivity of the material of a conductor is inversely proportional to the relaxation time for the free electrons in the conductor.

188. Two parallel straight wires of lengths 15 m and 20 m carrying currents 6.0 A and 8.0 A respectively in opposite directions, are 10 cm apart. Calculate the force on a 10 cm long section of the second wire near its centre. Also mention the nature of the force between these wires.

189. A bulb and an inductor of reactance X_L are connected in series with an ac source. How will the brightness of the bulb change when :
(A) an iron rod is inserted in the inductor?
(B) number of turns in the inductor is decreased?
(C) a capacitor of capacitive reactance $X_C(= X_L)$ is connected in series with the inductor?

190. What is meant by 'displacement current' ?
Show that during charging of a capacitor, displacement current is equal to conduction current in the circuit.

191. **Answer the following giving reasons:**
(A) The speed of emitted electrons depends on the work function of the photosensitive surface, for the incident radiation of a given frequency.
(B) The stopping potential (V_0) increases linearly with the frequency of incident radiation, for a given photosensitive surface.
(C) The photoelectric current increases linearly with the intensity of incident radiation, for a given surface.

192. Explain the origin of Lyman and Balmer series in the emission spectrum of hydrogen atom. How are the maximum and the minimum wavelength of lines in a series determined?

193. Explain the formation of energy bands in solids and hence define conduction band and valence band.

SECTION D

Questions number 29 and 30 are case study based questions. Read the following paragraphs and answer the questions that follow.

194. In a homogeneous medium, light travels along a straight line path. But when a ray of light travels from one medium to another, it deviates from its initial path. This bending of light is called refraction of light. The extent to which a ray deviates in medium 2 from its initial path in medium 1 , is determined by the refractive index of medium 2 with respect to medium 1 . The refractive index is also related to the ratio of speeds of light in the two media.

The phenomenon of total internal reflection occurs when light passes from a denser medium into a rarer medium and the angle of incidence exceeds the critical angle for the given pair of media.

(i) A ray of monochromatic light of wavelength λ and speed v travels from air into a glass slab. Inside the glass slab,

(a) both λ and v decrease
(b) both λ and v increase
(c) λ decreases and v increases
(d) λ increases and v decreases

(ii) (A) A ray of light travelling from air into a medium, is incident on the interface at an angle of 45°. If the ray deviates by 15° from its initial path, the refractive index of the medium is :

(a) 2 (b) $\sqrt{2}$
(c) $2\sqrt{2}$ (d) $\sqrt{3}$

OR

(ii) (B) A point source of light is kept at the bottom of a tank filled with a transparent liquid up to a height H . If the radius of the circular patch on the surface from which light can come out is $\frac{H}{\sqrt{3}}$, the refractive index of the liquid is close to :

(a) 1.3 (b) 1.5
(c) 1.7 (d) 2.0

(iii) In an optical fiber, the refractive indices of the core and cladding are μ_1 and μ_2 respectively. Then :

(a) $\mu_1 = \mu_2$
(b) $\mu_1 < \mu_2$
(c) μ_1 is slightly greater than μ_2
(d) μ_1 is large compared to μ_2

(iv) Light of wavelength λ travelling with speed c in air, enters a medium of refractive index μ. The frequency of light in the medium is :

(a) $\frac{c}{\mu\lambda}$ (b) $\frac{\mu c}{\lambda}$
(c) $\frac{\mu\lambda}{c}$ (d) $\frac{c}{\lambda}$

195. An electric dipole is a pair of equal and opposite point charges +q and -q separated by a distance 2a. A dipole can be characterised by dipole moment determined by its charge and separation between the two charges. It is a vector quantity. By convention the direction of a dipole is taken to be the direction from $-q$ to $+q$. Like fields due to a point charge, fields due to a given dipole at a point can be found.

When a dipole is placed in a uniform external electric field, it experiences a torque. This torque tends to rotate the dipole and work is done in this process. This work is stored as the potential energy of the system.

(i) An electric dipole is kept in a uniform electric field such that the dipole moment is not along the electric field. It will experience :

(a) A net force and a torque
(b) A net force but no torque
(c) A torque but no net force
(d) neither a net force nor a torque

(ii) An electric dipole consists of charges $+q$ and $-q$, separated by distance 2a. The force acting on a point charge placed at a distance x($\gg$ a) on the axis of the dipole is F . If the distance of the charge is doubled, the force will become :

(a) $\frac{F}{16}$ (b) $\frac{F}{8}$
(c) $\frac{F}{4}$ (d) $\frac{F}{2}$

(iii) Two identical small electric dipoles, each of dipole moment $\vec{p}$ are arranged perpendicular to each other such that their negative charges coincide. The magnitude of the net dipole moment of the arrangement will be :
(a) p (b) $2p$
(c) $p\sqrt{2}$ (d) $\frac{p}{\sqrt{2}}$

(iv) (A) A molecule with dipole moment $3.0 \times 10^{-30}\mathrm{C-m}$ is placed in a uniform electric field of $2 \times 10^{4}\mathrm{NC}^{-1}$. The maximum torque experienced by the molecule is:
(a) 1.5×10^{-34} N − m
(b) 6.0×10^{-26} N − m
(c) 4.5×10^{34} N − m
(d) 6.0×10^{-34} N − m

OR

(iv) (B) A electric dipole consists of two point charges +2 pC and -2 pC , separated by a distance 1 mm . It is kept in a uniform electric field of $2 \times 10^{5}\mathrm{NC}^{-1}$. The amount of work done in rotating it from its position of stable to unstable equilibrium will be :
(a) 2×10^{-10} J (b) 4×10^{-10} J
(c) 8×10^{-10} J (d) 1.6×10^{-11} J

SECTION E

196. **(A) (i)** A capacitor of capacitance **C** is charged to a potential difference V by a battery. The battery is disconnected and the separation between the plates is halved. How will the following quantities be affected?
(1) Capacitance of the capacitor
(2) Electric field between the plates
(3) Energy stored in the capacitor
Justify your answer in each case.
(ii) A capacitor of 20μ F is charged to 30 V . It is then connected to an uncharged 30μ F capacitor. Calculate the charges on each capacitor in equilibrium.

OR

(B) (i) Obtain an expression for electric potential at a distance r from a point charge Q.
(ii) Two point charges of 10μC and -5μC are placed at (-3 cm, 0) and (6 cm, 0) in an external electric field $E = \frac{A}{r^2}$, where $A = 1.8 \times 10^5\ \mathrm{NC^{-1}\ m^2}$. Calculate the electrostatic energy of the system.

197. **(A) (i)** Define the term 'self-inductance' of a coil. Obtain an expression for self-inductance of a solenoid of area of cross-section A , length L and having n turns per unit length.
(ii) The current flowing in a coil of inductance 50 mH is reduced from 10 A to 0 in 20 ms . Calculate the change in flux linked with the coil.

OR

(B) (i) Briefly explain the working of an ac generator. Obtain the expression for the instantaneous value of the emf induced in the generator.
(ii) Calculate the angular frequency at resonance of a series LCR circuit with $R = 12\Omega$, $L = 2.0$H and $C = 32\mu$ F, connected to an ac source.

198. **(A) (i)** What are coherent sources of light ? Briefly explain how a pair of coherent sources are obtained in a Young's double-slit experiment. Mention the conditions for constructive and destructive interferences in this experiment.
(ii) An object is kept 20 cm from a convex mirror of radius of curvature 60 cm . Find the position of the image formed. Will the image be real or virtual ?

OR

(B) (i) Answer the following giving reasons:
(1) In modern microscopes, multicomponent lenses are used for both the objective and the eyepiece.
(2) In a compound microscope, both the objective and the eyepiece have small focal lengths.
(3) When viewing through a compound microscope, our eyes should be positioned not on the eyepiece, but a short distance away from it for best viewing.

(ii) Two students are separated by a 6 m partition wall in a room 9 m high. If both light and sound waves can bend around obstacles, how is it that the students are unable to see each other, though they can talk easily?