General Instructions :

Read the following instructions very carefully and strictly follow them:

(i) This question paper contains 35 questions. All questions are compulsory.
(ii) This question paper is divided into five Sections —A, B, C, D and E.
(iii) In Section A - Questions no. 1 to 18 are Multiple Choice (MCQ) type questions, carrying 1 mark each.
(iv) In Section B - Questions no. 19 to 25 are Very Short Answer (VSA) type questions, carrying 2 marks each.
(v) In Section C - Questions no. 26 to 30 are Short Answer (SA) type questions, carrying 3 marks each.
(vi) In Section D - Questions no. 31 to 33 are Long Answer (LA) type questions carrying 5 marks each.
(vii) In Section E - Questions no. 34 and 35 are case-based questions carrying 4 marks each.
(viii) There is no overall choice. However, an internal choice has been provided in 2 questions in Section B, 2 questions in Section C, 3 questions in Section D and 2 questions in Section E.
(ix) Use of calculators is not allowed.

Use the following values of physical constants, if required:

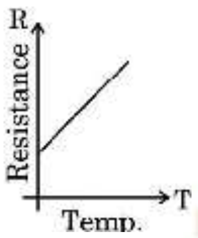
$c = 3 \times 10^8$ m/s
$h = 6.63 \times 10^{-34}$ Js
$e = 1.6 \times 10^{-19}$ C
$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}
$\varepsilon_0 = 8.854 \times 10^{-12} C^2 N^{-1} m^{-2}$
$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 N m^2 C^{-2}$
Mass of electron $(m_e) = 9.1 \times 10^{-31}$ kg
Mass of neutron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

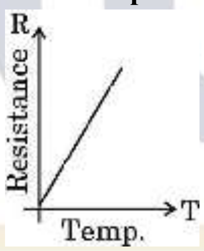
SECTION A

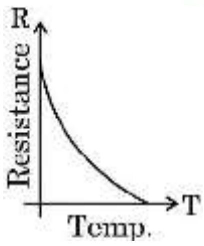
1. A point charge situated at a distance ' r ' from a short electric dipole on its axis, experiences a force $\vec{F}$. If the distance of the charge is ' $2r$ ', the force on the charge will be :

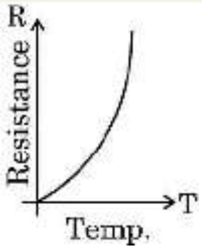
(a) $\frac{\vec{F}}{16}$ (b) $\frac{\vec{F}}{8}$
(c) $\frac{\vec{F}}{4}$ (d) $\frac{\vec{F}}{2}$

2. For a metallic conductor, the correct representation of variation of resistance R with temperature T is :

(a) 

(b) 

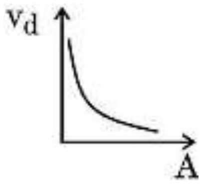
(c) 

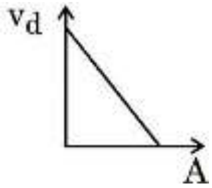
(d) 

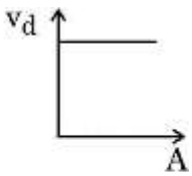
3. The potential difference across a cell in an open circuit is 8 V . It falls to 4 V when a current of 4 A is drawn from it. The internal resistance of the cell is :

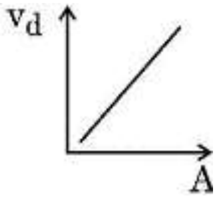
(a) 4Ω (b) 3Ω
(c) 2Ω (d) 1Ω

4. A steady current flows through a metallic wire whose area of cross-section (A) increases continuously from one end of the wire to the other. The magnitude of drift velocity (v_d) of the free electrons as a function of 'A' can be shown by :

(a) 

(b) 

(c) 

(d) 

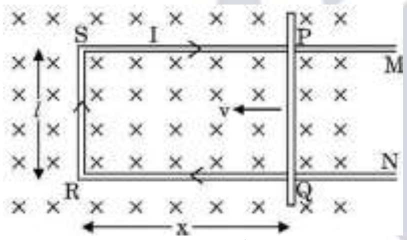
5. A diamagnetic substance is brought near the north or south pole of a bar magnet. It will be :

(a) repelled by both the poles.
(b) attracted by both the poles.
(c) repelled by the north pole and attracted by the south pole.
(d) attracted by the north pole and repelled by the south pole.

6. A circular coil of radius 8.0 cm and 40 turns is rotated about its vertical diameter with an angular speed of $\frac{25}{\pi}$ rads^{-1} in a uniform horizontal magnetic field of magnitude 3.0×10^{-2} T. The maximum emf induced in the coil is :

(a) 0.12 V (b) 0.15 V
(c) 0.19 V (d) 0.22 V

7. Figure shows a rectangular conductor PSRQ in which movable arm PQ has a resistance ' r ' and resistance of PSRQ is negligible. The magnitude of emf induced when PQ is moved with a velocity $\vec{v}$ does not depend on :



(a) magnetic field ($\vec{B}$) (b) velocity ($\vec{v}$)
(c) resistance (r) (d) length of PQ

8. In the process of charging of a capacitor, the current produced between the plates of the capacitor is : where symbols have their usual meanings.

(a) $\mu_0 \frac{d\phi_E}{dt}$ (b) $\frac{1}{\mu_0}\frac{d\phi_E}{dt}$
(c) $\varepsilon_0 \frac{d\phi_E}{dt}$ (d) $\frac{1}{\varepsilon_0}\frac{d\phi_E}{dt}$

9. For a concave mirror of focal length ' f ', the minimum distance between the object and its real image is :

(a) zero (b) f
(c) 2f (d) 4 f

10. The radius of the n^{th} orbit in Bohr model of hydrogen atom is proportional to :

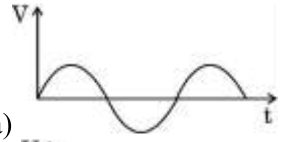
(a) $\frac{1}{n^2}$ (b) $\frac{1}{n}$
(c) n^2 (d) n

11. Hydrogen atom initially in the ground state, absorbs a photon which excites it to $n = 5$ level. The wavelength of the photon is :

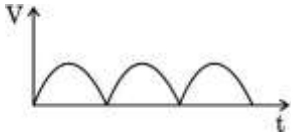
(a) 975 nm (b) 740 nm
(c) 523 nm (d) 95 nm

12. The mass density of a nucleus of mass number A is :
(a)proportional to $A^{1/3}$ (b)proportional to $A^{2/3}$
(c)proportional to A^{3} (d)independent of A

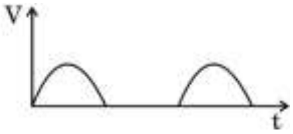
13. An ac source of voltage is connected in series with a p-n junction diode and a load resistor. The correct option for output voltage across load resistance will be :



(a)



(b)



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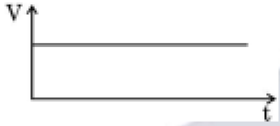


(d)

14. When an intrinsic semiconductor is doped with a small amount of trivalent impurity, then :
(a) its resistance increases.
(b) it becomes a p-type semiconductor.
(c) there will be more free electrons than holes in the semiconductor.
(d) dopant atoms become donor atoms.

15. In the energy-band diagram of n-type Si , the gap between the bottom of the conduction band E_C and the donor energy level E_D is of the order of :
(a) 10 eV (b) 1 eV
(c) 0.1 eV (d) 0.01 eV

Questions number 16 to 18 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.

16. Assertion (A) : When a bar of copper is placed in an external magnetic field, the field lines get concentrated inside the bar.
Reason (R) : Copper is a paramagnetic substance.

17. Assertion (A) : The phase difference between any two points on a wavefront is zero.
Reason (R) : All points on a wavefront are at the same distance from the source and thus oscillate in the same phase.

18. Assertion (A) : Photoelectric effect demonstrates the particle nature of light.
Reason (R) : Photoelectric current is proportional to intensity of incident radiation for frequencies more than the threshold frequency.

SECTION B

19. An alpha particle is projected with velocity $\vec{v} = (3.0 \times 10^5\ \mathrm{m/s})\hat{\imath}$ into a region in which magnetic field $\vec{B} = [(0 - 4\ \mathrm{T})\hat{\imath} + (0 - 3\ \mathrm{T})\hat{\jmath}]$ exists. Calculate the acceleration of the particle in the region. $\hat{\imath}, \hat{\jmath}$ and $\hat{k}$ are unit vectors along x, y and z axis respectively and charge to mass ratio for alpha particle is $4.8 \times 10^7\,\mathrm{C/kg}$.

20. Consider an induced magnetic field due to changing electric field and an induced electric field due to changing magnetic field. Which one is more easily observed? Justify your answer.

21. **(A)** Using Huygens' principle, draw a ray diagram showing the propagation of a plane wave refracting at a plane surface separating two media. Also verify Snell's law of refraction.

OR

(B) Why is a reflecting telescope preferred over a refracting telescope? Justify your answer giving two reasons.

22. Two coherent monochromatic light beams of intensities I and $4I$ superpose each other. Find the ratio of maximum and minimum intensities in the resulting beam.

23. The ground state energy of hydrogen atom is -13.6 eV . What is the potential energy and kinetic energy of an electron in the third excited state?

24. **(A)** Differentiate between intrinsic and extrinsic semiconductors.

OR

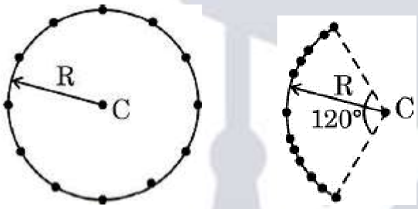
(B) Draw the circuit arrangement for studying the V − I characteristics of a p-n junction diode in forward bias and reverse bias. Show the plot of $V - I$ characteristic of a silicon diode.

25. Briefly explain how the diffusion and drift currents contribute to the formation of potential barrier in a p-n junction diode.

SECTION C

26. **(A)** Twelve negative charges of same magnitude are equally spaced and fixed on the circumference of a circle of radius R as shown in Fig. (i). Relative to potential being zero at infinity, find the electric potential and electric field at the centre C of the circle.

(B) If the charges are unequally spaced and fixed on an arc of 120° of radius R as shown in Fig. (ii), find electric potential at the centre C.



(i) **(ii)**

27. **(A)** How does the resistance differ from impedance? With the help of a suitable phasor diagram, obtain an expression for impedance of a series LCR circuit, connected to a source $v = v_m \sin \omega t$.

OR

(B) Find the condition for resonance in a series LCR circuit connected to a source $v = v_m \sin \omega t$, where ω can be varied. Give the factors on which the resonant frequency of a series LCR circuit depends. Plot a graph showing the variation of electric current with frequency in a series LCR circuit.

28. A long solenoid of radius r consists of n turns per unit length. A current $I = I_0 \sin \omega t$ flows in the solenoid. A coil of N turns is wound tightly around it near its centre. What is:

(A) the induced emf in the coil ?

(B) the mutual inductance between the solenoid and the coil ?

29. How does Einstein's photoelectric equation explain the emission of electrons from a metal surface? Explain briefly.

Plot the variation of photocurrent with :

(A) collector plate potential for different intensity of incident radiation, and

(B) intensity of incident radiation.

30. **(A)** Draw the energy level diagram for hydrogen atom. Mark the transitions corresponding to the series lying in the ultraviolet region, visible region and infrared region.

OR

(B) Draw a diagram to show the variation of binding energy per nucleon with mass number for different nuclei and mention its two features. Why do lighter nuclei usually undergo nuclear fusion?

SECTION D

31. (A) (i) State Coulomb's law in electrostatics and write it in vector form, for two charges.

(ii) 'Gauss's law is based on the inverse-square dependence on distance contained in the Coulomb's law.' Explain.

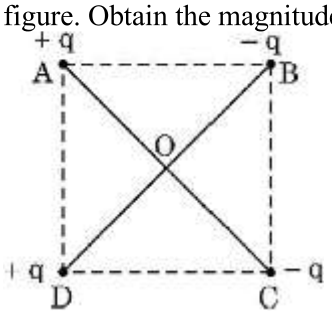
(iii) Two charges A (charge q) and B (charge $2q$) are located at points (0,0) and (a, a) respectively. Let $\hat{\imath}$ and $\hat{\jmath}$ be the unit vectors along x-axis and y-axis respectively. Find the force exerted by A on B, in terms of $\hat{\imath}$ and $\hat{\jmath}$.

OR

(B) (i) Derive an expression for the electric field at a point on the equatorial plane of an electric dipole consisting of charges q and - q separated by a distance $2a$.

(ii) The distance of a far off point on the equatorial plane of an electric dipole is halved. How will the electric field be affected for the dipole?

(iii) Two identical electric dipoles are placed along the diagonals of a square ABCD of side $\sqrt{2}$ m as shown in the figure. Obtain the magnitude and direction of the net electric field at the centre (O) of the square.



32. (A) (i) State Biot-Savart's law for the magnetic field due to a current carrying element. Use this law to obtain an expression for the magnetic field at the centre of a circular loop of radius ' a ' and carrying a current ' T. Draw the magnetic field lines for a current loop indicating the direction of magnetic field.

(ii) An electron is revolving around the nucleus in a circular orbit with a speed of 10^7 m s^{-1}. If the radius of the orbit is 10^{-10} m, find the current constituted by the revolving electron in the orbit.

OR

(B) (i) Derive an expression for the force acting on a current carrying straight conductor kept in a magnetic field. State the rule which is used to find the direction of this force. Give the condition under which this force is (1) maximum, and (2) minimum.

(ii) Two long parallel straight wires A and B are 2.5 cm apart in air. They carry 5.0 A and 2.5 A currents respectively in opposite directions. Calculate the magnitude of the force exerted by wire A on a 10 cm length of wire B.

33. (A) (i) (1) Write two points of difference between an interference pattern and a diffraction pattern.

(2) Name any two factors on which the fringe width in a Young's double-slit experiment depends.

(ii) In Young's double-slit experiment, the two slits are separated by a distance equal to 100 times the wavelength of light that passes through the slits. Calculate:

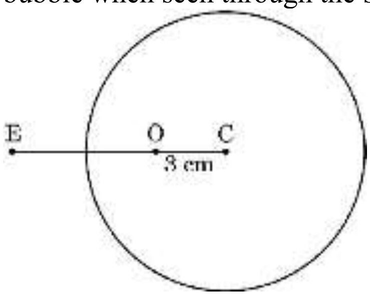
(1) the angular separation in radians between the central maximum and the adjacent maximum.

(2) the distance between these two maxima on a screen 50 cm from the slits.

OR

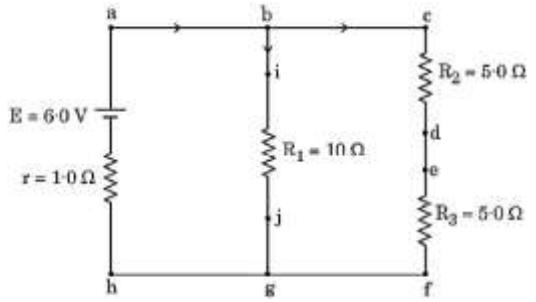
(B) (i) A spherical surface of radius of curvature R separates two media of refractive indices n_1 and n_2. A point object is placed in front of the surface at distance u in medium of refractive index n_1 and its image is formed by the surface at distance v , in the medium of refractive index n_2. Derive a relation between u and v .

(ii) A solid glass sphere of radius 6.0 cm has a small air bubble trapped at a distance 3.0 cm from its centre C as shown in the figure. The refractive index of the material of the sphere is 1.5. Find the apparent position of this bubble when seen through the surface of the sphere from an outside point E in air.



SECTION E

34. The following figure shows a circuit diagram. We can find the currents through and potential differences across different resistors using Kirchhoff's rules.



Answer the following questions based on the above :

(A) Which points are at the same potential in the circuit?

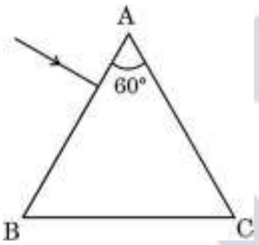
(B) What is the current through arm bg ?

(C) Find the potential difference across resistance R_3.

OR

(C) What is the power dissipated in resistance R_2 ?

35. Strontium titanate is a rare oxide - a natural mineral found in Siberia. It is used as a substitute for diamond because its refractive index and critical angle are $2 \cdot 41$ and $24 \cdot 5°$, respectively, which are approximately equal to the refractive index and critical angle of diamond. It has all the properties of diamond. Even an expert jeweller is unable to differentiate between diamond and strontium titanate. A ray of light is incident normally on one face of an equilateral triangular prism ABC made of strontium titanate.



Answer the following questions based on the above :

(A) Trace the path of the ray showing its passage through the prism.

(B) Find the velocity of light through the prism.

(C) Briefly explain two applications of total internal reflection.

OR

(C) Define total internal reflection of light. Give two conditions for it.

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

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

Mass of electron $(m_e) = 9.1 \times 10^{-31}$ kg
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Avogadro's number $= 6.023 \times 10^{23}$ per gram mole
Boltzmann constant $= 1.38 \times 10^{-23} JK^{-1}$

SECTION - A

36. The magnitude of the electric field due to a point charge object at a distance of 4.0 m is 9 N/C. From the same charged object the electric field of magnitude, $16 \frac{N}{C}$ will be at a distance of

(a) 1 m (b) 2 m
(c) 3 m (d) 6 m

37. A point P lies at a distance x from the mid point of an electric dipole on its axis. The electric potential at point P is proportional to

(a) $\frac{1}{x^2}$ (b) $\frac{1}{x^3}$
(c) $\frac{1}{x^4}$ (d) $\frac{1}{x^{1/2}}$

38. A current of 0.8 A flows in a conductor of 40Ω for 1 minute. The heat produced in the conductor will be

(a) 1445 J (b) 1536 J
(c) 1569 J (d) 1640 J

39. A cell of emf E is connected across an external resistance R . When current ' T ' is drawn from the cell, the potential difference across the electrodes of the cell drops to V . The internal resistance ' r ' of the cell is

(a) $\left(\frac{E-V}{E}\right)R$ (b) $\left(\frac{E-V}{R}\right)$
(c) $\frac{(E-V)R}{I}$ (d) $\left(\frac{E-V}{V}\right)R$

40. Beams of electrons and protons move parallel to each other in the same direction. They

(a) attract each other.
(b) repel each other.
(c) neither attract nor repel.
(d) force of attraction or repulsion depends upon speed of beams.

41. A long straight wire of radius 'a' carries a steady current ' T '. The current is uniformly distributed across its area of crossesection. The ratio of magnitude of magnetic field $\vec{B}_1$ at $\frac{a}{2}$ and $\vec{B}_2$ at distance 2a is

(a) $\frac{1}{2}$ (b) 1
(c) 2 (d) 4

42. $\vec{E}$ and $\vec{B}$ represent the electric and the magnetic field of an electromagnetic wave respectively. The direction of propagation of the wave is along

(a) $\vec{B}$ (b) $\vec{E}$
(c) $\vec{E} \times \vec{B}$ (d) $\vec{B} \times \vec{E}$

43. A ray of monochromatic light propagating in air, is incident on the surface of water. Which of the following will be the same for the reflected and refracted rays?

(a) Energy carried (b) Speed
(c) Frequency (d) Wavelength

44. A beam of light travels from air into a medium. Its speed and wavelength in the medium are 1.5×10^8 ms^{-1} and 230 nm respectively. The wavelength of light in air will be

(a) 230 nm (b) 345 nm
(c) 460 nm (d) 690 nm

45. Which one of the following metals does not exhibit emission of electrons from its surface when irradiated by visible light?

(a) Rubidium (b) Sodium
(c) Cadmium (d) Caesium

46. A hydrogen atom makes a transition from n = 5 to n = 1 orbit. The wavelength of photon emitted is λ. The wavelength of photon emitted when it makes a transition from n = 5 to n = 2 orbit is

(a) $\frac{8}{7}\lambda$ (b) $\frac{16}{7}\lambda$

(c) $\frac{24}{7}\lambda$ (d) $\frac{32}{7}\lambda$

47. The curve of binding energy per nucleon as a function of atomic mass number has a sharp peak for helium nucleus. This implies that helium nucleus is

(a) radioactive
(b) unstable
(c) easily fissionable
(d) more stable nucleus than its neighbours

48. In an extrinsic semiconductor, the number density of holes is $4 \times 10^{20}\ m^{-3}$. If the number density of intrinsic carriers is $1.2 \times 10^{15}\ m^{-3}$, the number density of electrons in it is

(a) $1.8 \times 10^{9}\ m^{-3}$ (b) $2.4 \times 10^{10}\ m^{-3}$

(c) $3.6 \times 10^{9}\ m^{-3}$ (d) $3.2 \times 10^{10}\ m^{-3}$

49. Pieces of copper and of silicon are initially at room temperature. Both are heated to temperature T. The conductivity of

(a) both increases.
(b) both decreases.
(c) copper increases and silicon decreases.
(d) copper decreases and silicon increases.

50. The formation of depletion region in a p-n junction diode is due to

(a) movement of dopant atoms
(b) diffusion of both electrons and holes
(c) drift of electrons only
(d) drift of holes only

Note : In question number 16 to 18, two statements are given - one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below :

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

51. Assertion (A) : Diamagnetic substances exhibit magnetism.
Reason (R) : Diamagnetic materials do not have permanent magnetic dipole moment.

52. Assertion (A) : Work done in moving a charge around a closed path, in an electric field is always zero.
Reason (R) : Electrostatic force is a conservative force.

53. Assertion (A) : In Young's double slit experiment all fringes are of equal width.
Reason (R) : The fringe width depends upon wavelength of light (λ) used, distance of screen from plane of slits (D) and slits separation (d).

SECTION – B

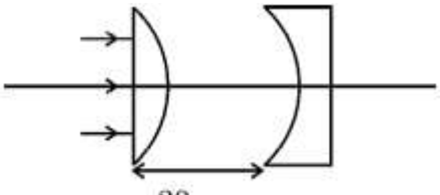
54. Briefly explain why and how a galvanometer is converted into an ammeter.

55. (A) How are infrared waves produced ? Why are these waves referred to as heat waves? Give any two uses of infrared waves.

OR

(B) How are X-rays produced ? Give any two uses of these.

56. In the given figure the radius of curvature of curved face in the planoconvex and the plano-concave lens is 15 cm each. The refractive index of the material of the lenses is 1.5 . Find the final position of the image formed.



57. What happens to the interference pattern when two coherent sources are

(A) infinitely close, and

(B) far apart from each other

58. (A) What is meant by ionisation energy ? Write its value for hydrogen atom.

OR

(B) Define the term, mass defect. How is it related to stability of the nucleus?

59. Draw energy band diagram for an n-type and p-type semiconductor at $T > 0$ K.

60. Answer the following giving reasons :

(i) A p-n junction diode is damaged by a strong current.

(ii) Impurities are added in intrinsic semiconductors.

SECTION – C

61. (A) Two charged conducting spheres of radii a and b are connected to each other by a wire. Find the ratio of the electric fields at their surfaces.

OR

(B) A parallel plate capacitor (A) of capacitance C is charged by a battery to voltage V . The battery is disconnected and an uncharged capacitor (B) of capacitance 2 C is connected across A . Find the ratio of

(i) final charges on A and B .

(ii) total electrostatic energy stored in A and B finally and that stored in A initially.

62. Define current density and relaxation time. Derive an expression for resistivity of a conductor in terms of number density of charge carriers in the conductor and relaxation time.

63. A series CR circuit with $R = 200\Omega$ and $C = (50/\pi)\mu F$ is connected across an ac source of peak voltage $\varepsilon_0 = 100$ V and frequency $v = 50$ Hz. Calculate (a) impedance of the circuit (Z), (b) phase angle (ϕ), and (c) voltage across the resistor.

64. Define critical angle for a given pair of media and total internal reflection. Obtain the relation between the critical angle and refractive index of the medium.

65. (A) (i) Distinguish between nuclear fission and fusion giving an example of each.

(ii) Explain the release of energy in nuclear fission and fusion on the basis of binding energy per nucleon curve.

OR

(B) (i) How is the size of a nucleus found experimentally ? Write the relation between the radius and mass number of a nucleus.

(ii) Prove that the density of a nucleus is independent of its mass number.

SECTION-D

66. (A) (i) Use Gauss' law to obtain an expression for the electric field due to an infinitely long thin straight wire with uniform linear charge density λ.

(ii) An infinitely long positively charged straight wire has a linear charge density λ. An electron is revolving in a circle with a constant speed v such that the wire passes through the centre, and is perpendicular to the plane, of the circle. Find the kinetic energy of the electron in terms of magnitudes of its charge and linear charge density λ on the wire.

(iii) Draw a graph of kinetic energy as a function of linear charge density λ.

OR

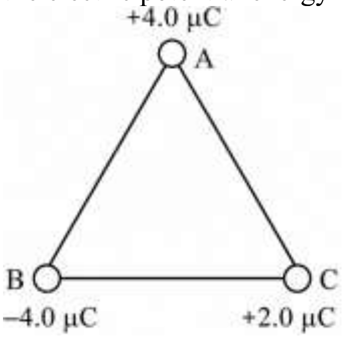
(B) (i) Consider two identical point charges located at points (0,0) and (a, 0).

(1) Is there a point on the line joining them at which the electric field is zero?

(2) Is there a point on the line joining them at which the electric potential is zero?

Justify your answers for each case.

(ii) State the significance of negative value of electrostatic potential energy of a system of charges.
Three charges are placed at the corners of an equilateral triangle ABC of side 2.0 m as shown in figure. Calculate the electric potential energy of the system of three charges.



67. **(A) (i)** Define coefficient of self-induction. Obtain an expression for self-inductance of a long solenoid of length l, area of crosssection A having N turns.

(ii) Calculate the self-inductance of a coil using the following data obtained when an AC source of frequency $\left(\frac{200}{\pi}\right)$ Hz and a DC source is applied across the coil.

AC Source		
S.No.	V (Volts)	I (A)
1	3.0	0.5
2	6.0	1.0
3	9.0	1.5
DC Source		
S.No.	V (Volts)	I (A)
1	4.0	1.0
2	6.0	1.5
3	8.0	2.0

OR

(B) (i) With the help of a labelled diagram, describe the principle and working of an ac generator. Hence, obtain an expression for the instantaneous value of the emf generated.

(ii) The coil of an ac generator consists of 100 turns of wire, each of area 0.5 m^2. The resistance of the wire is 100Ω. The coil is rotating in a magnetic field of 0.8 T perpendicular to its axis of rotation, at a constant angular speed of 60 radian per second. Calculate the maximum emf generated and power dissipated in the coil.

68. **(A) (i)** State Huygen's principle. With the help of a diagram, show how a plane wave is reflected from a surface. Hence verify the law of reflection.

(ii) A concave mirror of focal length 12 cm forms a three times magnified virtual image of an object. Find the distance of the object from the mirror.

OR

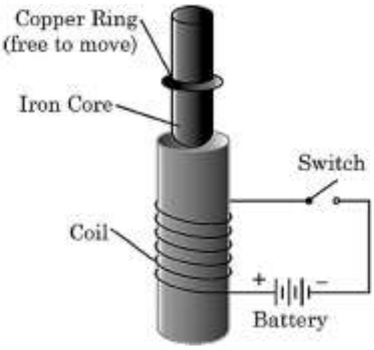
(B) (i) Draw a labelled ray diagram showing the image formation by a refracting telescope. Define its magnifying power. Write two limitations of a refracting telescope over a reflecting telescope.

(ii) The focal lengths of the objective and the eye-piece of a compound microscope are 1.0 cm and 2.5 cm respectively. Find the tube length of the microscope for obtaining a magnification of 300 .

SECTION – E

Note : Questions number 34 and 35 are Case Study based questions. Read the following paragraph and answer the questions.

69. (A) Consider the experimental set up shown in the figure. This jumping ring experiment is an outstanding demonstration of some simple laws of Physics. A conducting non-magnetic ring is placed over the vertical core of a solenoid. When current is passed through the solenoid, the ring is thrown off.



Answer the following questions:

(i) Explain the reason of jumping of the ring when the switch is closed in the circuit.

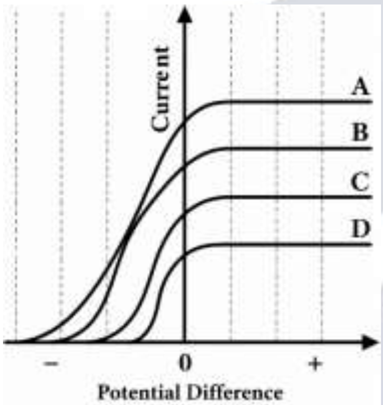
(ii) What will happen if the terminals of the battery are reversed and the switch is closed? Explain.

(iii) Explain the two laws that help us understand this phenomenon.

OR

(B) Briefly explain various ways to increase the strength of magnetic field produced by a given solenoid.

70. (A) Figure shows the variation of photoelectric current measured in a photo cell circuit as a function of the potential difference between the plates of the photo cell when light beams A, B, C and D of different wavelengths are incident on the photo cell. Examine the given figure and answer the following questions:



(i) Which light beam has the highest frequency and why?

(ii) Which light beam has the longest wavelength and why?

(iii) Which light beam ejects photoelectrons with maximum momentum and why ?

OR

(B) What is the effect on threshold frequency and stopping potential on increasing the frequency of incident beam of light ? Justify your answer.

General Instructions :

Read the following instructions very carefully and strictly follow them:

(i) This question paper contains 35 questions. All questions are compulsory.

(ii) This question paper is divided into five Sections —A, B, C, D and E.

(iii) In Section A - Questions no. 1 to 18 are Multiple Choice (MCQ) type questions, carrying 1 mark each.

(iv) In Section B - Questions no. 19 to 25 are Very Short Answer (VSA) type questions, carrying 2 marks each.

(v) In Section C - Questions no. 26 to 30 are Short Answer (SA) type questions, carrying 3 marks each.

(vi) In Section D - Questions no. 31 to 33 are Long Answer (LA) type questions carrying 5 marks each.

(vii) In Section E - Questions no. 34 and 35 are case-based questions carrying 4 marks each.

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

(ix) Use of calculators is not allowed.

Use the following values of physical constants, if required:

$c = 3 \times 10^8$ 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

71. An electron experiences a force $(1.6 \times 10^{-16}$ N$)\hat{i}$ in an electric field $\vec{E}$. The electric field $\vec{E}$ is :

(a) $\left(1.0 \times 10^3 \frac{N}{C}\right)\hat{i}$ (b) $-\left(1.0 \times 10^3 \frac{N}{C}\right)\hat{i}$

(c) $\left(1.0 \times 10^{-3} \frac{N}{C}\right)\hat{i}$ (d) $-\left(1.0 \times 10^{-3} \frac{N}{C}\right)\hat{i}$

72. Which one of the following is not a scalar quantity?

(a) Electric field (b) Voltage

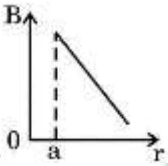
(c) Resistivity (d) Power

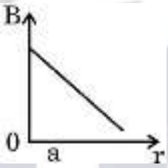
73. The current density due to drift of electrons in a conductor is given by : (symbols have their usual meanings)

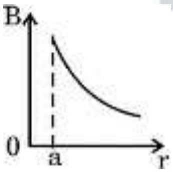
(a) $neAv_d$ (b) $\frac{nAv_d}{e}$

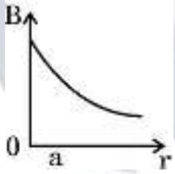
(c) $\frac{nv_d}{eA}$ (d) nev_d

74. Which of the following graphs correctly represents the variation of the magnitude of the magnetic field outside a straight infinite current carrying wire of radius ' a ', as a function of distance ' r ' from the centre of the wire ?

(a) 

(b) 

(c) 

(d) 

75. A particle of mass m and charge q moving with a uniform velocity $\vec{v} = v_{0x}\hat{i} + v_{0y}\hat{j}$ enters a region with a magnetic field $\vec{B} = B_0\hat{j}$. After some time, an electric field $\vec{E} = E_0\hat{j}$ is also switched on in the region. The resulting path described by the particle will be :

(a) a circle in x − z plane

(b) a parabola in x − y plane

(c) a helix with constant pitch

(d) a helix with increasing pitch

76. An inductor, a capacitor and a resistor are connected in series across an ac source of voltage. If the frequency of the source is decreased gradually, the reactance of :

(a) both the inductor and the capacitor decreases.

(b) inductor decreases and the capacitor increases.

(c) both the inductor and the capacitor increases.

(d) inductor increases and the capacitor decreases.

77. The electromagnetic radiations used to kill germs in water purifiers are called :

(a) Infrared waves (b) X-rays

(c) Gamma rays (d) Ultraviolet rays

78. In the wave picture of light, the intensity I of light is related to the amplitude A of the wave as :

(a) $I \propto \sqrt{A}$ (b) $I \propto A$

(c) $I \propto A^2$ (d) $I \propto \frac{1}{A^2}$

79. In a single-slit diffraction experiment, the width of the slit is halved. The width of the central maximum, in the diffraction pattern, will become :

(a) half (b) twice

(c) four times (d) one-fourth

80. A graph is plotted between the stopping potential (on y-axis) and the frequency of incident radiation (on x-axis) for a metal. The product of the slope of the straight line obtained and the magnitude of charge on an electron is equal to :

(a) h (b) $\frac{h}{c}$

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

81. Light of frequency 6.4×10^{14} Hz is incident on a metal of work function $2 \cdot 14$eV. The maximum kinetic energy of the emitted electrons is about :

(a) 0.25 eV (b) 0.51eV

(c) 1.02 eV (d) $0 \cdot 10$eV

82. The ratio of maximum frequency and minimum frequency of light emitted in Balmer series of hydrogen spectrum, in Bohr's model is :

(a) $\frac{11}{9}$ (b) $\frac{9}{5}$

(c) $\frac{11}{7}$ (d) $\frac{16}{7}$

83. At a certain temperature in an intrinsic semiconductor, the electrons and holes concentration is $1.5 \times 10^{16}\ m^{-9}$. When it is doped with a trivalent dopant, hole concentration increases to $4.5 \times 10^{22}\ m^{-3}$. In the doped semiconductor, the concentration of electrons (n_e) will be :

(a) $3 \times 10^6\ m^{-3}$ (b) $5 \times 10^7\ m^{-8}$

(c) $5 \times 10^9\ m^{-8}$ (d) $6.75 \times 10^{38}\ m^{-3}$

84. If a p-n junction diode is reverse biased,

(a) the potential barrier is lowered.

(b) the potential barrier remains unaffected.

(c) the potential barrier is raised.

(d) the current is mainly due to majority carriers.

85. A voltage signal is described by :

$v = V_0 \qquad \text{for } 0 \leq t \leq \frac{T}{2}$

$= 0 \qquad \text{for } \frac{T}{2} \leq t \leq T$

for a cycle. Its rms value is :

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

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

Questions number 16 to 18 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.

86. Assertion (A) : The internal resistance of a cell is constant.
Reason (R) : Ionic concentration of the electrolyte remains same during use of a cell.

87. Assertion (A) : When radius of a circular loop carrying a steady current is doubled, its magnetic moment becomes four times.
Reason (R) : The magnetic moment of a circular loop carrying a steady current is proportional to the area of the loop.

88. Assertion (A): The nucleus $_3^7X$ is more stable than the nucleus $_3^4Y$.
Reason (R): $_3^7X$ contains more number of protons.

SECTION B

89. A wire of length l is in the form of a circular loop A of one turn. This loop is reshaped into loop B of three turns. Find the ratio of the magnetic fields at the centres of loop A and loop B for the same current through them.

90. What is meant by the term 'displacement current'? Briefly explain how this current is different from a conduction current.

91. (A) State Huygens' principle. How did Huygens explain the absence of the backwave?

OR

(B) Use Huygens' principle to show reflection/refraction of a plane wave by **(i)** concave mirror, and **(ii)** a convex lens.

92. The refractive indices of two media A and B are 2 and $\sqrt{2}$ respectively. What is the critical angle for their interface?

93. (A) Draw a graph showing the variation of binding energy per nucleon as a function of mass number A . The binding energy per nucleon for heavy nuclei ($A > 170$) decreases with the increase in mass number. Explain.

OR

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

94. Explain the roles of diffusion current and drift current in the formation of the depletion layer in a p-n junction diode.

95. Explain the property of a p-n junction which makes it suitable for rectifying alternating voltages. Differentiate between a half-wave and a full-wave rectifier.

SECTION C

96. A potential difference V is applied across a conductor of length l and uniform cross-section area A. How will the **(i)** electric field E, **(ii)** drift velocity v_d, and **(iii)** current density j be affected when **(a)** V is doubled and **(b)** l is halved (keeping other factors constant) ?

97. What is meant by the term 'mutual inductance' of a pair of coils ? Obtain an expression for the mutual inductance of two long coaxial solenoids, each of length l but having different number of turns N_1 and N_2 and radii r_1 and $r_2 (r_2 > r_1)$.

98. (A) An ac source $v = v_m \sin \omega t$ is connected across an ideal capacitor. Derive the expression for the **(i)** current flowing in the circuit, and **(ii)** reactance of the capacitor. Plot a graph of current i versus ωt.

OR

(B) A series combination of an inductor L , a capacitor C and a resistor R is connected across an ac source of voltage in a circuit. Obtain an expression for the average power consumed by the circuit. Find power factor for **(i)** purely inductive circuit, and **(ii)** purely resistive circuit.

99. Calculate the wavelength of de Broglie waves associated with a proton having $\left(\frac{500}{1.673}\right)$ eV energy. How will the wavelength be affected for an alpha particle having the same energy?

100. (A) (i) Prove that the nuclear density is same for all nuclei.
(ii) Draw a plot of potential energy of a pair of nucleons as a function of their separation. Draw two inferences from this plot.

OR

(B) (i) Draw a graph to show the variation of the number of scattered particles detected (N) in Geiger-Marsden experiment as a function of scattering angle (θ).

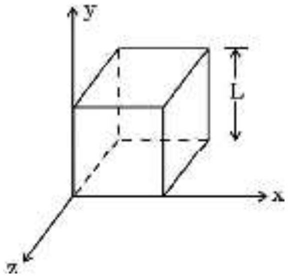
(ii) Discuss briefly two conclusions that can be drawn from this graph and how they lead to the discovery of nucleus in an atom.

SECTION D

101. **(A) (i)** Define electric flux and write its SI unit.

(ii) Use Gauss' law to obtain the expression for the electric field due to a uniformly charged infinite plane sheet.

(iii) A cube of side L is kept in space, as shown in the figure. An electric field $\vec{E} = (Ax + B)\hat{i}\frac{N}{C}$ exists in the region. Find the net charge enclosed by the cube.



OR

(B) (i) Define electric potential at a point and write its SI unit.
(ii) Two capacitors are connected in series. Derive an expression of the equivalent capacitance of the combination.
(iii) Two point charges $+q$ and $-q$ are located at points $(3a, 0)$ and $(0, 4a)$ respectively in $x - y$ plane. A third charge Q is kept at the origin. Find the value of Q, in terms of q and a, so that the electrostatic potential energy of the system is zero.

102. **(A) (i)** Write the principle and explain the working of a moving coil galvanometer. A galvanometer as such cannot be used to measure the current in a circuit. Why ?

(ii) Why is the magnetic field made radial in a moving coil galvanometer? How is it achieved?

OR

(B) (i) Derive an expression for magnetic field on the axis of a current carrying circular loop.
(ii) Write any two points of difference between a diamagnetic and a paramagnetic substance.

103. **(A) (i)** Draw a ray diagram showing the formation of a real image of an object placed at a distance ' u ' in front of a concave mirror of radius of curvature ' R '. Hence, obtain the relation for the image distance ' v ' in terms of u and R.

(ii) A 1.8 m tall person stands in front of a convex lens of focal length 1 m , at a distance of 5 m . Find the position and height of the image formed.

OR

(B) (i) Draw a ray diagram showing refraction of a ray of light through a triangular glass prism. Hence, obtain the relation for the refractive index (μ) in terms of angle of prism (A) and angle of minimum deviation (δ_m).
(ii) The radii of curvature of the two surfaces of a concave lens are 20 cm each. Find the refractive index of the material of the lens if its power is $-5 \cdot 0$D.

SECTION E

104. A beam of electrons moving horizontally with a velocity of 3×10^7 m/s enters a region between two plates as shown in the figure. A suitable potential difference is applied across the plates such that the electron beam just strikes the edge of the lower plate.

Answer the following questions based on the above:
(A) How long does an electron take to strike the edge ?
(B) What is the shape of the path followed by the electron and why?
(C) Find the potential difference applied.

OR

(C) Find the magnitude and direction of the magnetic field which should be created in the space between the plates so that the electron beam goes straight undeviated.

105. Diffraction of light is bending of light around the corners of an object whose size is comparable with the wavelength of light. Diffraction actually defines the limits of ray optics. This limit for optical instruments is set by the wavelength of light. An experimental arrangement is set up to observe the diffraction pattern due to a single slit.

Answer the following questions based on the above :

(A) How will the width of central maximum be affected if the wavelength of light is increased ?

(B) Under what condition is the first minimum obtained?

(C) Write two points of difference between interference and diffraction patterns.

OR

(C) Two students are separated by a 7 m partition wall in a room 10 m high. If both light and sound waves can bend around obstacles, how is it that the students are unable to see each other even though they can converse easily ?

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Read the following instructions very carefully and strictly follow them:

(i) This question paper contains 35 questions. All questions are compulsory.

(ii) This question paper is divided into five Sections $-$A, B, C, D and E.

(iii) In Section A - Questions no. 1 to 18 are Multiple Choice (MCQ) type questions, carrying 1 mark each.

(iv) In Section B - Questions no. 19 to 25 are Very Short Answer (VSA) type questions, carrying 2 marks each.

(v) In Section C - Questions no. 26 to 30 are Short Answer (SA) type questions, carrying 3 marks each.

(vi) In Section D - Questions no. 31 to 33 are Long Answer (LA) type questions carrying 5 marks each.

(vii) In Section E - Questions no. 34 and 35 are case-based questions carrying 4 marks each.

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

(ix) Use of calculators is not allowed.

Use the following values of physical constants, if required:

$c = 3 \times 10^8$ 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

106. Two charges q_1 and q_2 are placed at the centres of two spherical conducting shells of radius r_1 and r_2 respectively. The shells are arranged such that their centres are $d > (r_1 + r_2)]$ distance apart. The force on q_2 due to q_1 is:

(a) $\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{d^2}$ (b) $\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{(d-r_1)^2}$

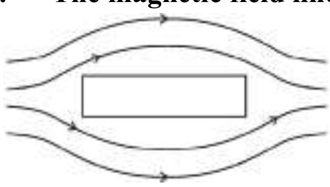
(c) Zero (d) $\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{[d-(r_1+r_2)]^2}$

107. An electron enters a uniform magnetic field with speed v. It describes a semicircular path and comes out of the field. The final speed of the electron is:

(a) Zero (b) v

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

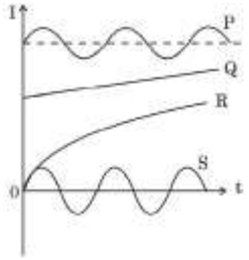
108. The magnetic field lines near a substance are as shown in the figure. The substance is :



(a) Copper (b) Iron

(c) Sodium (d) Aluminium

109. The figure shows variation of current (I) with time (t) in four devices P,Q,S and S . The device in which an alternating current flows is :



(a) P (b) Q
(c) R (d) S

110. The electromagnetic waves used in radar systems are :

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

111. In a Young's double-slit experiment, the fringe width is found to be β. If the entire apparatus is immersed in a liquid of refractive index μ, the new fringe width will be :

(a) β (b) $\mu\beta$
(c) $\frac{\beta}{\mu}$ (d) $\frac{\beta}{\mu^2}$

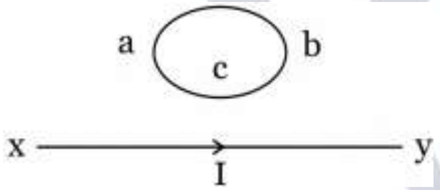
112. Photons of energy 3.2 eV are incident on a photosensitive surface. If the stopping potential for the emitted electrons is 1.5 V , the work function for the surface is :

(a) 1.5 eV (b) 1.7 eV
(c) 3.2 eV (d) 4.2 eV

113. Which of the following statements is not true for nuclear forces ?

(a) They are stronger than Coulomb forces.
(b) They have about the same magnitude for different pairs of nucleons.
(c) They are always attractive.
(d) They saturate as the separation between two nucleons increases.

114. The direction of induced current in the loop abc is:



(a) along abc if I decreases
(b) along acb if I increases
(c) along abe if I is constant
(d) along abc if I increases

115. An ac voltage $v = v_0 \sin\omega t$ is applied to a series combination of a resistor R and an element X. The instantaneous current in the circuit is $I = I_0 \sin\left(\omega t + \frac{\pi}{4}\right)$. Then which of the following is correct ?

(a) X is a capacitor and $X_C = \sqrt{2}R$
(b) X is an inductor and $X_L = R$
(c) X is an inductor and $X_L = \sqrt{2}R$
(d) X is a capacitor and $X_C = R$

116. A plane wavefront is incident on a concave mirror of radius of curvature R . The radius of the refracted wavefront will be :

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

117. A proton and an alpha particle have the same kinetic energy. The ratio of de Broglie wavelengths associated with the proton to that with the alpha particle is :

(a) 1 (b) 2

(c) $2\sqrt{2}$ (d) $\frac{1}{2}$

118. The potential energy of an electron in the second excited state in hydrogen atom is :

(a) $-3 \cdot 4 \mathrm{eV}$ (b) $-3 \cdot 02 \mathrm{~eV}$

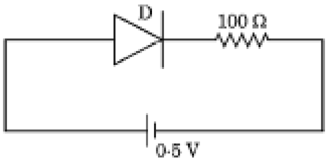
(c) $-1.51 \mathrm{eV}$ (d) $-6 \cdot 8 \mathrm{eV}$

119. The difference in mass of 7_X nucleus and total mass of its constituent nucleons is $21-00 \mathrm{u}$. The binding energy per nucleon for this nucleus is equal to the energy equivalent of :

(a) 3u (b) $3 \cdot 5 \mathrm{u}$

(c) 7u (d) 21u

120. The threshold voltage for a p-n junction diode used in the circuit is 0.7 V . The type of biasing and current in the circuit are :



(a) Forward biasing, 0 A
(b) Reverse biasing, 0 A
(c) Forward biasing, 5 mA
(d) Reverse biasing, 2 mA

Questions number 16 to 18 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.

121. Assertion (A) : When three electric bulbs of power 200 W, 100 W and 50 W are connected in series to a source, the power consumed by the 50 W bulb is maximum.

Reason (R): In a series circuit, current is the same through each bulb, but the potential difference across each bulb is different.

122. Assertion (A) : A current carrying square loop made of a wire of length L is placed in a magnetic field. It experiences a torque which is greater than the torque on a circular loop made of the same wire carrying the same current in the same magnetic field.

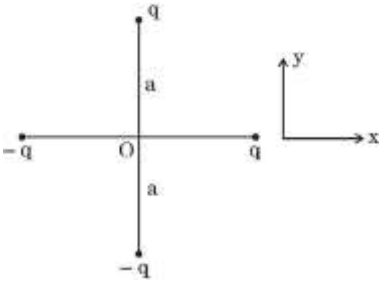
Reason (R) : A square loop occupies more area than a circular loop, both made of wire of the same length.

123. Assertion (A) : In ' n ' type semiconductor, number density of electrons is greater than the number density of holes but the crystal maintains an overall charge neutrality.

Reason (R) : The charge of electrons donated by donor atoms is just equal and opposite to that of the ionised donor.

SECTION B

124. Two identical dipoles are arranged in $x-y$ plane as shown in the figure. Find the magnitude and the direction of net electric field at the origin O .



125. Write two differences between the emf and terminal potential difference of a cell. What is the most important precaution that one should take while drawing current from a cell ?

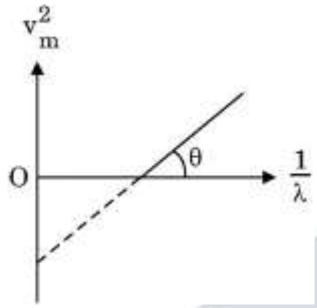
126. A small magnetised needle P is placed at the origin of x - y plane with its magnetic moment pointing along the y -axis. Another identical magnetised needle Q is placed in two positions, one by one.
Case 1: at (a,0) with its magnetic moment pointing along x -axis.
Case 2 : at (0, a) with its magnetic moment pointing along y -axis.
(A) In which case is the potential energy of P and Q minimum?
(B) In which case is P and Q not in equilibrium?
Justify your answers.

127. **(A)** What is a displacement current ?
How is it different from a conduction current ?

OR

(B) Write any two characteristics of an electromagnetic wave. Why are microwaves used in radar systems ?

128. The figure shows v_m^2 versus $\frac{1}{\lambda}$ graph for photoelectrons emitted from a surface where v_m is the maximum speed of electrons and λ is the wavelength of incident radiation. Using this graph and Einstein's photoelectric equation, obtain the expression for Planck's constant and work function of the surface.



129. Draw the graph showing the variation of binding energy per nucleon with mass number A of nuclei ($2 < A < 170$). Use this graph to explain the release of energy in nuclear fission.

130. **(A)** Obtain an expression for electrostatic potential energy of a system of three charges q, 2q and -3 q placed at the vertices of an equilateral triangle of side a.

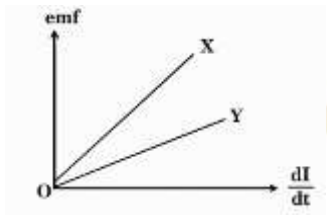
OR

(B) Two small conducting balls A and B of radius r_1 and r_2 have charges q_1 and q_2 respectively. They are connected by a wire.Obtain the expression for charges on A and B , in equilibrium.

SECTION C

131. Two circular loops A and B, each of radius 3 m, are placed coaxially at a distance of 4 m . They carry currents of 3 A and 2 A in opposite directions respectively. Find the net magnetic field at the centre of loop A.

132. **(A)** The figure shows the variation of induced emf as a function of rate of change of current for two identical solenoids X and Y. One is air cored and the other is iron cored. Which one of them is iron cored ? Why?



(B) Obtain an expression for self-inductance of a long solenoid of length L and cross-sectional area A having N turns.

133. **(A)** A resistor of 30Ω and a capacitor of $\frac{250}{\pi}\mu$ F are connected in series to a 200 V, 50 Hz ac source. Calculate (i) the current in the circuit, and (ii) voltage drops across the resistor and the capacitor. (iii) Is the algebraic sum of these voltages more than the source voltage? If yes, solve the paradox.

OR

(B) A series LCR circuit with $R = 20\Omega$, $L = 2H$ and $C = 50\mu$ F is connected to a 200 volts ac source of variable frequency. What is (i) the amplitude of the current, and (ii) the average power transferred to the circuit in one complete cycle, at resonance? (iii) Calculate the potential drop across the capacitor.

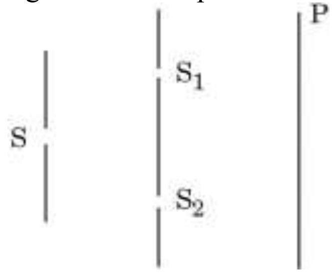
134. **(A)** **(i)** In diffraction due to a single slit, the phase difference between light waves reaching a point on the screen is 5π. Explain whether a bright or a dark fringe will be formed at the point.

(ii) What should the width (a) of each slit be to obtain eight maxima of two double-slit patterns (slit separation d) within the central maximum of the single slit pattern?

(iii) Draw the plot of intensity distribution in a diffraction pattern due to a single slit.

OR

(B) (i) In a Young's double-slit experiment $SS_2 - SS_1 = \frac{\lambda}{4}$, where S_1 and S_2 are the two slits as shown in the figure. Find the path difference $(S_2P - S_1P)$ for constructive and destructive interference at P.



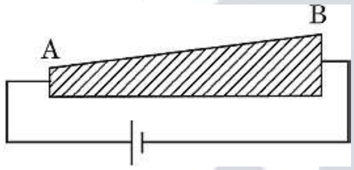
(ii) What is the effect on the interference fringes in a Young's double-slit experiment, if the monochromatic source S is replaced by a source of white light ?

135. Briefly explain Geiger-Marsden experiment. Show the variation of the number of particles scattered (N) with scattering angle (θ) in this experiment. What is the main conclusion that can be inferred from this plot?

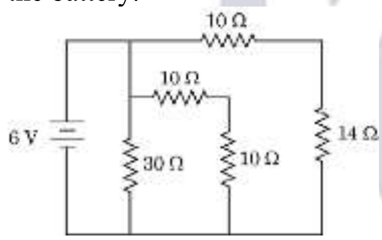
SECTION D

136. **(A) (i)** Define mobility of electrons. Give its SI units.

(ii) A steady current flows through a wire AB , as shown in the figure. What happens to the electric field and the drift velocity along the wire? Justify your answer.



(iii) Consider the circuit shown in the figure. Find the effective resistance of the circuit and the current drawn from the battery.

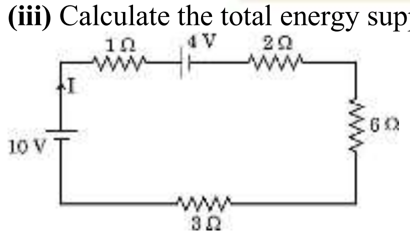


OR

(B) (i) Define electrical conductivity of a wire. Give its SI unit.

(ii) High current is to be drawn safely from (1) a low-voltage battery, and (2) a high-voltage battery. What can you say about the internal resistance of the two batteries?

(iii) Calculate the total energy supplied by the batteries to the circuit shown in the figure, in one minute.



137. **(A) (i)** Draw a ray diagram to show how the final image is formed at infinity in an astronomical refracting telescope. Obtain an expression for its magnifying power.

(ii) Two thin lenses L_1 and L_2, L_1 being a convex lens of focal length 24 cm and L_2 a concave lens of focal length 18 cm are placed coaxially at a separation of 45 cm . A 1 cm tall object is placed in front of the lens L_1 at a distance of 36 cm . Find the location and height of the image formed by the combination.

OR

(B) (i) Explain the working principle of an optical fibre with the help of a diagram. Mention one use of a light pipe.

(ii) A ray of light is incident at an angle of 60° on one face of a prism with the prism angle $A = 60°$. The ray passes symmetrically through the prism. Find the angle of minimum deviation (δ_m) and refractive index of the material of the prism. If the prism is immersed in water, how will δ_m be affected? Justify your answer.

138. **(A) (i)** A germanium crystal is doped with antimony. With the help of energy-band diagram, explain how the conductivity of the doped crystal is affected.

(ii) Briefly explain the two processes involved in the formation of a p-n junction.

(iii) What will the effect of (1) forward biasing, and (2) reverse biasing be on the width of depletion layer in a p-n junction diode?

OR

(B) (i) With the help of a circuit diagram, briefly explain the working of a full-wave rectifier using p-n junction diodes.

(ii) Draw V - 1 characteristics of a p-n junction diode. Explain how these characteristics make a diode suitable for rectification.

(iii) Carbon and silicon have the same lattice structure. Then why is carbon an insulator but silicon a semiconductor?

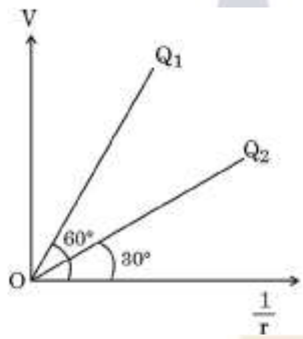
SECTION E

139. Electrostatics deals with the study of forces, fields and potentials arising from static charges. Force and electric field, due to a point charge is basically determined by Coulomb's law. For symmetric charge configurations, Gauss's law, which is also based on Coulomb's law, helps us to find the electric field. A charge/a system of charges like a dipole experience a force/torque in an electric field. Work is required to be done to provide a specific orientation to a dipole with respect to an electric field.

Answer the following questions based on the above :

(A) Consider a uniformly charged thin conducting shell of radius R . Plot a graph showing the variation of $|\vec{E}|$ with distance r from the centre, for points $0 \leq r \leq 3R$.

(B) The figure shows the variation of potential V with $\frac{1}{r}$ for two point charges Q_1 and Q_2, where V is the potential at a distance r due to a point charge. Find $\frac{Q_1}{Q_2}$.



(C) An electric dipole of dipole moment of $6 \times 10^{-7} C - m$ is kept in a uniform electric field of 10^4 N/C such that the dipole moment and the electric field are parallel. Calculate the potential energy of the dipole.

OR

(C) An electric dipole of dipole moment $\vec{p}$ is initially kept in a uniform electric field $\vec{E}$ such that $\vec{p}$ is perpendicular to $\vec{E}$. Find the amount of work done in rotating the dipole to a position at which $\vec{p}$ becomes antiparallel to $\vec{E}$.

140. The lens maker's formula is useful to design lenses of desired focal lengths using surfaces of suitable radii of curvature. The focal length also depends on the refractive index of the material of the lens and the surrounding medium. The refractive index depends on the wavelength of the light used. The power of a lens is related to its focal length.

Answer the following questions based on the above:

(A) How will the power of a lens be affected with an increase of wavelength of light ?

(B) The radius of curvature of two surfaces of a convex lens is R each. For what value of μ of its material will its focal length become equal to R ?

(C) The focal length of a concave lens of $\mu = 1.5$ is 20 cm in air. It is completely immersed in water of $\mu = \frac{4}{3}$. Calculate its focal length in water.

OR

(C) An object is placed in front of a lens which forms its erect image of magnification 3. The power of the lens is 5 D . Calculate the distance of the object and the image from the lens.

General Instructions :

Read the following instructions very carefully and strictly follow them:

(i) This question paper contains 35 questions. All questions are compulsory.
(ii) This question paper is divided into five Sections $-$A, B, C, D and E.
(iii) In Section A - Questions no. 1 to 18 are Multiple Choice (MCQ) type questions, carrying 1 mark each.
(iv) In Section B - Questions no. 19 to 25 are Very Short Answer (VSA) type questions, carrying 2 marks each.
(v) In Section C - Questions no. 26 to 30 are Short Answer (SA) type questions, carrying 3 marks each.
(vi) In Section D - Questions no. 31 to 33 are Long Answer (LA) type questions carrying 5 marks each.
(vii) In Section E - Questions no. 34 and 35 are case-based questions carrying 4 marks each.
(viii) There is no overall choice. However, an internal choice has been provided in 2 questions in Section B, 2 questions in Section C, 3 questions in Section D and 2 questions in Section E.
(ix) Use of calculators is not allowed.

Use the following values of physical constants, if required:

$c = 3 \times 10^8 \text{ m/s}$
$h = 6.63 \times 10^{-34} \text{Js}$
$e = 1.6 \times 10^{-19} \text{C}$
$\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$
$\varepsilon_0 = 8.854 \times 10^{-12} \text{C}^2 \text{ N}^{-1} \text{ m}^{-2}$
$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N m}^2\text{C}^{-2}$
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

141. An electric dipole of length 2 cm is placed at an angle of 30° with an electric field 2×10^5 N/C. If the dipole experiences a torque of 8×10^{-3}Nm, the magnitude of either charge of the dipole, is

(a) 4μC (b) 7μC
(c) 8 mC (d) 2 mC

142. Two long parallel wires kept 2 m apart carry 3A current each, in the same direction. The force per unit length on one wire due to the other is

(a) $4.5 \times 10^{-5} \text{Nm}^{-1}$, attractive
(b) 4.5×10^{-7} N/m, repulsive
(c) 9×10^{-7} N/m, repulsive
(d) 9×10^{-5} N/m, attractive

143. Which of the following has its permeability less than that of free space?

(a) Copper (b) Aluminium
(c) Copper chloride (d) Nickel

144. A square shaped coil of side 10 cm , having 100 turns is placed perpendicular to a magnetic field which is increasing at 1 T/s. The induced emf in the coil is

(a) 0.1 V (b) 0.5 V
(c) 0.75 V (d) 1.0 V

145. Which one of the following electromagnetic radiation has the least wavelength ?

(a) Gamma rays (b) Microwaves
(c) Visible light (d) X-rays

146. In a Young's double-slit experiment, the screen is moved away from the plane of the slits. What will be its effect on the following?

(i) Angular separation of the fringes.

(ii) Fringe-width.

(a) Both (i) and (ii) remain constant.

(b) (i) remains constant, but (ii) decreases.

(c) (i) remains constant, but (ii) increases.

(d) Both (i) and (ii) increase.

147. The energy of a photon of wavelength λ is

(a) hc λ (b) hc/λ

(c) λ/hc (d) $\lambda h/c$

148. The ratio of the nuclear densities of two nuclei having mass numbers 64 and 125 is

(a) $\frac{64}{125}$ (b) $\frac{4}{5}$

(c) $\frac{5}{4}$ (d) 1

149. During the formation of a p-n junction :

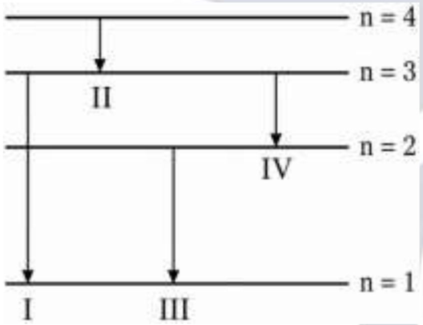
(a) diffusion current keeps increasing.

(b) drift current remains constant.

(c) both the diffusion current and drift current remain constant.

(d) diffusion current remains almost constant but drift current increases till both currents become equal.

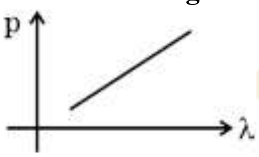
150. The diagram shows four energy level of an electron in Bohr model hydrogen atom. Identify the transition in which the emitted photon wil have the highest energy.

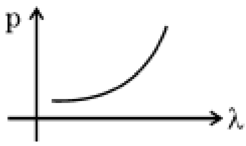


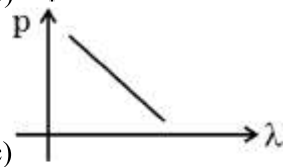
(a) I (b) II

(c) III (d) IV

151. Which of the following graphs correctly represents the variation of a particle momentum with its associated de-Broglie wavelength ?

(a)


(b)


(c)


(d)


152. The capacitors, each of 4μ F are to be connected in such a way that the effective capacitance of the combination is 6μ F. This can be achieved by connecting

(a) All three in parallel
(b) All three in series
(c) Two of them connected in series and the combination in parallel to the third.
(d) Two of them connected in parallel and the combination in series to the third.

153. Which of the following statements about a series LCR circuit connected to an ac source is correct?

(a) If the frequency of the source is increased, the impedance of the circuit first decreases and then increases.
(b) If the net reactance $(X_L - X_C)$ of circuit becomes equal to its resistance, then the current leads the voltage by $45°$.
(c) At resonance, the voltage drop across the inductor is more than that across the capacitor.
(d) At resonance, the voltage drop across the capacitor is more than that across the inductor.

154. According to Huygens principle, the amplitude of secondary wavelets is

(a) equal in both the forward and the backward directions.
(b) maximum in the forward direction and zero in the backward direction.
(c) large in the forward direction and small in the backward direction.
(d) small in the forward direction and large in the backward direction.

155. The radius of the n^{th} orbit in Bohr model of hydrogen atom is proportional to

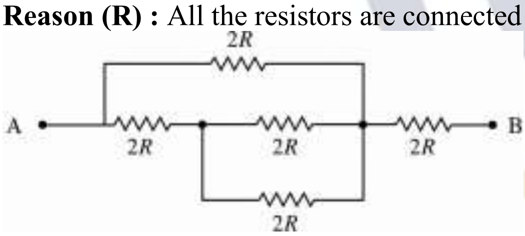
(a) n^2 (b) $\frac{1}{n^2}$
(c) n (d) $\frac{1}{n}$

Note: In question number 16 to 18 two statements are given - one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

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

156. Assertion (A) : The resistance of an intrinsic semiconductor decreases with increase in its temperature.
Reason (R) : The number of conduction electrons as well as hole increase in an intrinsic semiconductor with rise in its temperature.

157. Assertion (A) : The equivalent resistance between points A and B in the given network is 2 R .
Reason (R) : All the resistors are connected in parallel



158. Assertion (A) : The deflecting torque acting on a current carrying loop is zero when its plane is perpendicular to the direction of magnetic field.
Reason (R) : The deflecting torque acting on a loop of magnetic moment $\vec{m}$ in a magnetic field $\vec{B}$ is given by the dot product of $\vec{m}$ and $\vec{B}$.

SECTION-B

159. Draw a graph showing the variation of potential energy of a pair of nucleons as a function of their separation. Indicate the region in which the nuclear force is **(a)** attractive and **(b)** repulsive.

160. (A) How will the De Broglie wavelength associated with an electron be affected when the **(i)** velocity of the electron decreases ? and **(ii)** accelerating potential is increased ? Justify your answer.

OR

(B) How would the stopping potential for a given photosensitive surface change if **(i)** the frequency of the incident radiation were increased ? and **(ii)** the intensity of incident radiation were decreased ? Justify your answer.

161. Identify the electromagnetic wave whose wavelengths range is from about

(A) 10^{-12} m to about 10^{-8} m.

(B) 10^{-3} m to about 10^{-1} m.

Write one use of each.

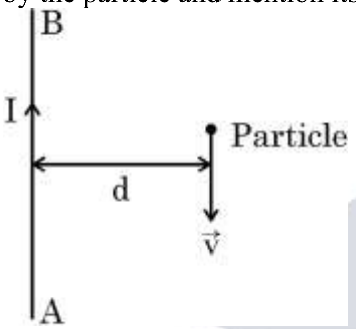
162. Depict the orientation of an electric dipole in **(a)** stable and **(b)** unstable equilibrium in an external uniform electric field.

Write the potential energy of the dipole in each case.

163. **(A)** Write the expression for the Lorentz force on a particle of charge q moving with a velocity $\vec{v}$ in a magnetic field $\vec{B}$. When is the magnitude of this force maximum ? Show that no work is done by this force on the particle during its motion from a point $\vec{r}_1$ to point $\vec{r}_2$.

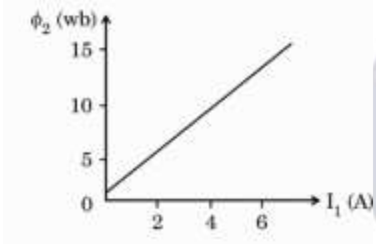
OR

(B) A long straight wire AB carries a current I . A particle (mass m and charge q) moves with a velocity $\vec{V}$, parallel to the wire, at a distance d from it as shown in the figure. Obtain the expression for the force experienced by the particle and mention its directions.



164. The potential difference applied across a given conductor is doubled. How will this affect **(i)** the mobility of electrons and **(ii)** the current density in the conductor? Justify your answers.

165. Two coils C_1 and C_2 are placed close to each other. The magnetic flux ϕ_2 linked with the coil C_2 varies with the current I_1 flowing in coil C_1, as shown in the figure. Find



(i) the mutual inductance of the arrangement, and

(ii) the rate of change of current $\left(\frac{dI_1}{dt}\right)$ that will induce an emf of 100 V in coil C_2.

SECTION-C

166. **(A)** A plane wave-front propagating in a medium of refractive index ' μ_1 ' is incident on a plane surface making an angle of incidence (i). It enters into a medium of refractive index $\mu_2(\mu_2 > \mu_1)$.

Use Huygen's construction of secondary wavelets to trace the retracted wave-front. Hence verify Snell's law of refraction.

OR

(B) Using Huygen's construction, show how a plane wave is reflected from a surface. Hence verify the law of reflection.

167. An alternating voltage of 220 V is applied across a device X . A current of 0.22 A flows in the circuit and it lags behind the applied voltage in phase by $\pi/2$ radian. When the same voltage is applied across another device Y , the current in the circuit remains the same and it is in phase with the applied voltage.

(i) Name the devices X and Y and,

(ii) Calculate the current flowing in the circuit when the same voltage is applied across the series combination of X and Y .

168. State the basic principle behind the working of an ac generator. Briefly describe its working and obtain the expression for the instantaneous value of emf induced.

169. **(A)** Briefly describe how the current sensitivity of a moving coil galvanometer can be increased.

(B) A galvanometer shows full scale deflection for current I_g. A resistance R_1 is required to convert it into a voltmeter of range ($0 - V$) and a resistance R_2 to convert it into a voltmeter of range $(0 - 2\text{ V})$. Find the resistance of the galvanometer.

170. **(A) (i)** Differentiate between 'distance of closest approach' and 'impact parameter'.

(ii) Determine the distance of closest approach when an alpha particle of kinetic energy 3.95 MeV approaches a nucleus of $Z = 79$, stops and reverses its directions.

OR

(B) (i) State three postulates of Bohr's theory of hydrogen atom.

(ii) Find the angular momentum of an electron revolving in the second orbit in Bohr's hydrogen atom.

SECTION – D

171. **(A) (i)** Explain how free electrons in a metal at constant temperature attain an average velocity under the action of an electric field. Hence obtain an expression for it.

(ii) Consider two conducting wires A and B of the same diameter but made of different materials joined in series across a battery. The number density of electrons in A is 1.5 times that in B . Find the ratio of drift velocity of electrons in wire A to that in wire B.

OR

(B) (i) A cell emf of (E) and internal resistance (r) is connected across a variable load resistance (R). Draw plots showing the variation of terminal voltage V with (1) R and (2) the current (I) in the load.

(ii) Three cells, each of emf E but internal resistances $2r, 3r$ and 6 r are connected in parallel across a resistor R. Obtain expressions for (1) current flowing in the circuit, and (2) the terminal potential difference across the equivalent cell.

172. **(A)** Draw the circuit arrangement for studying V-I characteristics of a p-n junction diode in **(i)** forward biasing and **(ii)** reverse biasing. Draw the typical V-I characteristics of a silicon diode. Describe briefly the following terms: (1) minority carrier injection in forward biasing and (2) breakdown voltage in reverse biasing.

OR

(B) Name two important processes involved in the formation of a p-n junction diode. With the help of a circuit diagram, explain the working of junction diode as a full wave rectifier. Draw its input and output waveforms. State the characteristic property of a junction diode that makes it suitable for rectification.

173. **(A) (i)** Draw a ray diagram to show the working of a compound microscope. Obtain the expression for the total magnification for the final image to be formed at the near point.

(ii) In a compound microscope an object is placed at a distance of 1.5 cm from the objective of focal length 1.25 cm. If the eye-piece has a focal length of 5 cm and the final image is formed at the near point, find the magnifying power of the microscope.

OR

(B) (i) Draw a ray diagram for the formation of image of an object by an astronomical telescope, in normal adjustment. Obtain the expression for its magnifying power.

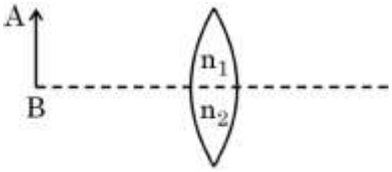
(ii) The magnifying power of an astronomical telescope in normal adjustment is 2.9 and the objective and the eyepiece are separated by a distance of 150 cm . Find the focal lengths of the two lenses.

SECTION – E

Note : Questions number 34 and 35 are Case Study based questions. Read the following paragraph and answer the questions.

174. A lens is a transparent optical medium bounded by two surfaces; at least one of which should be spherical. Considering image formation by a single spherical surface successively at the two surfaces of a lens, lens maker's formula is obtained. It is useful to design lenses of desired focal length using surfaces of suitable radii of curvature. This formula helps us obtain a relation between u, v and f for a lens. Lenses form images of objects and they are used in a number of optical devices, for example microscopes and telescopes.

(i) An object AB is kept in front of a composite convex lens, as shown in figure. Will the lens produce one image ? If not, explain.



(ii) A real image of an object formed by a convex lens is observed on a screen. If the screen is removed, will the image still be formed ? Explain.

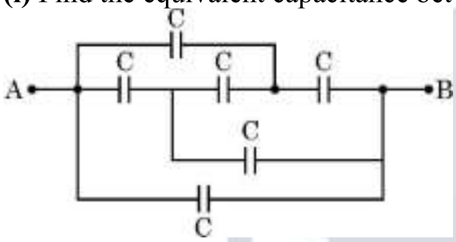
(iii) A double convex lens is made of glass of refractive index 1.55 with both faces of the same radius of curvature. Find the radius of curvature required if focal length is 20 cm .

OR

(iii) Two convex lenses A and B of focal lengths 15 cm and 10 cm respectively are placed coaxially 'd' distance apart. A point object is kept at a distance of 30 cm in front of lens A. Find the value of ' d ' so that the rays emerging from lens B are parallel to its principal axis.

175. A capacitor is a system of two conductors separated by an insulator. The two conductors have equal and opposite charges with a potential difference between them. The capacitance of a capacitor depends on the geometrical configuration (shape, size and separation) of the system and also on the nature of the insulator separating the two conductors. They are used to store charges. Like resistors, capacitors can be arranged in series or parallel or a combination of both to obtain desired value of capacitance.

(i) Find the equivalent capacitance between points A and B in the given diagram.

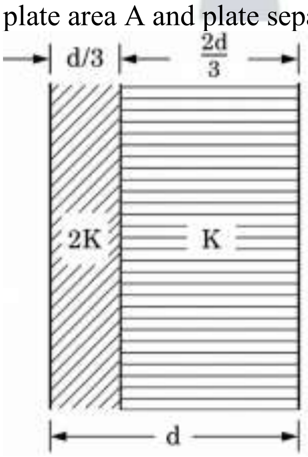


(ii) A dielectric slab is inserted between the plates of a parallel plate capacitor. The electric field between the plates decreases. Explain.

(iii) A capacitor A of capacitance C , having charge Q is connected across another uncharged capacitor B of capacitance 2 C . Find an expression for (a) the potential difference across the combination and (b) the charge lost by capacitor A .

OR

(iii) Two slabs of dielectric constants 2 K and K fill the space between the plates of a parallel plate capacitor of plate area A and plate separation d as shown in figure. Find an expression for capacitance of the system.



General Instructions :

Read the following instructions very carefully and strictly follow them:

(i) This question paper contains 35 questions. All questions are compulsory.

(ii) This question paper is divided into five Sections $-$A, B, C, D and E.

(iii) In Section A - Questions no. 1 to 18 are Multiple Choice (MCQ) type questions, carrying 1 mark each.

(iv) In Section B - Questions no. 19 to 25 are Very Short Answer (VSA) type questions, carrying 2 marks each.

(v) In Section C - Questions no. 26 to 30 are Short Answer (SA) type questions, carrying 3 marks each.

(vi) In Section D - Questions no. 31 to 33 are Long Answer (LA) type questions carrying 5 marks each.

(vii) In Section E - Questions no. 34 and 35 are case-based questions carrying 4 marks each.

(viii) There is no overall choice. However, an internal choice has been provided in 2 questions in Section B, 2 questions in Section C, 3 questions in Section D and 2 questions in Section E.
(ix) Use of calculators is not allowed.
Use the following values of physical constants, if required:
$c = 3 \times 10^8$ 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

176. The charge on a body is 8×10^{-12}C. It means that the body has:
(a) lost 8×10^{-12} electrons
(b) gained 4×10^{10} electrons
(c) gained 2×10^8 electrons
(d) lost 5×10^7 electrons

177. A current flows through a series combination of two copper wires of equal length but their radii are in the ratio of 1: 2. The ratio of drift velocities of free electrons in the wires will be:
(a) 8 (b) 4
(c) 2 (d) 1

178. A charged particle at rest is subjected to an external magnetic field $\vec{B}$. If no other force acts on the particle, then it will :
(a) accelerate along $\vec{B}$
(b) remain at rest
(c) move in a circular path
(d) move with a constant speed along $\vec{B}$

179. The magnetic flux (in SI units) through a coil varies with time as $\phi = 3t^2 + 4t + 7$. The ratio of emf induced in the coil at $t = 2$ s to that at $t = 1$ s will be:
(a) 2 (b) 0.8
(c) 1.6 (d) 4

180. A current carrying loop is placed in a uniform magnetic field. The torque acting on it does not depend upon the :
(a) magnetic field (b) current in the loop
(c) area of the loop (d) shape of the loop

181. Two identical coils carrying equal currents are held concentric with their planes perpendicular to each other. The ratio of the magnitude of magnetic field at the centre of one coil to that of the resultant magnetic field at the centre is:
(a) $\frac{1}{\sqrt{2}}$ (b) $\sqrt{2}$
(c) $\frac{1}{2}$ (d) 2

182. An electron is revolving around a nucleus in a circular orbit of radius r with a constant speed v. The magnetic moment associated with the circulating current is:

(a) $\frac{\text{evr}}{4}$ (b) 4 evr

(c) 2 evr (d) $\frac{\text{evr}}{2}$

183. Which of the following statements is not correct ?

(a) Lenz's law is the consequence of the law of conservation of energy.

(b) The magnitude of induced emf in a coil is directly proportional to the rate of change of magnetic flux.

(c) Inserting an iron core in a coil decreases its self-inductance.

(d) An emf can be induced in a straight conductor by moving it perpendicularly through a uniform magnetic field.

184. In a plane electromagnetic wave, the magnetic field oscillates sinusoidally with a frequency of 3×10^{10} Hz, and amplitude 2.4×10^{-8} T. The amplitude of the oscillating electric field is :

(a) $1.6 \mathrm{Vm}^{-1}$ (b) $3 \cdot 2 \mathrm{Vm}^{-1}$

(c) $7 \cdot 2 \mathrm{Vm}^{-1}$ (d) $8 \mathrm{Vm}^{-1}$

185. An object is placed at a distance of 10 cm in front of a concave mirror of radius of curvature 15 cm . The nature and position the image formed is :

(a) real and inverted, 30 cm in front of the mirror

(b) real and inverted, 15 cm in front of the mirror

(c) virtual and erect, 30 cm behind the mirror

(d) virtual and erect, 15 cm behind the mirror

186. The energy of a photon in a beam of red light with a wavelength of 6.60×10^{-7} m is close to :

(a) 4.42×10^{-19} J (b) 4.0×10^{-19} J

(c) 2.19×10^{-19} J (d) 3.0×10^{-19} J

187. A photon absorbed by a hydrogen atom excites it from $\mathrm{n} = 3$ level to $n = 5$ level. The energy of the photon is :

(a) $+0.97$eV (b) -0.97 eV

(c) +1.51 eV (d) -0.54 eV

188. The number of neutrons in $^{237}_{91}$ Pa is:

(a) 91 (b) 146

(c) 237 (d) 164

189. Which of the following is not a semiconductor?

(a) Ge (b) Si

(c) Sn (d) CdS

190. In an intrinsic semiconductor, the intrinsic carrier concentration ($\mathrm{n_i}$), electron concentration ($\mathrm{n_e}$) and hole concentration (n_h) are related as :

(a) $n_e + n_h = n_i$ (b) $n_i = \sqrt{n_e n_h}$

(c) $n_e = n_h = n_i$ (d) $n_e + n_h = \frac{n_i}{2}$

Questions number 16 to 18 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.

191. Assertion (A) : The speed of light decreases when it passes from air into a denser medium.

Reason ($\boldsymbol{R}$) : The speed of light in a denser medium is given by $v = \frac{c}{\mu}$, where c is the speed of light in air and μ is the refractive index of the denser medium.

192. Assertion (A) : Silicon is preferred over Germanium for making semiconductor devices.

Reason ($\boldsymbol{R}$) : Silicon can be used at a higher temperature as compared to Germanium.

193. **Assertion (A) :** The energy (E) and momentum (p) of a photon are related as $p=\frac{h}{E}$.

Reason $(\boldsymbol{R})$ **:** Photons behave as a wave.

SECTION B

194. The terminal potential difference of a cell is 19 V when a current of 1.0 A flows in the circuit. It reduces to 17 V when the current supplied by the cell is 3.0 A . Find the emf and internal resistance of the cell.

195. **(A)** What is meant by displacement current ? Explain. Give an example where such current exists.

OR

(B) Write the wavelength range of infrared waves. Why are these waves often called 'heat waves'? Explain.

196. A glass jug is filled with water to a height of 9.6 cm . The depth of a coin lying on its bottom as measured by a microscope is 7.2 cm . Find the refractive index of the water and the speed of light in water.

197. A convex lens is made of the material of refractive index n_1. What will happen if it were immersed in a medium of refractive index n_2 in the following cases?

(A) $n_2>n_1$

(B) $\mathrm{n}_2=\mathrm{n}_1$

198. State Bohr's postulates of hydrogen atom. How is a photon emitted by an excited hydrogen atom ?

199. **Define the following terms in relation to the working of a p-n junction diode :**

(i) Knee voltage

(ii) Reverse saturation current

200. **(A)** How are the potential barrier and width of the depletion region affected when a p-n junction diode is **(i)** forward-biased, and **(ii)** reverse-biased ?

OR

(B) Briefly explain doping of a semiconductor and its necessity.

201. Name the factors on which electrical conductivity of a material depends. Obtain the relation between current density in a conductor and the conductivity of its material.

202. **(A) (i)** Differentiate between the resistance and reactance of a series LCR circuit.

(ii) Explain how a capacitor blocks a direct current and an inductor opposes an alternating current.

OR

(B) Show mathematically that in an ac circuit containing a pure inductor, the current lags behind the voltage in phase by $\frac{\pi}{2}$.

203. Define the term 'self-inductance' of a coil. Obtain the expression for the self-inductance of a long solenoid of length l, cross-sectional area A and having N turns.

204. Briefly explain how Einstein's photoelectric equation accounts for all observations on photoelectric effect.

205. **(A)** Explain two main features of the plot of the binding energy per nucleon versus the mass number of the nuclei. Mention two conclusions that can be drawn from these features.

OR

(B) Briefly explain the observations made in Geiger-Marsden experiment. Write the important conclusions drawn about the structure of atom from these observations.

206. **(A) (i)** What is an electric dipole ? Derive an expression for the torque acting on an electric dipole in a uniform electric field.

(ii) An electric dipole with dipole moment 6×10^{-9}C-m is aligned at an angle of 30° with the direction of a uniform electric field of magnitude $4\times10^{4}\mathrm{NC}^{-1}$. Calculate magnitude of the torque acting on the electric dipole.

OR

(B) (i) State Gauss's law in electrostatics. Using it, derive an expression for the electric field due to a uniformly charged thin spherical shell of radius R at a point (1) outside, and (2) inside the shell.

(ii) A point charge of 4μC is at the centre of a cubic Gaussian surface, 1.0 m on edge. Find the electric flux through one of the faces of the Gaussian surface.

207. **(A) (i)** Two long parallel straight conductors carrying current I_1 and I_2 are kept r distance apart in air. Obtain an expression for the force per unit length on one conductor due to the magnetic field produced by the other conductor. Hence, define one ampere. Under what condition will the force between the conductors be attractive in nature?

(ii) A closely wound circular coil of radius 6.28 cm , having 50 turns carries a steady current of 4 A . Find the magnetic field at the centre of the coil. How will the magnitude of the magnetic field be affected if the radius of the coil is halved keeping other factors same?

OR

(B) (i) A particle of mass m and charge q , at the origin moves with a velocity $\vec{v}$ in xy-plane making an angle θ with x -axis. It is subjected to a uniform magnetic field $\vec{B}$ along x -axis. Justify that the particle will move in a helical path. Hence, obtain expression for the radius of the helix.

(ii) A long straight wire kept horizontally carries a current of 4 A from west to east direction. Find the direction and magnitude of magnetic field $\vec{B}$ at a point 20 cm below the wire.

208. **(A) (i)** What is meant by total internal reflection of light ? Write the two conditions necessary for this phenomenon to occur. Briefly explain one of its technological applications.

(ii) A thin converging lens of focal length 10 cm is placed coaxially in contact with a thin diverging lens of focal length 15 cm . Find the nature and focal length of the combined lens.

OR

(B) (i) Answer the following giving reasons:

(1) The angular size of the image equals the angular size of the object in a simple microscope, yet it offers magnification.

(2) Both the objective and the eyepiece of a compound microscope have short focal lengths.

(3) A microscope and a telescope play different roles with respect to resolution and magnification of the image.

(ii) In Young's double-slit experiment, the two slits are 1.0 mm apart. They are illuminated with light of wavelength 600 nm . Find the fringe width on a screen 2.0 m away from the slits.

SECTION E

209. After centuries of efforts, careful studies, experiments and analysis by different scientists, it was concluded that there are two kinds of entities called the electric charge. The property which differentiates the two kinds is called the polarity of charge. The two kinds of charges were named as positive (+) and negative (-) by American scientist Benjamin Franklin.

A small sphere S_1 with charge $-8q$ is 1.6 m away from another identical sphere S_2 with charge $+2q$. The two spheres are brought in contact with each other and then separated by a distance 1.6 m . Initially the force between the two spheres was 8.1×10^{-4} N.

Based on the above facts, answer the following questions:

(i) Which sphere will transfer the electrons to the other sphere after they were brought in contact ?

(ii) How does the net electric field at the midpoint on the line joining the two spheres change after contact?

(iii) What was initial charge on spheres S_1 and S_2 ?

OR

(iii) What is the charge on spheres S_1 and S_2 after contact?

210. Diffraction of light : According to rectilinear propagation of light, light travels in a straight line. But Italian scientist Grimaldi discovered that light bends near the edges of the aperture of the obstacles whose size is comparable with the wavelength of light. This phenomenon of bending of light around the corners of an obstacle is called diffraction of light. If we place a screen in front of the slit, the diffraction pattern observed on it is of unequal widths and unequal intensities. The diffraction phenomenon can be explained on the basis of wave nature of light.

Based on the above facts, answer the following questions:

(i) What is the most essential condition for observing diffraction?

(ii) Which characteristic of light is used in X-ray crystallography?

(iii) How does the wave theory of light provide an explanation for diffraction? Explain.

OR

(iii) In a single slit diffraction, if red light is replaced by blue light, then how does the diffraction pattern change ?