General Instructions :

Read the following instructions carefully and follow them:

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

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

$c = 3 \times 10^8$ m/s
$h = 6.63 \times 10^{-34}$ Js
$e = 1.6 \times 10^{-19}$ C
$\mu_0 = 4\pi \times 10^{-7}$ TmA^{-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. Three point charges $2q, -2q$ and q are kept at the vertices of an equilateral triangle of side l. The potential energy of the system is

(a) zero (b) $\frac{-2q^2}{\pi\varepsilon_0 l}$
(c) $\frac{q^2}{2\pi\varepsilon_0 l}$ (d) $\frac{-q^2}{\pi\varepsilon_0 l}$

2. Two metal spheres of radii r_1 and $r_2(> r_1)$ having charges q_1 and q_2 respectively kept in air, are brought in contact. Which of the following statements is not correct?

(a) The total charge of the two spheres is conserved.
(b) Both spheres attain the same potential.
(c) The final potential of the system equals $\frac{1}{4\pi\varepsilon_0}\frac{(q_1+q_2)}{(r_1+r_2)}$
(d) The final potential of the system equals $\frac{1}{4\pi\varepsilon_0}\frac{(q_1+q_2)(r_1+r_2)}{r_1 r_2}$

3. The maximum kinetic energy of the electrons emitted from a photo sensitive surface depends on

(a) work function of the surface ' ϕ_0 ' only.
(b) frequency of the incident radiation ' v ' only.
(c) intensity of the incident radiation ' T ' only.
(d) Both ϕ_0 and v.

4. In Bohr model of hydrogen atom, for large values of n, the distance between the consecutive orbits is proportional to

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

5. A straight long wire lying along y-axis, carries a current of 1 A along -y direction. The magnetic field due to the conductor at a point $(50\text{ cm}, 0, 0)$ will point along.

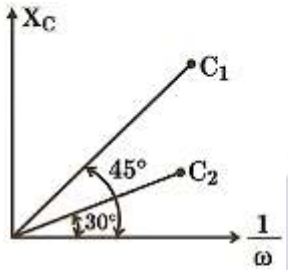
(a) z-axis (b) -z-axis
(c) x-axis (d) $-$x-axis

6. **Which of the following materials has positive and small value of magnetic susceptibility?**
(a) Cu (b) Al
(c) Bi (d) Ni

7. **A galvanometer of resistance 27Ω is converted into an ammeter of range $(0-10\text{ mA})$ using a resistance of 3Ω. The galvanometer will show full scale deflection for a current of about -**
(a) 10 mA (b) 100 mA
(c) 1 mA (d) 3 mA

8. **The magnetic flux ϕ (in Wb) linked with a coil is related to time t (in s) as $\phi = 5At^2 + Bt - 2C$. The SI units of A and B are respectively**
(a) Wbs^2, Wbs (b) Wbs^{-1}, Wb
(c) Wbs^{-2}, Wbs^{-1} (d) Wbs^{-1}, Wbs^{-2}

9. **The figure shows the variation of capacitive reactance (X_C) of two ideal capacitors of capacitances C_1 & C_2 with the reciprocal of angular frequency $(1/\omega)$ of ac source. The value of C_1/C_2 is**



(a) $\frac{1}{2}$ (b) 2
(c) $\sqrt{3}$ (d) $\frac{1}{\sqrt{3}}$

10. **A magnet held vertically, with its north pole down is dropped along the axis of a closed solenoid placed vertically on a table. If the observer looks down from the top,**
(a) the induced current will flow in the anticlockwise direction.
(b) the induced current will flow in the clockwise direction.
(c) no induced current will flow in the solenoid.
(d) the magnet will fall with a constant velocity.

11. **An electromagnetic wave is propagating along x-axis. At any instant, the phase difference (in radian) between the electric field ($\vec{E}$) and the magnetic field ($\vec{B}$) associated with the wave is**
(a) zero (b) $\frac{\pi}{4}$
(d) $\frac{\pi}{2}$ (d) π

12. **In Bohr model of hydrogen atom, the electron makes a transition from $n = 5$ to $n = 1$ state. As a result, a photon of wavelength λ is emitted in the process. The wavelength of the photon emitted when an electron makes a transition from energy level $n = 5$ to $n = 2$ will be**
(a) $\frac{8}{7}\lambda$ (b) $\frac{24}{7}\lambda$
(c) $\frac{16}{7}\lambda$ (d) $\frac{32}{7}\lambda$

For question numbers 13 to 16 , two statements are given - one labelled as Assertion (A) and the other labelled as 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 Assertion (A).
(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of Assertion (A).
(c) Assertion (A) is true, but Reason (R) is false.
(d) Assertion (A) is false and Reason (R) is also false.

13. **Assertion (A) :** On increasing the intensity of incident light of frequency $v(> v_0)$ on a photosensitive surface, the photocurrent increases.

Reason (R) : The stopping potential for a photosensitive surface increases with increase of frequency $\nu(>\nu_0)$ of incident light.

14. **Assertion (A) :** On forward biasing a p-n junction diode, the height of the barrier potential increases.
Reason (R) : In forward biasing of a p-n junction diode, the direction of the applied voltage is in the same direction as the built-in potential.

15. **Assertion (A) :** Light added to light can produce darkness.
Reason (R) : When two coherent light waves interfere, there is darkness at position of destructive interference.

16. **Assertion (A) :** Two electric heaters of power P_1 and $P_2(>P_1)$ are joined in series across a dc source of voltage V. The power consumed by the combination will be less than that consumed by P_1 when connected across the same source.
Reason (R) : The power consumed by a electric device when connected to a dc source of voltage V is proportional to its resistance.

SECTION – B

17. Write two points of difference between intrinsic and extrinsic semiconductors.

18. Find ratio (λ_a/λ_p) of the de Broglie wavelength λ_a and λ_p associated respectively with an alpha particle and a proton,
(i) if they are moving with the same kinetic energy.
(ii) just after they are accelerated through the same potential difference.

19. A ray of light in air is incident at angle $\angle i$ on a face of an equilateral glass prism and is refracted through the prism. As $\angle i$ is varied, it is observed that the ray undergoes minimum deviation, when the $\angle i$ is three-fourth of the angle of the prism. Calculate the speed of light in the prism.

20. A heating element using nichrome is connected to a 220 V supply. Initially it draws a current of 2.9 A . After some time, the current attains a steady value of 2.5 A . Find the steady temperature of the heating element if the room temperature is $27^\circ C$. The temperature coefficient of resistance of nichrome is $1.7\times10^{-4}\,{}^\circ C^{-1}$.

21. A 5 cm long pencil is placed along the principal axis of a concave mirror of focal length 20 cm such that its nearest end is at a distance of 25 cm from the mirror. Calculate the length of the image of the pencil.

OR

In a Young's double-slit experiment, a beam of light consisting of two wavelengths 500 nm and 600 nm is used. The interference fringes are observed at a screen placed 1.8 m away from the plane of slits (slit separation 0.3 mm). Calculate the least distance from the central maximum where the bright fringes due to both the wavelengths coincide.

SECTION – C

22. **(A)** Consider the following nuclides:
${}^{12}_{6}C$, ${}^{198}_{80}Hg$, ${}^{14}_{6}C$, ${}^{197}_{79}Au$
Group them into isotopes and isotones.
(B) How does the size of a nucleus depend on its mass number A ? Hence prove that the density of nucleus is a constant, independent of A, for all nuclei.

23. **(A)** An electric field $\vec{E}=E_0\hat{i}$ exists in a region of space. Draw three equipotential surfaces in the region.
(B) Two point charges $-q$ and $+q$ are located at points ($-a,0,0$) and $(a,0,0)$ respectively. Find the electrostatic potential at point $(x,0,0)$ where $x\gg a$.

24. **Name the electromagnetic waves which are used for**
(I) detection of fractures in bones
(II) physiotherapy
(III) radar systems
Also write their wavelength range.

25. **(i)** Define mutual inductance of a pair of coils. Write its SI unit.
(ii) A long solenoid of radius R and length L has n turns per unit length. A circular loop of radius $r(<R)$ is placed inside at the centre of the solenoid such that its axis coincides with the axis of the solenoid. Obtain the mutual inductance of the solenoid and the loop.

OR

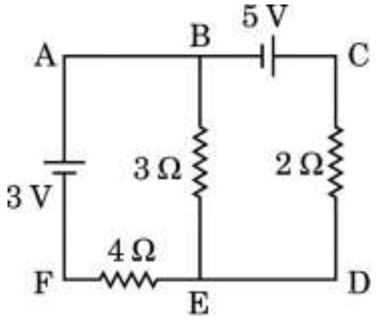
Two long straight parallel conductors A and B carrying steady currents I_a and I_b in the same direction are separated by a distance d. Deduce the expressions for the force acting on length L of conductor B due to conductor A and show it in figure. Write the expression for the force acting on length L of conductor A due to conductor B and show that it follows Newton's third law.

26. **(A)** State Bohr's second postulate and mention its significance.

(B) Prove that, in Bohr model of hydrogen atom as principal quantum number n becomes large, the energy levels get closer and closer.

27. **(A)** Explain the statement : "Current is a scalar although we represent current with an arrow".

(B) Use Kirchhoff's rules to find the current through 3Ω resistor in the circuit shown in the figure :



28. Derive an expression for the magnetic field $\vec{B}$, due to a circular coil of N turns, each of radius r carrying current I, at a distance ' x ' from the centre along its axis.

SECTION – D

29. A p-type or n-type semiconductor can be converted into a $p - n$ junction by doping it with suitable impurity. The motion of majority charge carriers causes diffusion current across the junction while the barrier electric field causes motion of minority carriers for drift current. In case of unbiased diode, the diffusion and drift currents are equal. This equilibrium is disturbed by the biasing batteries. Diodes, therefore, allow currents in one direction. This property of diode is used in making rectifiers.

(i) Silicon is doped with which of the following to obtain p-type semiconductor?

(a) Phosphorus (b) Arsenic
(c) Boron (d) Antimony

(ii) A semiconductor has an electron concentration of $5 \times 10^{22}\ m^{-3}$. The concentration of holes is (given $n_i = 1.5 \times 10^{16}\ m^{-3}$)

(a) $5 \times 10^{22}\ m^{-3}$ (b) $1.5 \times 10^{6}\ m^{-3}$
(c) $9 \times 10^{8}\ m^{-3}$ (d) $4.5 \times 10^{9}\ m^{-3}$

(iii) During forward biasing of a p-n junction diode, the

(a) current is mainly due to drifting of majority carriers.
(b) current is mainly due to drifting of minority carriers.
(c) diffusion and drift currents are equal.
(d) current is of the order of 1 A .

(iv) The threshold voltage for silicon diode is about

(a) 0.2 V (b) 0.5 V
(c) 0.7 V (d) 1.5 V

OR

(iv) When we dope Ge with a pentavalent element, four of its electrons bond with four germanium neighbours but fifth electron remains weakly bound. The ionisation energy for this electron is about

(a) 0.01 eV (b) 0.05 eV
(c) 0.1 eV (d) 0.15 eV

30. In an experiment with convex lens of focal length f, the screen is fixed at a distance D from the object. A student slowly moves the lens away from the object towards the screen and finds that she is able to form sharp image of the object for two positions of the lens. The distance between these two positions of the lens is d.

(i) The value of d is

(a) $\sqrt{D(D-4f)}$ (b) $\sqrt{D(D-2f)}$

(c) $2\sqrt{Df}$ (d) $\sqrt{D(D-f)}$

(ii) Compared to the size of the object, the images formed in the two positions of the lens are respectively

(a) reduced, enlarged (b) reduced, reduced

(c) enlarged, enlarged (d) enlarged, reduced

(iii) If the distance between object and screen is 80.00 cm and the lens forms sharp images at two positions separated by 20.00 cm ., the focal length of convex lens is

(a) 15.50 cm (b) 18.75 cm

(c) 20.50 cm (d) 22.75 cm

(iv) Consider a convex lens of focal length 15 cms . For which of the following values of object-screen distance, two positions of the object can be found to obtain sharp image on the screen?

(a) 45 cm (b) 50 cm

(c) 55 cm (d) 65 cm

OR

(iv) A thin convex lens of focal length 10 cm and another thin lens of focal length ' f ' are placed coaxially in contact. If the power of their combination is $\frac{10}{3}$ D, the value of ' f ' is

(a) -15 cm (b) -10 cm

(c) -20 cm (d) -30 cm

SECTION-E

31. **(A)** What are coherent sources ? Why they are necessary for observing stable interference pattern? Draw a graph showing the variation of intensity of light with the position on the screen in Young's doubleslit experiment.

(B) Find the intensity of light at a point on the screen when two interfering waves of the same intensity (I_0) have a path difference of **(i)** $\frac{\lambda}{4}$ and **(ii)** $\frac{\lambda}{3}$.

OR

(A) Draw a labelled ray diagram of a refracting telescope when it forms image of a distant object at infinity. Derive expression for its magnifying power.

(B) (i) In a telescope the objective has much larger aperture than the eye piece. Why?

(ii) Write two advantages of reflecting telescope over refracting telescope.

32. **(A)** Derive an expression for the capacitance of a parallel plate capacitor of plate area A and plate separation d with air present between the plates.

(B) Two air-filled capacitors of capacitances C_1 and C_2 are connected in parallel with a dc battery. After the capacitors are fully charged, a slab of dielectric constant K is inserted between the plates of each capacitor. How will the **(i)** charge on each capacitor and **(ii)** energy stored in the capacitor affected after the slab is introduced.

OR

(A) An electric field $\vec{E}$ is established across the ends of a cylindrical conductor of length L and area of cross-section A. Discuss how electrons attain an average velocity, independent of time. Hence, obtain a relation between current in the conductor and this 'average velocity' of electrons.

(B) (i) This 'average velocity' is found be few mm/s for currents in range of a few amperes. How then is current established almost the instant a circuit is closed ?

(ii) Two copper wires having their radii in the ratio of 3: 2 are connected in series across a battery. Find the ratio of the drift velocities of the electrons in the wires

33. **(A)** A series combination of L, C and R is connected to an a.c. source. Using a phasor diagram, derive an expression for the impedance of the circuit and phase difference between V and I .

(B) Under what conditions the

(i) impedance of the circuit is minimum ?

(ii) Wattless current flows in the circuit?

OR

(i) With the help of a labelled diagram, explain the principle, construction and working of an a.c. generator.

(ii) Deduce an expression for the induced emf in the coil of the generator.

(iii) If T is the time period of the rotation of the coil, at what values of T in a cycle, the emf generator is maximum?

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

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$\varepsilon_0 = 8.854 \times 10^{-12} \mathrm{C}^2 \mathrm{~N}^{-1} \mathrm{~m}^{-2}$
$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \mathrm{~N~m}^2 \mathrm{C}^{-2}$
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 $= 1.38 \times 10^{-23} \mathrm{JK}^{-1}$

SECTION A

34. A particle of mass m and charge q starts from rest and moves in an electric field $\vec{E} = E_0\hat{i}$. After travelling a distance x in the field along x -axis, the kinetic energy of the particle will be :

(a) qE_0x^2 (b) qE_0x
(c) q^2E_0x (d) $q^2E_0^2x$

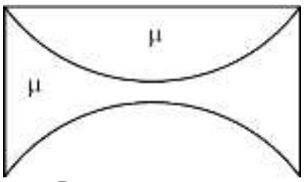
35. A square loop of side 50 cm is placed in a uniform magnetic field of 3.0 T acting perpendicular to the plane of the loop. If the loop is rotated through an angle of 90° in 0.3 s , the value of emf induced in the loop would be :

(a) 0.25 V (b) 0.50 V
(c) 0.75 V (d) 1.0 V

36. A plane electromagnetic wave travels through a medium and the magnetic field associated with it is given by $B = 5 \times 10^{-8} \sin(3 \times 10^{10} t - 150x) T$ where x is in metres and t is in seconds. The velocity of the wave is:

(a) $2.0 \times 10^8 \mathrm{~ms}^{-1}$ (b) $4.5 \times 10^7 \mathrm{~ms}^{-1}$
(c) $3.5 \times 10^7 \mathrm{~ms}^{-1}$ (d) $2.5 \times 10^8 \mathrm{~ms}^{-1}$

37. A thin plano-convex lens and a thin equi-concave lens are kept coaxially in contact as shown in the figure. Assuming both the lenses are made of glass of refractive index μ, and R is the radius of curvature of each curved surface, the focal length of the combination is :



(a) $\frac{R}{\mu-1}$ (b) $-\frac{R}{\mu-1}$
(c) $\frac{2R}{\mu-1}$ (d) $-\frac{2R}{\mu-1}$

38. The phase difference between the two superimposing waves that give rise to a bright spot in a Young's double-slit experiment is (n is an integer) :

(a) $2n\pi$ (b) $2n\pi+\frac{\pi}{4}$

(c) $2n\pi+\frac{\pi}{2}$ (d) $2n\pi+\pi$

39. A telescope has an objective lens of focal length 144 cm and an eyepiece of focal length 6.0 cm . The magnifying power and the length of telescope tube will be respectively :

(a) 24,150 cm (b) 42,138 cm

(c) 24,138 cm (d) 42,150 cm

40. In which of the following, total internal reflection does not occur?

(a) Twinkling of stars (b) Brilliance of diamonds

(c) Optical fibre (d) Reflecting prism

41. Radiation of wavelength 200 nm is incident on a photosensitive surface of work function 4 · 2eV. The kinetic energy of fastest photoelectrons emitted from this surface will be close to :

(a) 3.5 eV (b) 3.0 eV

(c) 2.5 eV (d) 2.0 eV

42. A proton and an alpha particle have equal momentum. The ratio of their kinetic energies (E_p/E_a) and de Broglie wavelengths associated with them (λ_p/λ_a) respectively are:

(a) 2,1 (b) 1,2

(c) 4,1 (d) 1,4

43. If r_1 and r_2 are the radii of atomic nuclei of mass numbers 64 and 27 respectively, then the value of $\left(\frac{r_1}{r_2}\right)$ is:

(a) 1 (b) $\frac{4}{3}$

(c) $\frac{3}{4}$ (d) $\frac{27}{64}$

44. When the forward bias voltage in a semiconductor diode is changed from 0.8 V to 1.0 V , the forward current changes by 2.0 mA . The forward bias resistance of the diode will be :

(a) 200Ω (b) 175Ω

(c) 100Ω (d) 125Ω

45. The process named 'minority carrier injection' in a p-n junction diode occurs during :

(a) forward biasing

(b) reverse biasing

(c) no biasing at low temperature

(d) no biasing at high temperature

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

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

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

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

(d) Both Assertion (A) and Reason (R) are false.

46. Assertion (A) : In a Wheatstone bridge circuit, if we interchange the position of the cell and the galvanometer, the balance condition $\frac{P}{Q}=\frac{R}{S}$ remains unchanged.

Reason (R): $\frac{P}{Q}=\frac{R}{S} \Rightarrow \frac{Q}{S}=\frac{P}{R}$ so balance condition remains same.

47. Assertion (A) : The cylindrical soft iron core in a moving coil galvanometer only makes the magnetic field radial and does not affect the strength of the magnetic field.

Reason (R) : In a moving coil galvanometer, the plane of the coil is always perpendicular to the magnetic field.

48. Assertion (A) : Photoelectric current depends upon the intensity of the incident radiation.

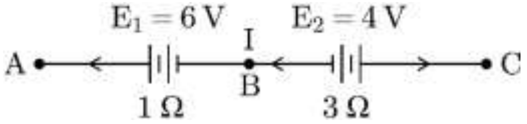
Reason (R) : Stopping potential is independent of the intensity of the incident radiation.

49. **Assertion (A) :** Nuclear forces are always attractive.

Reason (*R*) : The nuclear force between protons and neutrons in a nucleus is a weak force.

SECTION B

50. **(A)** In the given figure, a steady current I flows through the circuit when points A and C are connected by a wire of negligible resistance. Find the potential difference between points B and C.



OR

(B) A battery of emf 21 V and internal resistance 3Ω is connected to a resistor. If the current in the circuit is 3 A , find :

(i) the resistance of the resistor.

(ii) the terminal voltage of the battery.

51. Explain why diffraction of sound is more common in daily experience than that of light.

52. Explain the terms mass defect and binding energy. How are they related?

53. A particle of mass M at rest splits up into two particles of masses m_1 and m_2 having non-zero velocities. Calculate the ratio of the de Broglie wavelengths associated with the two particles.

54. How are charge carriers created in an intrinsic semiconductor? Explain.

SECTION C

55. **(A)** Establish the relation between drift velocity of electrons (v_d) and electric current (I) in a conductor.

(B) How is v_d affected when the length of the conductor is doubled, keeping the voltage applied across the conductor constant ?

56. **(A)** A circular coil of 30 turns and radius 8.0 cm carrying a current of 6 A is suspended vertically in a uniform horizontal magnetic field of 1.0 T . The field lines make an angle of 30° with the plane of the coil. Calculate the magnitude of the external torque that must be applied to prevent the coil from turning. What would happen if the circular coil is replaced by a planar coil of irregular shape that encloses the same area, keeping other parameters unchanged?

OR

(B) An alpha particle (mass 6.4×10^{-27} kg and charge 3.2×10^{-19}C) having 8.0 MeV energy, enters a region of a uniform magnetic field of 0.5 T . If the field is directed perpendicular to the velocity of the particle, find the radius of the circular path described by the particle. Mention the condition under which the particle in this region **(i)** describes a helical path, and **(ii)** goes straight undeviated.

57. **(A)** Discuss the behaviour of an inductor connected to **(i)** a dc source, and **(ii)** a high frequency ac source.

(B) What is the phase relation between current and voltage in an ideal inductor connected to an ac source? Draw a phasor diagram for the circuit.

58. **(A)** Depict the variation of electric field ($\vec{E}$) and magnetic field ($\vec{B}$) with respect to the direction of propagation of an electromagnetic wave. Write their two important characteristics.

(B) Show that $\frac{1}{\sqrt{\varepsilon_0 \mu_0}}$ gives the velocity of an electromagnetic wave in free space.

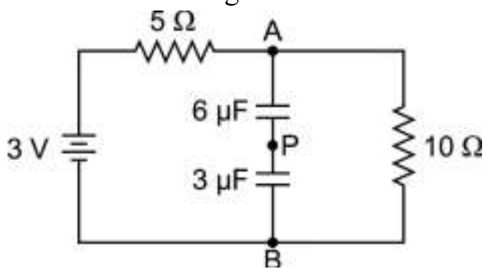
59. A ray of light is travelling through a rectangular glass slab (refractive index $\frac{3}{2}$) and is incident on the horizontal glass-air surface at the critical angle for the two media. The slab is then brought in contact with water (refractive index $\frac{4}{3}$) such that a thin horizontal layer of water is formed on the surface of the slab. Find the angle at which the ray will emerge into air from the water-air surface.

60. Differentiate between nuclear fission and nuclear fusion. Give one example for each with nuclear reaction.

61. With the help of circuit diagrams, briefly explain the forward biasing and the reverse biasing of a p-n junction diode.

SECTION D

62. Capacitors are manufactured with certain standard capacitances and working voltages. However, these standard values may not be the ones that are actually needed in a particular application. Two or more capacitors can be grouped in series or in parallel to achieve desired capacitance and voltage. When connected in series, the total capacitance decreases while the voltage rating increases, whereas in parallel connections, the total capacitance increases and maintains the same voltage rating. A capacitor stores energy in the electric field between its plates and stored energy is proportional to the square of the voltage and capacitance $U = \frac{1}{2}CV^2$, where symbols have their usual meanings.



Two capacitors, one of 3μ F and the other of 6μ F, are connected in series in the circuit as shown in the figure, for a long time.

(i) The total capacitance of the circuit is :

(a) 6μ F (b) 3μ F
(c) 9μ F (d) 2μ F

(ii) The current in the 10Ω resistor is :

(a) 0.3 A (b) 0.6 A
(c) $0 \cdot 2$ A (d) 0

(iii) The potential difference between point A and B is :

(a) 2 V (b) 0.3 V
(c) 0.2 V (d) 3 V

(iv) (A) The value of charge on the plates of the 6μ F capacitor is:

(a) $6\mu C$ (b) $4\mu C$
(c) $12\mu C$ (d) $8\mu C$

OR

(B) The wire between two capacitors is cut at point P . The current in the circuit will :

(a) increase
(b) decrease
(c) remain the same
(d) first increase then become stable

63. A charged particle $+q$ in an electric field $\vec{E}$ experiences a force in the direction of the electric field. As a result, its kinetic energy changes. Similarly, the charged particle also experiences a force when it moves in a magnetic field $\vec{B}$. But this magnetic force is perpendicular to both velocity $\vec{v}$ of the charged particle and the magnetic field $\vec{B}$, so it cannot change the kinetic energy of the charged particle. Consider two charged particles 1 and 2 of masses m and $\frac{m}{2}$ having charges -q and +2 q respectively. They are accelerated from rest through the same potential difference V and acquire kinetic energy K_1 and K_2. Then they enter in a region of uniform magnetic field $\vec{B}$ perpendicular to their velocities.

(i) The ratio of their kinetic energies $\left(\frac{K_1}{K_2}\right)$ is:

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

(ii) The ratio of the radii of the circular paths described by them $\left(\frac{r_1}{r_2}\right)$ is:

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

(iii) Suppose particles 1 and 2 enter the magnetic field $\vec{B} = B_0\hat{k}$ with velocities $\vec{v}_1 = v_1\hat{\imath}$ and $\vec{v}_2 = v_2\hat{\imath}$. Then :

(a) both particles revolve clockwise
(b) both particles revolve anticlockwise

(c) particle 1 revolves clockwise while particle 2 revolves anticlockwise
(d) particle 1 revolves anticlockwise while particle 2 revolves clockwise

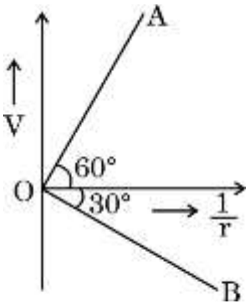
(iv) (A) If period of revolution for particle 1 is 4 s , then for particle 2, the period will be :
(a) 1 s (b) 2 s
(c) 4 s (d) 8 s

OR

(B) If the value of momentum for particles 1 and 2 are p_1 and p_2, then :
(a) $p_1 = \frac{p_2}{2}$ (b) $p_1 = p_2$
(c) $p_1 = 2p_2$ (d) $p_1 = 4p_2$

SECTION E

64. (A) (i) In the figure, OA and OB show the variation of electric potential V at a point due to two point charges Q_1 and Q_2 with $\frac{1}{r}$ respectively. Here r represents the distance of the point from the two point charges.



(I) Identify the nature of the two charges Q_1 and Q_2.
(II) What is the value of $\left(\frac{Q_1}{Q_2}\right)$? Justify your answer.
(ii) Two point charges - $2\mu C$ and $5\mu C$ are placed at (-30 cm, 0) and (30 cm, 0) respectively in an external electric field $\vec{E} = \frac{A}{x^2}\hat{\imath}$, where $A = 9 \times 10^5 \mathrm{Nm^2C^{-1}}$. Find the electrostatic potential energy of this configuration.

OR

(B) (i) Two infinitely long straight wires having linear charge densities $-\lambda$ and 3λ are held vertically parallel to each other, distance r apart in free space. Find the nature and magnitude of the force/length exerted by one wire on the other.
(ii) A small hollow conducting sphere of radius r_1 is given a charge Q. It is surrounded by a concentric conducting spherical shell of inner radius r_2 and outer radius r_3, having charge - $3q$.
If a point charge $2q$ were kept at the centre, find :
(I) the electric flux through a concentric spherical Gaussian surface of radius x for (1) $x < r_1$, and (2) $r_1 < x < r_2$.
(II) electric field at a point distant x from the centre for (1) $x > r_3$, and (2) $r_1 < x < r_2$.
(III) surface charge density on the inner surface of (1) sphere, and (2) shell.

65. (A) (i) A light bulb and an open coil inductor are connected in series across an ac source of variable frequency. How will the glow of the bulb be affected when :
(I) an iron bar is inserted inside the coil, and
(II) the frequency of the source is decreased?
Justify your answers. Assume that in each above case other factors remain unchanged.
(ii) An ac voltage $V = 280\sin(100\pi t)$ volt is connected across a series LCR circuit in which $R = 400\Omega$, $L = \frac{5}{\pi}$ H and $C = \frac{50}{\pi}\mu$ F. Taking $\sqrt{2} = 1 \cdot 4$, calculate :
(I) impedance of the circuit.
(II) rms value of current that flows in the circuit.
(III) power factor of the circuit.

OR

(B) (i) State Lenz's law and explain that it follows the law of conservation of energy.
(ii) Write the dimensional formula for self-inductance.
The current in a coil changes from 8.0 A to 2.0 A in 0.6 s . If an average emf induced in the coil is 50 V , calculate the self-inductance of the coil.

66. **(A) (i)** A point object is kept in front of a convex spherical surface of radius of curvature R . Draw the ray diagram to show the formation of image and derive the relation between the object and image distance (u and v) in terms of refractive index n of the medium and R.

(ii) A convex lens of focal length of 20 cm is used to form the image of an object placed 30 cm away from the lens. Find the position and nature of the image formed.

OR

(B) (i) Two thin converging lenses of focal length f_1 and f_2 are placed coaxially in contact. Derive expression for the focal length of the combination.

(ii) A beam of coherent light of wavelength 550 nm is incident normal to the plane of a pair of two slits S_1 and S_2 each of width 1.2×10^{-6} m separated by 1.1 mm . Dark and bright fringes are observed on a screen 2.2 m away from the plane of the slits.

Calculate :

(I) fringe width.

(II) distance of the second dark fringe from the central maximum.

(III) what will happen when the entire apparatus is immersed in water.

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

(x) Use of calculators is not allowed.

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

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

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

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

$\mu_0 = 4\pi \times 10^{-7}$ TmA^{-1}

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

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

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

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

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

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

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

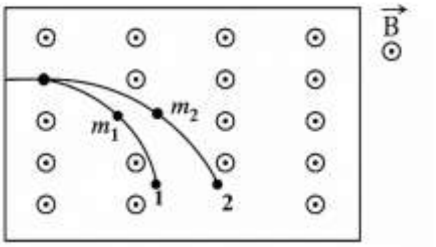
SECTION A

67. Two wires of same length and same area of cross-section but made of different material of resistivities ρ_1 and ρ_2 are connected in series. The equivalent resistivity of the combination is :

(a) $\frac{1}{2}(\rho_1 + \rho_2)$ (b) $\rho_1 + \rho_2$

(c) $\sqrt{\rho_1 \rho_2}$ (d) $2(\rho_1 + \rho_2)$

68. Two particles of masses m_1 and m_2 having charges q_1 and q_2 respectively are projected with the same velocity in a region of uniform magnetic field $\vec{B}$ pointing vertically upward. If they describe circular paths as shown in the figure, one may conclude that:



(a) $\frac{m_1}{m_2} > \frac{q_1}{q_2}$ (b) $\frac{m_1}{m_2} > \frac{q_2}{q_1}$

(c) $\frac{m_1}{m_2} < \frac{q_1}{q_2}$ (d) $\frac{m_1}{m_2} < \frac{q_2}{q_1}$

69. An electron moves around the nucleus in a circular orbit of radius r and makes n revolutions per second. The value of equivalent current in the orbit is :

(a) $\frac{e}{n}$ (b) ne

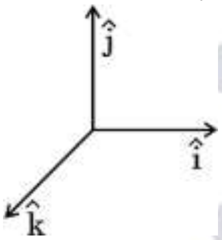
(c) $\frac{ne}{r}$ (d) $\frac{e}{nr}$

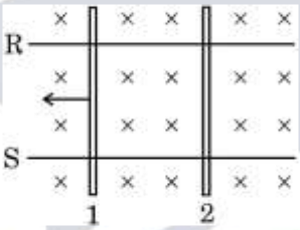
70. The dimensions of the rate of change of magnetic flux are :

(a) $[MLT^{-3}\,A]$ (b) $[ML^2\,T^{-3}\,A^{-1}]$

(c) $[ML^2\,T^{-2}\,A^{-1}]$ (d) $[ML^2\,T^{-3}\,A^{-2}]$

71. Two identical conductors 1 and 2 are placed on two frictionless conducting rails R and S in a uniform magnetic field directed vertically downward into the plane of the page. If conductor 1 is moved with a constant velocity in the direction as shown in figure, the force on conductor 2 will be along :





(a) $-\hat{i}$ (b) $-\hat{j}$

(c) $\hat{k}$ (d) $\hat{j}$

72. An ac voltage is given as $v = 14\sin(314t)v$. The average and the effective value of the voltage (in V) over a cycle are respectively :

(a) 14 and 7 (b) 10 and 14

(c) 0 and 10 (d) 10 and 0

73. The ratio of amplitude of electric field to the amplitude of the magnetic field associated with an electromagnetic wave propagating in glass $(n = 1 \cdot 5)$ is :

(a) $3 \times 10^8\ ms^{-1}$ (b) $2 \times 10^8\ ms^{-1}$

(c) $3.3 \times 10^{-9}\ ms^{-1}$ (d) $5 \times 10^{-9}\ ms^{-1}$

74. While studying photoelectric emission from a given surface, the wavelength of the incident radiation is changed from 600 nm to 400 nm , keeping the intensity of radiation the same. Then :

(a) cut-off potential will decrease.

(b) cut-off potential will increase.

(c) saturation current will decrease.

(d) saturation current will increase.

75. Radiation of wavelength 331 nm irradiates the following metals :

Metal	Work Function (eV)
Na	1.92
K	2.15
Ca	3.20

Mo	4.17

Which of the following statements is correct ?
(a) Only Na and K show photoelectric emission.
(b) Only Mo will not show photoelectric emission.
(c) All of the given metals show photoelectric emission.
(d) None of them show photoelectric emission.

76. The kinetic energy of a charged particle is increased to four times of its initial value. The de Broglie wavelength associated with the particle will :
(a) increase by 100% of its initial value.
(b) increase by 50% of its initial value.
(c) decrease by 25% of its initial value.
(d) decrease by 50% of its initial value.

77. Paschen series in spectrum of hydrogen atom lies in :
(a) infrared region
(b) ultraviolet region
(c) visible region
(d) partly in ultraviolet region and partly in visible region

78. In a reversed-biased p-n junction diode, the applied voltage mostly drops across:
(a) p-region only (b) n-region only
(c) depletion region (d) the diode

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

79. Assertion (A) : The work done, in taking a unit charge around a closed loop of an electric circuit involving cells and resistors in the loop, is zero.
Reason (R): The potential at a point depends on the location of the point in the loop. After completing one round, the charge comes back to the point of start.

80. Assertion (A) : When a ferromagnetic substance is heated to high temperature it becomes paramagnetic in nature.
Reason (R) : The disappearance of magnetisation of a ferromagnet is abrupt and not gradual.

81. Assertion (A) : When a convex lens made of glass is immersed in water, its converging power increases.
Reason (R) : The focal length of a lens depends only on the radii of curvature of its two faces.

82. Assertion (A) : The conductivity of an n-type semiconductor is higher than that of a p-type semiconductor at a given temperature.
Reason (R): The electrons being in the conduction band in n-type semiconductor are more mobile than the holes in the valence band in p-type semiconductor.

SECTION B

83. An electric dipole consists of two point charges $+1\mu$C and -1μC, held 10 cm apart. It is subjected to a uniform electric field of 100 N/C. Calculate the amount of work done in turning the dipole from its position of stable equilibrium to the position of unstable equilibrium, in the field.

84. (A) State Huygens principle. How did Huygens justify the absence of the backwave on a spherical wavefront ?

OR

(B) In a single-slit diffraction experiment, light of wavelength λ illuminates the slit of width ' a '. The diffraction pattern is observed on a screen kept at a distance D from the slits.
(i) Depict variation of intensity in the fringe pattern with the angular position of the fringes.
(ii) How is the linear width of central maximum affected when separation between the slit and the screen is decreased?

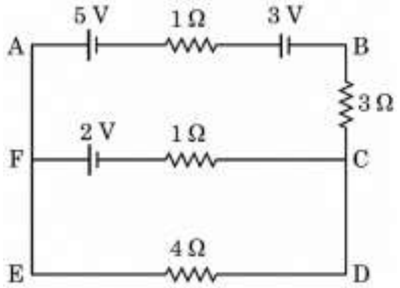
85. A small bulb is placed at the bottom of a tank, containing a transparent liquid of refractive index $\sqrt{2}$, to a depth of 1 m . Calculate the area of the surface of the liquid through which light from the bulb emerges.

86. Draw the graph showing the variation of number of scattered alpha particles (N) detected with scattering angle (θ) in Geiger-Marsden experiment. Infer two conclusions from the graph.

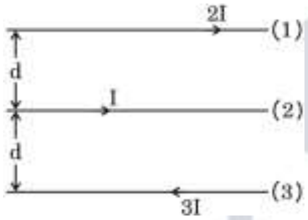
87. The hole concentration in an intrinsic semiconductor is $5 \times 10^{8}\ \mathrm{m}^{-3}$. When it is doped with certain impurity, the electron concentration becomes $4 \times 10^{12}\ \mathrm{m}^{-3}$. Find the new value of the hole concentration. Also identify the type of new semiconductor formed after doping.

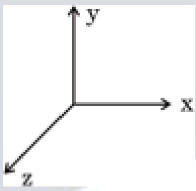
SECTION C

88. State Kirchhoff's rules. Using these rules, find the current flowing through branch FC in the given circuit.



89. **(A)** The figure given below shows three straight long parallel conductors (1), (2) and (3) kept in x-y plane, carrying currents 2 I , I and 3I respectively as shown in figure.





Find the magnitude and direction of :

(i) net magnetic field at a point on conductor (1) and

(ii) net magnetic force acting on unit length of conductor (1), due to conductors (2) and (3).

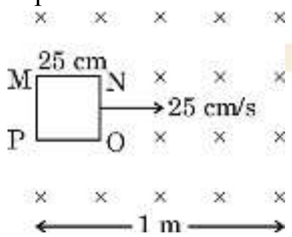
OR

(B) A rectangular loop of sides l and b and resistance ' R ' is kept in a region in which the magnetic field varies as $B = B_0 \sin \omega t$.

(i) Derive expression for the emf induced in the loop.

(ii) Find the effective value of current that flows in the loop.

90. The figure given below shows a square-shaped loop MNOP of side 25 cm placed horizontally in a uniform magnetic field $\vec{B}$ directed vertically downward. The position of the loop at $t = 0$ s is as shown in figure. The loop is pulled with a constant velocity of 25 cm/s till it goes out of the field.



(A) What will be the direction of the induced current in the loop as it goes out of the field? For how long would the current in the loop persist ?

(B) Plot graphs showing the variation of magnetic flux and magnitude of induced emf as a function of time.

91. What are infrared waves ? Why are these waves referred to as heat waves'? Give any two uses of these waves.

92. **(A)** Explain how the dual aspect of matter is evident in the de Broglie relation.

(B) Radiation of wavelength λ is incident on a photosensitive surface. Find the de Broglie wavelength of electrons emitted from the surface. Assume that the work function of the surface is negligible.

93. In the nuclear reaction :

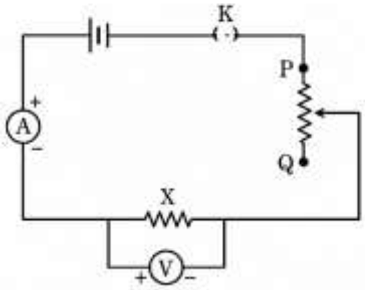
$${}_{1}^{2}\mathrm{H} + {}_{1}^{2}\mathrm{H} \rightarrow {}_{2}^{A}\mathrm{X} + {}_{0}^{1}\mathrm{n}$$

(A) Find the value of A .
(B) Calculate the amount of energy released in the reaction.
Given : $m({}^{2}_{1}H) = 2 \cdot 014102u, m({}^{A}_{2}X) = 3 \cdot 016049u$
$m({}^{1}_{0}n) = 1 \cdot 008665u, 1u = 931 \cdot 5MeV/c^2$

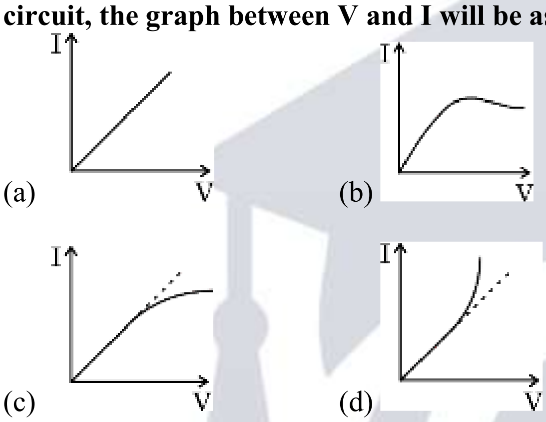
94. With the help of a circuit diagram, explain the working of a full wave rectifier. Depict the input and output waveforms.

SECTION D

95. A student sets up the circuit as shown in the figure to find the value of unknown resistance X and records a set of readings of the voltmeter and the ammeter by using the rheostat.



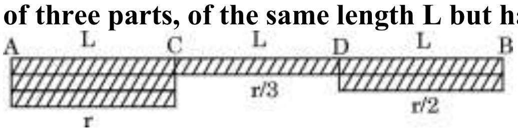
(i) If resistor X were made of manganin and readings for V and I are taken without switching off the circuit, the graph between V and I will be as :



(ii) Error in the value of X obtained from different sets of voltmeter and ammeter readings, is :
(a) due to error in voltmeter reading only.
(b) due to error in ammeter reading only.
(c) equal to the sum of error in voltmeter reading and error in ammeter reading.
(d) equal to error in voltmeter reading divided by the error in ammeter reading.

(iii) If the movable end of rheostat is moved towards P, then :
(a) reading in ammeter decreases and reading in voltmeter increases.
(b) readings in both voltmeter and ammeter increase.
(c) reading in ammeter increases and reading in voltmeter decreases.
(d) readings in both voltmeter and ammeter decrease.

(iv) (A) Suppose the unknown resistance X is replaced by a wire made of the same metal. This wire consists of three parts, of the same length L but has radii $r, r/3$ and $r/2$ as shown in the figure.



For a particular setting of the rheostat, let v_1, v_2 and v_3 be the value of drift velocities in parts AC, CD and DB . Then :

(a) $v_1 > v_2 > v_3$ (b) $v_2 > v_3 > v_1$
(c) $v_3 > v_2 > v_1$ (d) $v_1 = v_2 = v_3$

OR

(B) Consider the same wire, as shown in figure in question (iv) (a) connected in place of X . For a particular setting of rheostat, let E_1, E_2 and E_3 be the value of electric fields in part AC, CD and DB . Then :

(a) $E_1 = E_2 = E_3$ (b) $E_3 > E_2 > E_1$
(c) $E_2 > E_3 > E_1$ (d) $E_1 > E_2 > E_3$

96. An astronomical telescope consists of two converging lenses. One of them of large aperture and large focal length is called objective lens and the other one, of smaller focal length and smaller aperture is called the eyepiece. It is used to see distant objects which are not seen clearly with naked eyes. The image formed by the objective lens acts as an object for the eyepiece and the final image produced by the eyepiece is magnified.

(i) The images formed by the objective lens and the eyepiece are respectively :

(a) virtual, real (b) real, virtual
(c) virtual, virtual (d) real, real

(ii) The magnification produced by the telescope does not depend upon the :

(a) colour of light
(b) focal length of objective lens
(c) focal length of eyepiece
(d) apertures of objective lens and eyepiece

(iii) Which of the following statements is not correct for this telescope?

(a) The focal length of objective lens (f_0) is larger than the focal length of eyepiece (f_e).
(b) Its magnifying power can be increased by increasing the focal length of objective lens (f_0).
(c) The distance between two lenses is more than $(f_0 + f_e)$.
(d) The magnifying power can be decreased by increasing the focal length of eyepiece.

(iv) (A) An astronomical telescope has objective lens and eyepiece of focal lengths 80 cm and 4 cm respectively. To view the image in normal adjustment, the lenses must be separated by a distance of :

(a) 84 cm (b) 76 cm
(c) 20 cm (d) 320 cm

OR

(B) Consider the telescope described in question (iv) (A). Its magnifying power in normal adjustment will be :

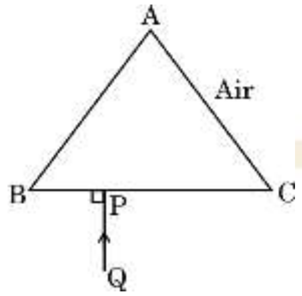
(a) 320 (b) 84
(c) 76 (d) 20

SECTION E

97. (A) (i) Define refractive index of a medium in terms of speed of light.

(ii) Derive the relation for the refractive index (μ) of a prism in terms of angle of minimum derivation (δ_m) and angle of prism (A).

(iii) A ray of light QP is incident normally on the face BC of a triangular prism ABC of refractive index 1.5 kept in air, as shown in the figure. Trace the path of the ray as it passes through the prism and give relevant explanation.



OR

(B) (i) What is the difference between a ray and a wavefront ?

(ii) A plane wave is incident on a reflecting surface. Using Huygens principle, show how it is reflected from the surface. Hence, verify the law of reflection.

(iii) Depict refraction of a plane wave by a convex lens.

98. (A) (i) Define the terms **(I)** resonant frequency, and **(II)** power factor of a series LCR circuit. For what value of the power factor will the power dissipated in the circuit be maximum?

(ii) An inductor of $\frac{5}{\pi}$ H, a capacitor of $\frac{50}{\pi}\mu$ F and a resistor of 400Ω are connected in series across an ac voltage $v = 140\sin(100\pi t)$V. Calculate :

(I) impedance of the circuit, and

(II) rms value of current that flows in the circuit.

(Take $\sqrt{2} = 1 \cdot 4$)

OR

(B) (i) Draw a labelled diagram of a step-up transformer. Obtain the ratio of secondary voltage to primary voltage in terms of number of turns in the two coils.

(ii) The number of turns in the primary and the secondary coil of an ideal transformer are 100 and 5000 respectively. If $3 \cdot 3$ kW power is supplied to the transformer at 220 V , find **(I)** current in the primary coil, and **(II)** output voltage.

99. **(A) (i)** Explain the following statements giving reason :

(I) An equipotential surface through a point is normal to the electric field at that point.

(II) When a dielectric is placed in an external electric field, the electric field inside the dielectric is less than that outside it.

(III) The potential difference between the plates of a charged parallel plate capacitor decreases when its plates are brought closer.

(ii) Obtain an expression for the work done to dissociate the system of three charges $q, -4q$ and $2q$ placed at the vertices A, B and C respectively of an equilateral triangle of side ' a '.

OR

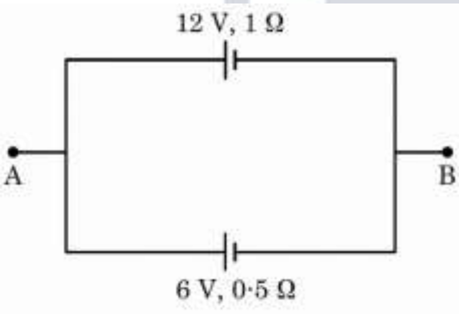
(B) (i) Answer the following giving reason :

(I) The electron drift speed is estimated to be only a few $\mathrm{mm/s}$ for currents in the range of a few amperes. How, then, is the current established almost the instant a circuit is closed ?

(II) A low voltage supply from which one needs high currents must have very low internal resistance. Why ?

(III) The assertion that V = IR is a statement of Ohm's law is not true. Why ?

(ii) Two cells of emfs 12 V and 6 V are connected in parallel as shown in the figure. Their internal resistances are 1Ω and 0.5Ω respectively. Calculate the emf and internal resistance of the equivalent cell between points A and B .



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(x) Use of calculators is not allowed.

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

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

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

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

100. Two small identical metallic balls having charges q and $-2q$ are kept far at a separation r. They are brought in contact and then separated at distance $\frac{r}{2}$. Compared to the initial force F, they will now :

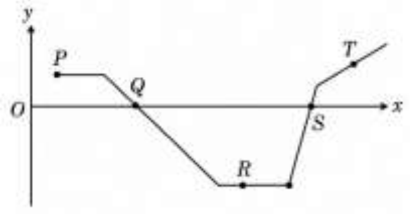
(a) attract with a force $\frac{F}{2}$

(b) repel with a force $\frac{F}{2}$

(c) repel with a force F

(d) attract with a force F

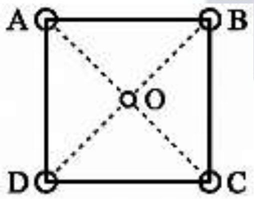
101. The figure represents the variation of the electric potential V at a point in a region of space as a function of its position along the x-axis. A charged particle will experience the maximum force at :



(a) (P) (b) (Q)

(c) (R) (d) (S)

102. Four long straight thin wires are held vertically at the corners A, B, C and D of a square of side ' a ', kept on a table and carry equal current ' T '. The wire at A carries current in upward direction whereas the current in the remaining wires flows in downward direction. The net magnetic field at the centre of the square will have the magnitude :



(a) $\frac{\mu_0 I}{\pi a}$ and directed along OC

(b) $\frac{\mu_0 I}{\pi a\sqrt{2}}$ and directed along OD

(c) $\frac{\mu_0 I\sqrt{2}}{\pi a}$ and directed along OB

(d) $\frac{2\mu_0 I}{\pi a}$ and directed along OA

103. The magnetic flux through a loop placed in a magnetic field can be changed by changing:

(a) area of the loop only

(b) the value of magnetic field only

(c) orientation of the loop in the magnetic field only

(d) any one or more of the factors given in (a), (b) and (c)

104. Which of the following statements is not true for electric energy in ac form compared to that in dc form ?

(a) Production of ac is economical.

(b) ac can be easily and efficiently converted from one voltage to the other.

(c) ac can be transmitted economically over long distances.

(d) ac is less dangerous.

105. The magnetic field in a plane electromagnetic wave travelling in glass $(n = 1.5)$ is given by $B_y = (2 \times 10^{-7} T)\sin(\alpha x + 1.5 \times 10^{11} t)$. where x is in metres and t is in seconds. The value of α is :

(a) $0.5 \times 10^3 \text{ m}^{-1}$ (b) $6.0 \times 10^2 \text{ m}^{-1}$
(c) $7.5 \times 10^2 \text{ m}^{-1}$ (d) $1.5 \times 10^3 \text{ m}^{-1}$

106. Light of which of the following colours will have the maximum energy in a photon associated with it ?

(a) Red light (b) Yellow light
(c) Green light (d) Blue light

107. Nuclides with the same number of neutrons are called :

(a) Isobars (b) Isotones
(c) Isotopes (d) Isomers

108. The radius of a nucleus of mass number 125 is

(a) 6.0 fm (b) 30 fm
(c) 72 fm (d) 150 fm

109. The energy of an electron in an orbit in hydrogen atom is $-3 \cdot 4$eV. Its angular momentum in the orbit will be:

(a) $\frac{3\text{ h}}{2\pi}$ (b) $\frac{2\text{ h}}{\pi}$
(c) $\frac{\text{h}}{\pi}$ (d) $\frac{\text{h}}{2\pi}$

110. A good diode checked by a multimeter should indicate :

(a) high resistance in reverse bias and a low resistance in forward bias
(b) high resistance in both forward bias and reverse bias
(c) low resistance in both reverse bias and forward bias
(d) high resistance in forward bias and low resistance in reverse bias

111. The rms and the average value of an ac voltage $V = V_0 \sin\omega t$ volt over a cycle respectively will be :

(a) $\frac{V_0}{2}, \frac{V_0}{\sqrt{2}}$ (b) $\frac{V_0}{\pi}, \frac{V_0}{2}$
(c) $\frac{V_0}{\sqrt{2}}, 0$ (d) $V_0, \frac{V_0}{\sqrt{2}}$

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

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

112. Assertion (A) : Induced emf produced in a coil will be more when the magnetic flux linked with the coil is more.

Reason (R): Induced emf produced is directly proportional to the magnetic flux.

113. Assertion (A) : In Young's double-slit experiment, the fringe width for dark and bright fringes is the same.

Reason (R) : Fringe width is given by $\beta = \frac{\lambda D}{d}$, where symbols have their usual meanings.

114. Assertion (A) : Energy is released when heavy nuclei undergo fission or light nuclei undergo fusion.

Reason (R) : For heavy nuclei, binding energy per nucleon increases with increasing Z while for light nuclei, it decreases with increasing Z .

115. Assertion (A) : Photoelectric effect is a spontaneous phenomenon.

Reason (R) : According to the wave picture of radiation, an electron would take hours/days to absorb sufficient energy to overcome the work function and come out from a metal surface.

SECTION B

116. (A) An electric iron rated $2 \cdot 2$ kW, 220 V is operated at 110 V supply. Find :

(i) its resistance, and

(ii) heat produced by it in 10 minutes.

OR

(B) A current of 4.0 A flows through a wire of length 1 m and cross-sectional area $1.0\ \mathrm{mm}^2$, when potential difference of 2 V is applied across its ends.

117. A plane circular coil is rotated about its vertical diameter with a constant angular speed ω in a uniform horizontal magnetic field. Initially the plane of the coil is parallel to the magnetic field. Draw plots showing the variation of the following physical quantities as the function of ωt, where t represents time elapsed :

(A) Magnetic flux ϕ linked with the coil, and

(B) emf induced in the coil.

118. A tank is filled with a liquid to a height of 12.5 m . The apparent depth of a needle lying at the bottom of the tank is measured to be 9.0 m . Calculate the speed of light in the liquid.

119. Two thin lenses of focal length f_1 and f_2 are placed in contact with each other coaxially. Prove that the focal length f of the combination is given by $\mathrm{f}=\frac{\mathrm{f}_1 \mathrm{f}_2}{\mathrm{f}_1+\mathrm{f}_2}$.

120. Suppose a pure Si crystal has 5×10^{28} atoms per m^3. It is doped with 5×10^{22} atoms per m^3 of Arsenic. Calculate the majority and minority carrier concentration in the doped silicon. (Given : $\mathrm{n}_{\mathrm{i}}=1.5 \times 10^{16}\ m^{-3}$)

SECTION C

121. Two parallel plate capacitors X and Y are connected in series to a 6 V battery. They have the same plate area and same plate separation but capacitor X has air between its plates, whereas capacitor Y contains a material of dielectric constant 4.

(A) Calculate the capacitances of X and Y , if the equivalent capacitance of the combination of X and Y is 4μ F.

(B) Calculate the potential difference across the plates of X and Y .

122. Write the expression for the magnetic field due to a current element in vector form. Consider a 1 cm segment of a wire, centered at the origin, carrying a current of 10 A in positive x -direction. Calculate the magnetic field $\vec{\mathrm{B}}$ at a point ($1\ \mathrm{m}, 1\ \mathrm{m}, 0$).

123. A long solenoid of length L and radius r_1 having N_1 turns is surrounded symmetrically by a coil of radius $r_2(>r_1)$ having N_2 turns $(N_2 \ll N_1)$ around its mid-point. Derive an expression for the mutual inductance of solenoid and coil. Is $\mathrm{M}_{12}=\mathrm{M}_{21}$ valid in this case?

124. What is displacement current (i_{d}) ? Considering the case of charging of a capacitor, show that $i_d=\varepsilon_0 \frac{d \phi_E}{d t}$. What is the value of i_d for a conductor across which a constant voltage is applied ?

125. **(A) (i)** Write any two features of nuclear forces.

(ii) If both the number of protons and the neutrons are conserved in each nuclear reaction, in what way is mass converted into energy (or vice versa) in a nuclear reaction ? Explain.

OR

(B) (i) Draw the number of scattered particles versus the scattering angle graph for scattering of alpha particles by a thin foil. Write two important conclusions that can be drawn from this plot.

(ii) If Bohr's quantization postulate (angular momentum $=\frac{\mathrm{nh}}{2 \pi}$) is a basic law of nature, it should be equally valid for the case of planetary motion also. Why, then, do we never speak of quantization of orbits of planets around the Sun? Explain.

126. **Photoemission of electrons occurs from a metal ($\phi_0=1.96\mathrm{eV}$) when light of frequency 6.4×10^{14} Hz is incident on it. Calculate :**

(A) Energy of a photon in the incident light,

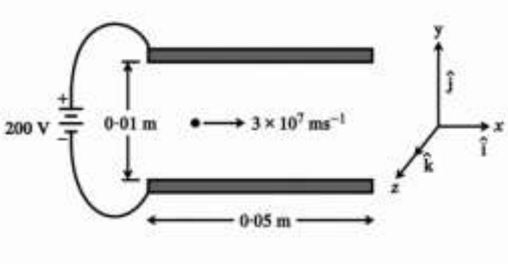
(B) The maximum kinetic energy of the emitted electrons, and

(C) The stopping potential.

127. Draw a circuit diagram of a full-wave rectifier using p-n junction diodes. Explain its working and show the input-output waveforms.

SECTION D

128. The electric potential (V) and electric field (E) are closely related concepts in electrostatics. The electric field is a vector quantity that represents the force per unit charge at a given point in space, whereas electric potential is a scalar quantity that represents the potential energy per unit charge at a given point in space. Electric field and electric potential are related by the equations $E_r=\frac{-d V}{d r}$ and $\vec{E}=E_r \hat{r}$, i.e., electric field is the negative gradient of the electric potential. This means that electric field points in the direction of decreasing potential and its magnitude is the rate of change of potential with distance. The electric field is the force that drives a unit charge to move from higher potential region to lower potential region and electric potential difference between the two points determines the work done in moving a unit charge from one point to the other point.



A pair of square conducting plates having sides of length 0.05 m are arranged parallel to each other in x-y plane. They are 0.01 m apart along z-axis and are connected to a 200 V power supply as shown in the figure. An electron enters with a speed of $3 \times 10^7\ \mathrm{ms^{-1}}$ horizontally and symmetrically in the space between the two plates. Neglect the effect of gravity on the electron.

(i) The electric field $\vec{E}$ in the region between the plates is:

(a) $\left(2 \times 10^2 \frac{\mathrm{V}}{\mathrm{m}}\right)\hat{k}$ (b) $-\left(2 \times 10^2 \frac{\mathrm{V}}{\mathrm{m}}\right)\hat{k}$

(c) $\left(2 \times 10^4 \frac{\mathrm{V}}{\mathrm{m}}\right)\hat{k}$ (d) $-\left(2 \times 10^4 \frac{\mathrm{V}}{\mathrm{m}}\right)\hat{k}$

(ii) In the region between the plates, the electron moves with an acceleration $\vec{a}$ given by :

(a) $-(3.5 \times 10^{15}\ \mathrm{ms^{-2}})\hat{k}$

(b) $(3.5 \times 10^{15}\ \mathrm{ms^{-2}})\hat{k}$

(c) $(3.5 \times 10^{13}\ \mathrm{ms^{-2}})\hat{\imath}$

(d) $-(3.5 \times 10^{13}\ \mathrm{ms^{-2}})\hat{\imath}$

(iii) (A) Time interval during which an electron moves through the region between the plates is :

(a) 9.0×10^{-9} s (b) 1.67×10^{-8} s

(c) 1.67×10^{-9} s (d) 2.17×10^{-9} s

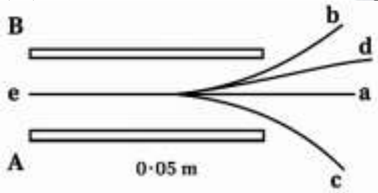
OR

(B) The vertical displacement of the electron which travels through the region between the plates is :

(a) 10 mm (b) 4.9 mm

(c) 5.9 mm (d) 3.0 mm

(iv) Which one of the following is the path traced by the electron in between the two plates?

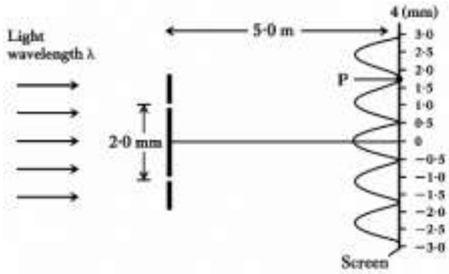


(a) a (b) b

(c) c (d) d

129. In a Young's double-slit experiment, the two slits behave as coherent sources. When coherent light waves superpose over each other they create an interference pattern of successive bright and dark regions due to constructive and destructive interference.

Two slits 2 mm apart are illuminated by a source of monochromatic light and the interference pattern is observed on a screen 5.0 m away from the slits as shown in the figure.



(i) What property of light does this interference experiment demonstrate?
(a) Wave nature of light
(b) Particle nature of light
(c) Transverse nature of light
(d) Both wave nature and transverse nature of light

(ii) (A) The wavelength of light used in this experiment is :
(a) 720 nm (b) 590 nm
(c) 480 nm (d) 364 nm

OR

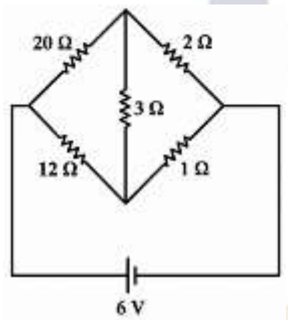
(B) The fringe width in the interference pattern formed on the screen is:
(a) 1.2 mm (b) 0.2 mm
(c) 4.2 mm (d) 6.8 mm

(iii) The path difference between the two waves meeting at point *P*, where there is a minimum in the interference pattern is:
(a) 8.1×10^{-7} m (b) 7.2×10^{-7} m
(c) 6.5×10^{-7} m (d) 6.0×10^{-7} m

(iv) When the experiment is performed in a liquid of refractive index greater than 1 , then fringe pattern will :
(a) disappear (b) become blurred
(c) be widened (d) be compressed

SECTION E

130. **(A) (i)** Derive the condition for which a Wheatstone Bridge is balanced.
(ii) Determine the current in 3Ω branch of a Wheatstone Bridge in the circuit shown in the figure.



OR

(B) (i) Consider a cylindrical conductor of length l and area of cross-section A. Current I is maintained in the conductor and electrons drift with velocity v_d $\left(|\vec{v}_d| = \frac{e|\vec{E}|}{m}\tau\right)$, (where symbols have their usual meanings). Show that the conductivity σ of the material of the conductor is given by $\sigma = \frac{\mathrm{ne}^2}{\mathrm{m}}\tau$.
(ii) The resistance of a metal wire at 20°C is 1.05Ω and at 100°C is 1.38Ω. Determine the temperature coefficient of resistivity of this metal.

131. **(A) (i)** A rectangular loop of sides a and b carrying current I is placed in a magnetic field $\vec{B}$ such that its area vector $\vec{A}$ makes an angle θ with $\vec{B}$. With the help of a suitable diagram, show that the torque $\vec{\tau}$ acting on the loop is given by $\vec{\tau} = \vec{m} \times \vec{B}$, where $\vec{m}(= I\vec{A})$ is the magnetic dipole moment of the loop.
(ii) A circular coil of 100 turns and radius $\left(\frac{10}{\sqrt{\pi}}\right)$ cm carrying current of 5.0 A is suspended vertically in a uniform horizontal magnetic field of 2.0 T . The field makes an angle 30° with the normal to the coil. Calculate :

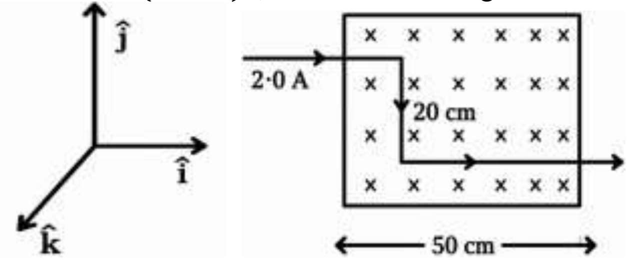
(I) the magnetic dipole moment of the coil, and

(II) the magnitude of the counter torque that must be applied to prevent the coil from turning.

OR

(B) (i) Derive an expression for the force $\vec{F}$ acting on a conductor of length L and area of cross-section A carrying current I and placed in a magnetic field $\vec{B}$.

(ii) A part of a wire carrying 2.0 A current and bent at 90° at two points is placed in a region of uniform magnetic field $\vec{B} = -(0.50\ \text{T})\hat{k}$, as shown in the figure. Calculate the magnitude of the net force acting on the wire.



132. **(A) (i)** A parallel beam of monochromatic light falls normally on a single slit of width ' a ' and a diffraction pattern is observed on a screen placed at distance D from the slits. Explain:

(I) the formation of maxima and minima in the diffraction pattern, and

(II) why the maxima go on becoming weaker and weaker with its increasing number (n).

(ii) Write any two points of difference between interference pattern due to double-slit and diffraction pattern due to single-slit.

OR

(B) (i) With the help of a ray diagram, describe the construction and working of a compound microscope.

(ii) (I) The real image of an object placed between f and 2f from a convex lens can be seen on a screen placed at the image location. If the screen is removed, is the image still there? Explain.

(II) Plane and convex mirrors produce virtual images of objects. Can they produce real images under some circumstances? Explain.

General Instructions :

Read the following instructions carefully and follow them:

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

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

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

133. In a region, the electric potential varies as $V = 10 - 50x$, where V is in volts and x in meters. The electric field in the region is :

(a) 10 N/C along +x (b) 10 N/C along −x
(c) 50 N/C along +x (d) 50 N/C along −x

134. A conducting wire connects two charged metallic spheres A and B of radii r_1 and r_2 respectively. The distance between the spheres is very large compared to their radii. The ratio of electric fields, (E_A/E_B) at the surfaces of spheres A and B will be

(a) $\frac{r_1}{r_2}$ (b) $\frac{r_2}{r_1}$
(c) $\frac{r_1{}^2}{r_2{}^2}$ (d) $\frac{r_2{}^2}{r_1{}^2}$

135. A long straight wire of circular cross-section (radius a) carries a steady current I. The current is uniformly distributed across this cross-section. The magnitude of the magnetic field produced at a point at a distance (a/2) from the axis of the wire will be

(a) Zero (b) $\frac{\mu_0 I}{2\pi a}$
(c) $\frac{\mu_0 I}{4\pi a}$ (d) $\frac{\mu_0 I}{6\pi a}$

136. The shape of the interference fringes in Young's double-slit experiment, when the distance between the slit and the screen is very large as compared to the slit-separation, is nearly

(a) straight (b) parabolic
(c) circular (d) hyperbolic

137. An electromagnetic wave passes from vacuum into a dielectric medium with relative electrical permittivity (3/2) and relative magnetic permeability (8/3). Then, its

(a) wavelength is doubled and frequency remains unchanged.
(b) wavelength is doubled and frequency is halved.
(c) wavelength is halved and frequency remains unchanged.
(d) wavelength and frequency both will remain unchanged.

138. In a series LCR circuit, the voltage across the resistor, capacitor and inductor is 10 V each. If the capacitor is short circuited, the voltage across the inductor will be

(a) 10 V (b) $5\sqrt{2}$ V
(c) $\frac{5}{\sqrt{2}}$ V (d) $10\sqrt{2}$ V

139. Electromagnetic waves used in a diagnostic tool in medicine have a wavelength range

(a) 1 nm to 10^{-3} nm (b) 400 nm to 1 nm
(c) 1 mm to 700 nm (d) 0.1 m to 1 mm

140. The 'distance of closest approach' of an alpha-particle is 'd' when it moves with a velocity v head-on towards the target nucleus. If the velocity of alpha particle is halved, the new 'distance of closest approach' will be -

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

141. A concave lens of focal length 10 cm is cut into two identical plano-concave lenses. The focal length of each lens will be

(a) 20 cm (b) 30 cm
(c) 40 cm (d) 5 cm

142. Four independent waves are expressed as

(I) $y_1 = A_1 \sin\omega t$
(II) $y_2 = A_2 \sin 2\omega t$
(III) $y_3 = A_3 \cos\omega t$
(IV) $y_4 = A_4 \sin(\omega t + \pi/3)$

The interference between two of these waves is possible in
(a)(I) and (III) only (b)(III) and (IV) only
(c)(I), (III) and (IV) only (d)All of them

143. Two heaters rated as (P_1, V) and (P_2, V) are connected in series across a dc source of $\frac{V}{2}$ volt. The power consumed by the combination will be -
(a) $(P_1 + P_2)$ (b) $\frac{P_1+P_2}{2}$
(c) $\frac{P_1P_2}{2(P_1+P_2)}$ (d) $\frac{P_1P_2}{4(P_1+P_2)}$

144. In an unbiased p-n junction, at equilibrium, which of the following statements is true?
(a) Diffusion current is zero but drift current exists.
(b) Diffusion current exists but drift current is zero.
(c) Diffusion and drift currents are equal and opposite.
(d) Both the diffusion and drift currents exist but are unequal.

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

145. Assertion (A) : All atoms have a net magnetic moment.
Reason (R) : A current loop does not always behave as a magnetic dipole.

146. Assertion (A) : If accelerated electrons are passed through a narrow slit, a diffraction pattern is observed.
Reason (R) : Electrons behave as both particles and waves.

147. Reason (A) : The mass of a nucleus is less than the sum of the masses of the constituent nucleons.
Reason (R): Energy is absorbed when the nucleons are bound together to form a nucleus.

148. Reason (A) : In Bohr model of hydrogen atom, the energy levels are discrete and quantised.
Reason (R): In a hydrogen atom, the electrostatic force on the electron provides the necessary centripetal force to it to revolve around the nucleus.

SECTION – B

149. In a photoelectric experiment, the emitter plate is irradiated with radiation of 200 nm . The photocurrent becomes zero when the collector plate potential is -0.80 V . Calculate the work function (in eV) of the emitter.

150. (A) A beam of light consisting of two wavelengths 400 nm and 600 nm is used to illuminate a single slit of width 1 mm . Find the least distance of the point from the central maximum where the dark fringes due to both wavelengths coincide on the screen placed 1.5 m from the slit.

OR

(B) In a Young's double-slit experimental set-up with slit separation 0.6 mm a beam of light consisting of two wavelengths 440 nm and 660 nm is used to obtain interference pattern on a screen kept 1.5 m in front of the slits. Find the least distance of the point from the central maximum where the bright fringes due to both the wavelengths coincide.

151. A wire of length L is bent round into (i) a square coil having N turns and (ii) a circular coil having N turns. The coil in both cases is free to turn about a vertical axis coinciding with the plane of the coil, in a uniform, horizontal magnetic field and carry the same currents. Find the ratio of the maximum value of the torque acting on the square coil to that on the circular coil.

152. What is the order of magnitude of drift velocity of electrons in a conductor ? Deduce the relation between the current flowing through a conductor and drift velocity of electrons in it.

153. Draw the plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions that can be drawn from this plot.

SECTION – C

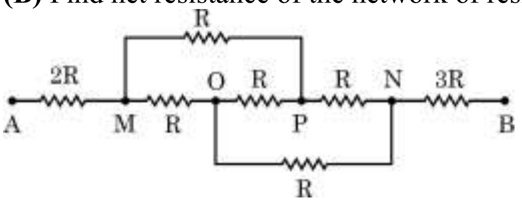
154. **(A)** Using Gauss's law, deduce an experession for electric field at a point due to a uniformly charged infinite plane thin sheet.

(B) Two large thin plane sheets, each having surface charge density σ, are held close and parallel to each other in air. What is the net electric field at a point **(i)** inside and **(ii)** outside, the sheets?

OR

(A) Obtain the condition of balance of a Wheatstone bridge.

(B) Find net resistance of the network of resistors connected between A and B , as shown in figure.



155. A parallel plate capacitor of capacitance C has a dielectric slab between its plates. It is charged to a potential difference V by connecting it across a battery. The battery is then disconnected. If the dielectric slab is now withdrawn from the capacitor, how will the following be affected?

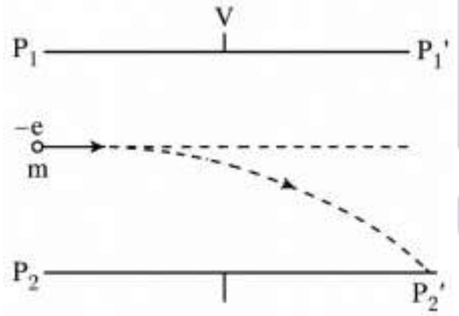
(A) Capacitance of the capacitor,

(B) Energy stored in the capacitor, and

(C) The potential difference between the plates of the capacitor.

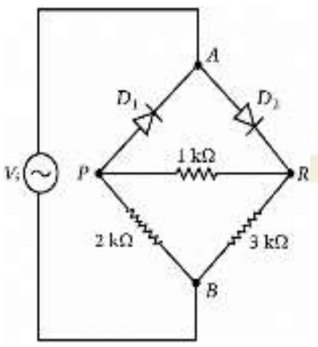
Justify your answer in each case.

156. Figure shows a narrow beam of electrons entering with a velocity of 3×10^7 m/s, symmetrically through the space between two parallel horizontal plates P_1P_1' and P_2P_2' kept 2 cm apart.



If each plate is 3 cm long, calculate the potential difference V applied between the plates so that the beam just strikes the end P_2'.

157.



An ac voltage $V_i = 12\sin(100\pi t)$V is applied between points A and B in a network of two ideal diodes and three resistors as shown in figure.

During the positive half-cycle of the input voltage V_i supplied to the network.

(A) Identify which of the two diodes will conduct and why?

(B) Redraw an equivalent circuit diagram to show the flow of current.

(C) Calculate the output voltage drops V_0 across the three resistors when the input voltage attains its peak value.

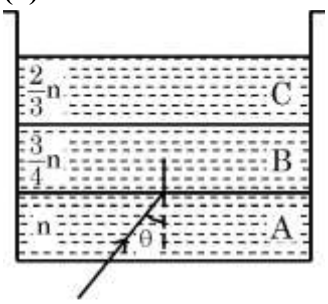
158. Briefly explain the two important processes that occur during the formation of a p-n junction.

159. **(A)** Draw the ray diagram to show the image formation by a refracting telescope and write the expression for angular magnification for the telescope in normal adjustment.

(B) Give two reasons to explain why a reflecting telescope is preferred over a refracting telescope.

160. **(i)** State the two conditions under which total internal reflection occurs.

(ii)



A transparent container contains layers of three immiscible transparent liquids A, B and C of refractive indices n, $\frac{3}{4}$n and $\frac{2}{3}$n, respectively. A laser beam is incident at the interface between A and B at an angle θ as shown in figure. Prove that the beam does not enter region C at all for $\sin\theta \geq \frac{2}{3}$.

SECTION – D

161. A galvanometer is used to detect or/and measure small currents in an electrical circuit. It essentially works on the fact that a current-carrying coil experiences a deflecting torque when placed in a magnetic field. This deflection in the coil can be measured and it is related to the current flowing in the coil, the number of turns in the coil, area of the coil and the magnetic field. A hair spring attached to the coil provides a counter torque and helps in measuring the deflection. A galvanometer can be converted to an ammeter or a voltmeter of desired range by using suitable resistances.

(i) The torque on the coil remains constant irrespective of the coil's orientation during rotation due to
(a) use of soft iron core which increases the magnetic field.
(b) radial magnetic field
(c) hair spring which provides the counter torque
(d) eddy current in the iron core which causes damping.

(ii) The best way to increase current sensitivity of a galvanometer is by
(a) increasing number of turns of the coil
(b) increasing area of coil and magnitic field strength
(c) decreasing area of coil and magnetic field strength
(d) increasing torsional constant of the hair spring

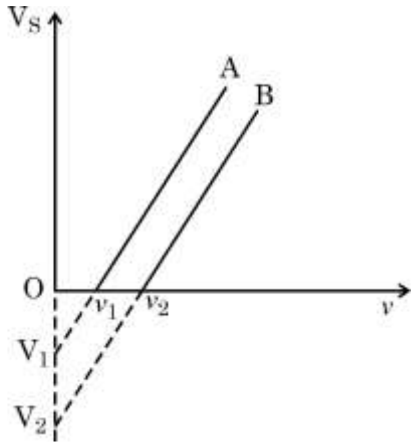
(iii) (A) A moving coil galvanometer has a coil with area of cross-section 4.0×10^{-3} m^2 and number of turns 50 . The coil is rotating in a magnetic field of 0.25 T . The torque acting on the coil when a current of 5 A passes through it is
(a) 1.0 N m (b) 2.0 N m
(c) 0.50 N m (d) 0.25 N m

OR

(B) A galvanometer coil has a resistance of 15Ω and the meter shows full scale deflection for a current of 3 mA . The value of resistance required to convert it into a voltmeter of range $(0-12 \text{ V})$ is
(a) 4015Ω (b) 3985Ω
(c) 415Ω (d) 385Ω

(iv) A galvanometer with coil of resistance 20Ω shows full scale deflection for a current of 5 mA . To convert it into an ammeter of range $(0-10 \text{ A})$, a resistance of
(a) 0.05Ω should be connected in series with it.
(b) 0.05Ω should be connected in parallel with it.
(c) 0.01Ω should be connected in parallel with it.
(d) 0.01Ω should be connected in series with it.

162. A researcher performs an experiment on photo-electric effect using two metals A and B with unknown work functions. She illuminates the surfaces of A and B with monochromatic radiation of various frequencies and records the value of corrosponding stopping potentials (V_s). The graph shows the variation of stopping potential (V_s) with the frequency of incident radiation (v) for metals A and B .



Answer the following questions :

(i) From the graph, the work functions of A and B are (h is Planck's constant and e value of charge on an electron)

(a) v_1 and v_2 (b) V_1 and V_2

(c) hv_1 and hv_2 (d) $\frac{hv_1}{e}$ and $\frac{hv_2}{e}$

(ii) For radiation of frequency $v > v_2$ incident on the surfaces of A and B, the maximum kinetic energy of ejected electron is

(a) greater for metal A because it has a smaller work function.
(b) greater for metal B because it has a larger work function.
(c) greater for metal B because it has higher threshold frequency.
(d) the same for both metal A and metal B because it is independent of work functions of metals.

(iii) If the intensity of the incident radiation for both metals A and B , is doubled keeping its frequency constant, then

(a) the slope of the parallel lines will increase.
(b) the slope of the parallel lines will decrease.
(c) the threshold frequencies for both A and B will decrease.
(d) the slope of the parallel lines will not change but more electrons will be emitted per second.

(iv) (A) The threshold frequency for a metal surface is v_0. If the radiation of frequency $3v_0$ illuminates the surface, the maximum kinetic energy (KE) of photoelectrons is E_1. If the frequency were increased to $6v_0$, the maximum KE of the photoelectrons becomes E_2. Then $\left(\frac{E_1}{E_2}\right)$ equals

(a) 1/3 (b) 1/2
(c) 2/5 (d) 3/4

OR

(B) Let m be the slope of the graph line for metal B . If e is the value of electron charge, then Planck's constant ' h ' is given by

(a) me (b) $\frac{1}{me}$
(c) $\frac{m}{e}$ (d) $\frac{e}{m}$

SECTION – E

163. **(A)** An electric dipole consists of two point charges q and $-q$ separated by a distance 2a. Derive an expression for the electric field $\vec{E}$ due to this dipole at a point distant **r** from the centre of the dipole on the equatorial plane. Write the expression for the electric field at a far off point, i.e. $r \gg a$.

(B) A dipole is placed in $x-y$ plane such that charges q and -q are located at $x = a$ and $x = b$ respectively. There exists an electric field $\vec{E} = 2\hat{i}\frac{N}{C}$ in the region. Calculate the force $\vec{F}$ and torque $\vec{\tau}$ experienced by the dipole.

OR

(A) Two cells of emf E_1 and E_2 with internal resistances r_1 and r_2 respectively, are connected in parallel by connecting their positive terminals together and negative terminals together. Deduce an expression for equivalent emf and equivalent internal resistance of the combination.

(B) A parallel combination, as stated in (a) above, of two cells of emfs E and 3E and internal resistances R each is connected across a resistance 2R. Find the current that flows through resistance 2R.

164. **(A)** Using the relation for refraction at a curved spherical surface, derive the expression for lens maker's formula.

(B) Three lenses L_1, L_2 and L_3, each of focal length 40 cm , are placed coaxially. The distance between L_1 and L_2 and between L_2 and L_3 are 120 cm and 20 cm respectively. An object is kept at a distance of 80 cm to the left of lens L_1.

Find the distance of the final image formed from the object.

OR

(A) Draw a ray diagram to show the image formation by a concave mirror when the object is kept between its focus and the centre of curvature. Using this diagram, derive the mirror formula.

(B) A concave mirror produces a two times magnified virtual image of an object kept 10 cm in front of it. Calculate the focal length of the mirror.

165. **(A)** State Faraday's law of electromagnetic induction.

(B) Derive an expression for the self-inductance of an air-filled long solenoid of length l and cross-sectional area A having N turns.

(C) A conducting rod of length 50 cm , with one end pivoted, is rotated with angular speed of 60 rpm in a uniform magnetic field of 4.0 mT directed perpendicular to the plane of rotation of rod. Find the emf induced in the rod.

OR

(A) Draw a labelled diagram of a step-up transformer. State the principle on which it works and obtain the ratio of secondary voltage to primary voltage in terms of number of turns and currents in the two coils.

(B) The ratio of the number of turns in the primary to the secondary of an ideal transformer is 1: 5. If 5 kW power at 200 V is supplied to the primary, find

(i) current in the primary, and

(ii) output voltage.

General Instructions :

Read the following instructions carefully and follow them:

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

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

(iii) In Section A - Questions no. 1 to 16 are Multiple Choice type questions. Each question carries 1 mark.

(iv) In Section B - Questions no. 17 to 21 are Very Short Answer type questions. Each question carries 2 marks.

(v) In Section C - Questions no. 22 to 28 are Short Answer type questions. Each question carries 3 marks.

(vi) In Section D - Questions no. 29 and 30 are Case Study-based questions. Each question carries 4 marks.

(vii) In Section E - Questions no. 31 to 33 are Long Answer type questions. Each question carries 5 marks.

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

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

(x) Use of calculators is not allowed.

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

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

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

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

$\mu_0 = 4\pi \times 10^{-7}$ TmA^{-1}

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

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

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

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

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

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

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

SECTION - A

166. **How many protons are needed to make 1 nC charge ?**

(a) $1.60 \times 10^{+28}$ (b) $1.60 \times 10^{+10}$

(c) 3.1×10^9 (d) 6.25×10^9

167. A lightning strike can transfer 10^{20} electrons from the cloud to the ground in 2 minutes. The average electric current flown from cloud to the ground is-

(a) 8.0 A (b) 1.96×10^{-2} A

(c) 4.0 A (d) 1.33×10^{-1} A

168. An electric current can be induced in a wire loop if -

(a) the wire loop is wound around a bar magnet.

(b) a bar magnet is placed in contact with the wire loop.

(c) a bar magnet is placed near the wire loop.

(d) a bar magnet is moved rapidly towards the wire loop.

169. The process that allows light to travel through a tube which is not straight is -

(a) reflection of light (b) dispersion of light

(c) scattering of light (d) total internal reflection

170. A beam of blue light is incident on a metal surface with a work function of $\phi_0 = \frac{hc}{550 \text{ nm}}$ and photoelectrons are ejected from the surface. If the blue light is replaced by red light of same intensity, then

(a) emitted electrons will be more energetic.

(b) emitted electrons will be less energetic.

(c) no electrons are emitted.

(d) less number of electrons are emitted.

171. An electron and a proton are accelerated through the same potential difference. Let λ_e and λ_p be the de Broglie wavelength associated with electron and proton respectively. Then λ_e/λ_p is

(a) m_e/m_p (b) m_p/m_e

(c) $\sqrt{\frac{m_e}{m_p}}$ (d) $\sqrt{\frac{m_p}{m_e}}$

172. Suppose there is an atom that contains five energy levels. How many transitions are possible in which photons are emitted?

(a) 4 (b) 5

(c) 10 (d) 15

173. Which of the following particles do not exist in ${}_{92}U^{238}$ nucleus?

(a) 92 protons (b) 92 electrons

(c) 146 neutrons (d) 238 nucleons

174. The main source for energy generation in the stars is -

(a) fusion of lighter nuclei

(b) fission of heavy nuclei

(c) chemical reaction

(d) fusion of heavy nuclei

175. In Bohr's model of hydrogen atom, the potential energy of the electron in the ground state is -

(a) -27.2 eV (b) 27.2 eV

(c) -13.6 eV (d) 13.6 eV

176. A n-type semiconductor is obtained by doping silicon with

(a) Boron (b) Arsenic

(c) Indium (d) Aluminium

177. When a forward biasing is applied across a junction diode, it -

(a) raises the potential barrier height.

(b) decreases the depletion layer width.

(c) increases the resistance of the p-n junction.

(d) reduces the majority carrier current to zero.

Question number 13 to 16 are Assertion (A) and Reason (R) type questions. Two statements are given - one labelled as Assertion (A) and 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 Assertion (A).
(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of Assertion (A).
(c) Assertion (A) is true, but Reason (R) is false.
(d) Both Assertion (A) and Reason (R) are false.

178. **Assertion (A) :** Displacement current does not have the same physical effect as the conduction current.
Reason (R) : The concept of displacement current is introduced only to satisfy Kirchhoff's rules.

179. **Assertion (A) :** In a series LCR circuit at resonance, the impedance is equal to ohmic resistance (R) in the circuit.
Reason (R) : At resonance, the capacitive reactance is not equal to the inductive reactance.

180. **Assertion (A) :** When a ray of light enters from air into glass, frequency of light remains the same.
Reason (R) : The speed and wavelength of light both changes in glass.

181. **Assertion (A):** Photoelectric effect demonstrates particle nature of light.
Reason (R) : The number of photoelectrons emitted from a surface depends upon the intensity of radiation.

SECTION – B

182. **A battery of emf 6 V and internal resistance 1Ω is connected to a resistor. The current in the circuit is 0.5 A . Calculate**
(i) the resistance of the resistor and
(ii) the terminal voltage of the battery.

183. **(A)** A ray of light travelling along the principal axis is incident on a spherical mirror and reflected back along the same path. Explain, why?

OR

(B) Write all the sign convention followed for a convex lens.

184. A small object is placed in air in front of a convex glass surface ($n = 1.5$ and radius of curvature 20 cm) at a distance of 50 cm from it. Find the position and nature of the image.

185. What is meant by threshold frequency (v_0) for photoelectric emission ? Does it depends on the intensity of light ? How does photoelectric current vary with the intensities of radiation of frequency $v(> v_0)$?

186. Differentiate between n -type and p-type semiconductors.

SECTION – C

187. **(A)** **(i)** An electric field $\vec{E}$ is maintained in a conductor of length L and area of cross-section A . Show that the electrons drift with an average velocity $\vec{v}_d = \frac{-e\vec{E}}{m}\tau$. Here symbols have their usual meanings.
(ii) Electrons in metals drift due to force experienced by electrons in the electric field inside the conductor. Thus, the motion of electrons should be accelerated. Then why do the electrons acquire a steady average drift speed?

OR

(B) Define resistance of a conductor and give its units. Name the factors on which the resistance of conductor at a fixed temperature depends. Write the corresponding relation between them.

188. **(A)** A straight vertical wire carries a current of 3 A upward along +z axis. Calculate the magnitude and direction of the magnetic field at a point 15 cm away from the wire on +x -axis. Name the rule used to find the direction of magnetic field.
(B) A flexible loop of irregular shape carrying current is placed in an external magnetic field. Why does it change to circular shape?

189. **(A)** Briefly explain how Lenz's law is consistent with the law of conservation of energy.
(B) Considering the case of the magnetic field B inside a solenoid of length l, area of cross-section A , prove that magnetic energy per unit volume is $B^2/(2\mu_o)$.

190. **(A)** A sinusoidal electromagnetic wave of frequency 40 MHz travels in free space in the x-direction. Calculate the wavelength and time period of the wave.
(B) At some point and at some instant the electric field in the above electromagnetic wave has its maximum value of 750 N/C and is along the y -axis. Calculate the magnitude and direction of the magnetic field at this position and time.

191. What are coherent sources of light ? Why are coherent sources of light required to produce interference of light ? Give an example of interference of light in daily life.

192. The total energy of an electron is an orbit in Bohr model of hydrogen atom is -3.4 eV . Calculate :

(i) the angular momentum of the electron, in this orbit and

(ii) the potential energy of the electron, in this orbit.

193. **(A)** Explain the working of a junction diode as a half-wave rectifier.

(B) The efficiency of a half-wave rectifier is 40%. What happens to the remaining 60% power?

SECTION – D

194. When an electric dipole of charges $\pm q$ and dipole moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$ making an angle θ with the electric field $\vec{E}$, then two charges experience equal and opposite forces $+q\vec{E}$ and $-q\vec{E}$. These equal and opposite forces cancel each other. As the two forces are not collinear so a torque acts on the dipole. Since the net force acting on the dipole is zero, no work is done in moving the electric dipole in a uniform electric field, but some work will be done in rotating the dipole against the torque acting on it.

(i) Two charges $+q$ and $-q$ are located at points (a, 0) and (3a, 0) on x -axis. The dipole moment of the system has magnitude

(a) 2qa and is along +x-axis.

(b) 2qa and is along-x-axis.

(c) qa and is along +x-axis.

(d) qa and is along-x-axis.

(ii) The magnitude of electric field at a certain distance from a dipole on its axis is E_1 and at the same distance on the equatorial plane of the dipole is E_2. Then $\left(\frac{E_1}{E_2}\right)$ is

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

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

(iii) (A) An electric dipole having dipole moment of 4×10^{-9}Cm is placed in a uniform electric field of 5×10^4 N/C. If the angle between the dipole moment and the electric field is 30° then the value of potential energy of the dipole is -

(a) 3.23×10^{-4} J (b) 1.0×10^{-5} J

(c) 1.73×10^{-4} J (d) 5×10^4 J

OR

(B) The dimensional formula of dipole moment is -

(a) $[L^2\ T^2\ A^{-2}]$ (b) $[M^2\ L^2TA^2]$

(c) $[LTA^2]$ (d) $[LTA]$

(iv) An electric dipole of dipole moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$. The torque exerted by the field on the dipole at that instant is -

(a) parallel to both the $\vec{E}$&$\vec{p}$.

(b) perpendicular to both $\vec{E}$&$\vec{p}$.

(c) parallel to $\vec{E}$ and perpendicular to $\vec{p}$.

(d) perpendicular to $\vec{E}$ and parallel to $\vec{p}$.

195. A charged particle is moving horizontally with a velocity $\vec{v}$. If a uniform magnetic field $\vec{B}$ directly vertically up is set-up in the region, the particle moves in a circle of radius R in anticlockwise direction.

(i) The charged particle exhibiting this motion is

(a) electron (b) proton

(c) alpha-particle (d) neutron

(ii) The direction of the magnetic force acting on the moving particle is given by -

(a) Biot-Savart's law (b) Lenz's law

(c) Ampere's circuital law (d) Right hand rule

(iii) (A) If the velocity of the particle is doubled, the radius of the circle described will be

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

(c) 2 R (d) R

OR

(B) A particle having charge 1μC is moving with a velocity of $5 \times 10^6\ ms^{-1}$ in a uniform magnetic field of 1 T . If the angle between the velocity ($\vec{v}$) and the magnetic field ($\vec{B}$) is 30°, the magnitude of the force on the particle will be -

(a) 25 N (b) 5 N
(c) 2.5 N (d) 1.2 N

(iv) The frequency of revolution of a particle of mass m and charge q , moving with speed v along a circular path of radius R, in magnetic field $\vec{B}$ (perpendicular to $\vec{v}$) will be

(a) $\frac{mv}{qB}$ (b) $\frac{qB}{2\pi m}$
(c) $\frac{qB}{2\pi R}$ (d) $\frac{\pi m}{2qB}$

SECTION – E

196. **(A)** Deduce the relation between the electric field ($\vec{E}$) at a point due to a charge Q and

(i) the force $\vec{F}$ on a charge q placed at that point.

(ii) the potential at that point due to charge Q .

(B) Three point charges, q each, are placed at the three vertices of an equilateral triangle of side ' a '. Obtain an expression for the net force on one charge due to the other two charges.

OR

(A) Derive an expression for the energy stored in a parallel plate capacitor having air between its plates. How will the energy stored in the capacitor be affected when space between its plates is filled by a medium of dielectric constant K. Justify your answer.

(B) A parallel plate capacitor of plate area A and plate separation d is completely filled with two dielectric slabs of dielectric constants K_1 and K_2, each of area $\frac{A}{2}$. Find the effective capacitance of the capacitor.

197. **(A)** Define mutual inductance. Give its units. State two factors on which the mutual inductance between a given pair of coils depends.

(B) A 1.0 m long solenoid of radius 2 cm having 2000 turns has a secondary coil of 1000 turns wound closely near its midpoint. Find the mutual inductance between the two coils.

OR

(A) Prove that in an ac circuit containing only a pure inductor, the voltage is ahead of the current in phase by $\frac{\pi}{2}$ radian. Hence define inductive reactance.

(B) The instaneous value of a voltage (in volt) is given by $E = 140 \sin 314t$, where t is in seconds. Find :

(i) rms value of the applied voltage.

(ii) the frequency of ac supply.

198. **(A)** In a single slit diffraction pattern, how is the angular width of central maximum affected when

(i) slit width is increased

(ii) the distance between the slit and the screen is increased.

(iii) light of smaller wavelength is used.

Justify your answer.

(B) A slit of width d is illuminated by light of wavelength 700 nm . Find the value of d for which the first minimum falls at an angle of 30°.

OR

(A) Briefly explain the working of a reflecting type telescope. Write its two advantages over a refracting telescope.

(B) A telescope consists of two lenses of focal length 125 cm and 5 cm . Find its magnifying power when final image is at **(i)** infinity **(ii)** at a distance of 25 cm from eye.