QUESTION PAPER-1
PHYSICS

Time Allowed : 3.00 Hours   **Maximum Marks : 70**

General Instructions :

1.   There are 33 questions in all. All questions are compulsory.

2.   This question paper has five sections: Section A, Section B, Section C, Section D and Section E.

3.   All the sections are compulsory.

4.   Section A contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, Section B contains five questions of two marks each, Section C contains seven questions of three marks each, Section D contains two case study based questions of four marks each and Section E contains three long answer questions of five marks each.

5.   There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C, one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions.

6.   Use of calculators is not allowed.

7.   You may use the following values of physical constants where ever necessary

    i. $c = 3 \times 10^8$ m/s   ii. $m_e = 9.1 \times 10^{-31}$ kg

    iii. $e = 1.6 \times 10^{-19}$ C   iv. $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}

    v. $h = 6.63 \times 10^{-34}$ Js   vi. $\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}

    vii. Avogadro's number = 6.023×10^{23} per gram mole

SECTION-A

1.   The variation potential V with r and electric field E with r for a point charge is correctly shown in the graph
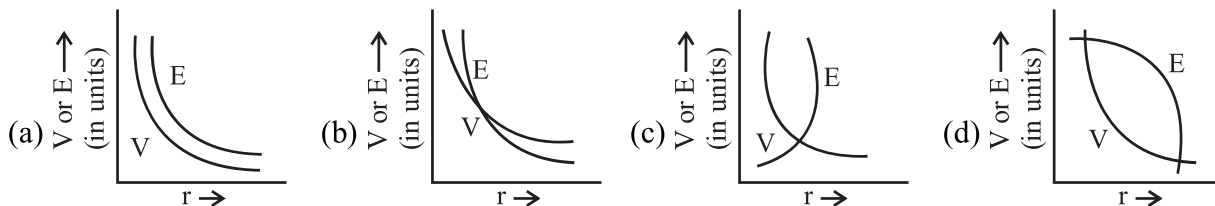
2.   Two charges q_1 and q_2 are placed at the centres of two spherical counducting shells of radius r_1 and r_2 respectively. The shells are arranged such that their centres are d $[> (r_1 + r_2)]$ distance apart. The force on q_2 due to q_1 is

(a) $\dfrac{1}{4\pi\varepsilon_0} \dfrac{q_1 q_2}{d^2}$ (b) $\dfrac{1}{4\pi\varepsilon_0} \dfrac{q_1 q_2}{(d - r_1)^2}$

(c) Zero   (d) $\dfrac{1}{4\pi\varepsilon_0} \dfrac{q_1 q_2}{\left[d - (r_1 + r_2) \right]^2}$

3. A metallic plate exposed to white light emits electrons. For which of the following colours of light, the stopping potential will be maximum?
   (a) Blue   (b) Yellow   (c) Red   (d) Violet

4. When alpha particles are sent through a thin gold foil, most of them go straight through the foil, because
   (a) alpha particles are positively charged
   (b) the mass of an alpha particle is more than the mass of an electron
   (c) most of the part of an atom is empty space
   (d) alpha particles move with high velocity

5. An electron is moving along positive x-axis in a magnetic field which is parallel to the positive y-axis. In what direction will the magnetic force be acting on the electron?
   (a) Along −x axis   (b) Along −z axis   (c) Along +z axis   (d) Along −y axis

6. Above Curie temperature, a
   (a) ferromagnetic material becomes diamagnetic.   (b) ferromagnetic material becomes paramagnetic
   (c) paramagnetic material becomes ferromagnetic   (d) paramagnetic material becomes diamagnetic.

7. In an ammeter 4% of the mains current is passing through galvanometer. If the galvanometer is shunted with a 5 resistance, then resistance of galvanometer will be
   (a) 116 Ω   (b) 117 Ω   (c) 118 Ω   (d) 120 Ω

8. An electron with angular momentum L moving around the nucleus has a magnetic moment given by
   (a) eL/2m   (b) eL/3m   (c) eL/4m   (d) eL/m

9. Which among the following is not a cause for power loss in a transformer ?
   (a) Eddy currents are produced in the soft iron core of a transformer.
   (b) Electric flux sharing not properly done in primary and secondary coils.
   (c) Humming sound produced in the transformers due to magnetostriction.
   (d) Primary coil is made up of a very thick copper wire.

10. During the propagation of electromagnetic waves in a medium
    (a) electric energy density is double of the magnetic energy density.
    (b) electric energy density is half of the magnetic energy density.
    (c) electric energy density is equal to the magnetic energy density.
    (d) both electric and magnetic energy densities are zero.

11. Figure shows a rectangular conductor PSRQ in which movable arm PQ has a resistance 'r and resistance of PSRQ is negligible. The magnitude of emf induced when PQ is moved with a velocity $\vec{v}$ does not depend on
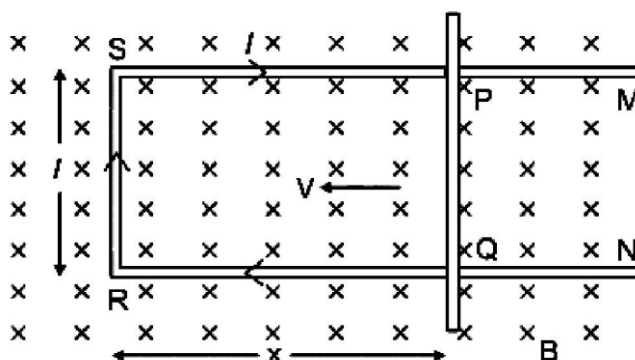
(a) magnetic field $\vec{B}$ (b) velocity field $\vec{v}$ (c) resistance (r)   (d) length of PQ

12.   The energy of an electron in n^{th} orbit of hydrogen atom is $E_n = -13.6/n^2$ eV. The negative sign of energy indicates that

(a) electron is free to move.

(b) electron is bound to the nucleus.

(c) kinetic energy of electron is equal to potential energy of electron.

(d) atom is radiating energy.

13.   **Assertion (A) :** An electron and a photon possessing same wavelength, will have the same momentum.

Reason (R) : Momentum of both particle is same by de-Broglie hypothesis.

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

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

(c) (A) is true but (R) is false

(d) (A) is false but (R) is true

14.   **Assertion (A) :** When the temperature of a semiconductor is increased, the its resistance decrease.

Reason (R) : The energy gap between valence and conduction bands is very small for semiconductors.

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

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

(c) (A) is true but (R) is false

(d) (A) is false but (R) is true

15.   **Assertion (A) :** An electron has a higher potential energy when it is at a location associated with a negative value of potential and has a lower potential energy when at a location associated with a positive potential.

Reason (R) : Electrons move from a region of higher potential to a region of lower potential.

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

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

(c) (A) is true but (R) is false

(d) (A) is false but (R) is true

16.   **Assertion (A) :** If a convex lens is kept in water, its convergence power decreases.

Reason (R) : The refractive index of convex lens relative to water is less than that relative to air.

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

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

(c) (A) is true but (R) is false

(d) (A) is false but (R) is true

SECTION-B

17.   (a) Name the device which utilizes unilateral action of a p-n diode to convert ac into dc.

(b) Draw the circuit diagram of full wave rectifier.

18. Plot a graph showing variation of de Broglie wavelength λ versus $\dfrac{1}{\sqrt{V}}$, where V is accelerating potential for two particles A and B carrying same charge but of masses m_1, m_2 ($m_1 > m_2$). Which one of the two represents a particle of smaller mass and why ?

19. (a) Explain briefly how the focal length of a convex lens changes with increase in wavelength of incident light.

   (b) What happens to the focal length of convex lens when it is immersed in water? Refractive index of the material of lens is greater than that of water.

20. Draw a graph to show a variation of resistance of a metal wire as a function of its diameter keeping its length and material constant.

21. Show that the least possible distance between an object and its real image in a convex lens is 4f, where f is the focal length of the lens.

<div align="center">OR</div>

   In an astronomical telescope in normal adjustment a straight black line of length L is drawn on the objective lens. The eyepiece forms a real image of this line whose length is l. What is the angular magnification of the telescope ?
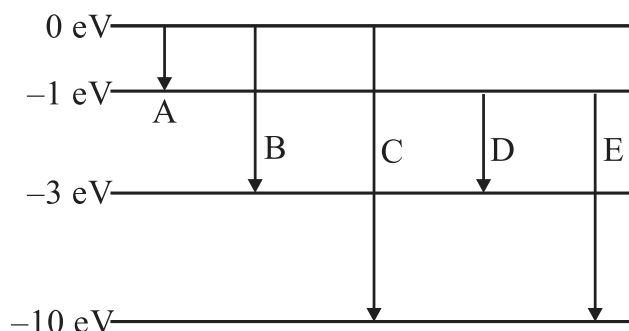
<div align="center">SECTION-C</div>

22. (a) In the following nuclear reaction

   $$n + {}^{235}_{92}U \rightarrow {}^{144}_{Z}Ba + {}^{A}_{36}X + 3n$$

   assign the values of Z and A.

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

23. A thin metallic spherical shell of radius R carries a charge Q on its surface. A point charge $\dfrac{Q}{2}$ is placed at the centre C and another charge +2Q is placed outside the shell at A at a distance x from the centre as shown in the figure.
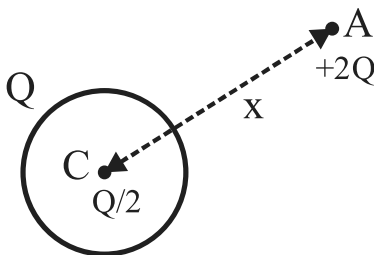

   (i) Find the electric flux through the shell.

   (ii) State the law used.

   (iii) Find the force on the charges at the centre C of the shell and at the point A.

24. The energy lelvels of an atom are given below in the diagram


Which of the transitions belong to Lyman and Balmer series ? Calculate the ratio of the shortest wavelengths of the Lyman and the Balmer series of the spectra.

25. A wire of uniform cross-section and resistance 4 ohm is bent in the shape of square ABCD. Point A is connected to a point P on DC by a wire AP of resistance 1 ohm. When a potential difference is applied between A and C, the points B and P are seen to be at the same potential. What is the resistance of the part DP ?
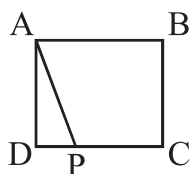
26. The given figure shows a long straight wire of a circular cross-section (radius a) carrying steady current I. The current I is uniformly distributed across this cross-section. Calculate the magnetic field in the region $r < a$ and $r > a$.
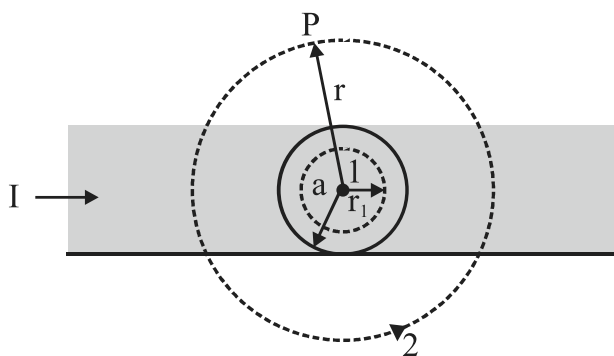
27. What is a displacement current ? How is it different from a conduction current ?

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

OR

Two long straight parallel current carrying conductors are kept 'a' distant apart in air. The direction of current in both the conductors is same. Find the magnitude of force per unit length and direction of the force between them. Hence define one ampere.

SECTION-D
Case Study based quenstions

29. Read the paragraph given below and answer the questions that follow-

Motions of the Charge Carriers : If you burst a helium-filled balloon, helium atoms will diffuse (spread) outward into the surrounding air. This happens because these are very few helium atoms in normal air. In more formal language, there is a helium density gradient at the balloon-air interface (the number density of helium atoms varies across the interface), the helium atoms move so as to reduce the gradient.
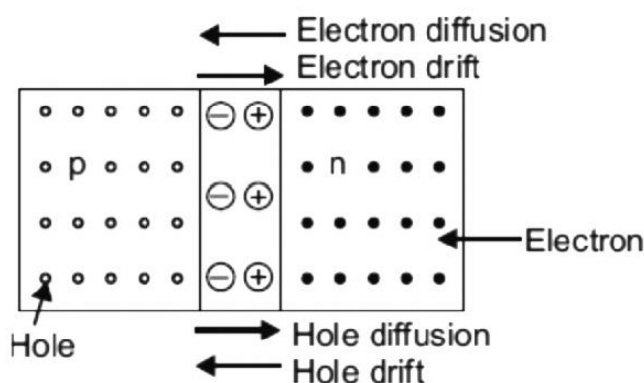
In same way, electrons on the n-side are close to the junction plane tend to diffuse across it and into the p-side, where there are very few free electrons. Similarly, holes on the p-side are close to the junction plane tend to diffuse across that plane and into the n-side, where there are very few holes. The motions of both the electrons and the holes contribute to a diffusion current ($I_{diff.}$).

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

(a) Phosphorus   (b) Gallium   (c) Bismuth   (d) Germanium

(ii) A semiconductor has an electron concentration of 6×10^{22} per m^3 and hole concentration of 8.5×10^9 per m^3. Then it is

(a) n-type semiconductor   (b) p-type semi conductor

(c) intrinsic semiconductor   (d) conductor

(iii) In a p-n-junction diode

(a) the current in the reverse biased condition is generally very small $\sim \mu A$

(b) the current in the reverse biased condition is small but the forward biased current is independent of the bias voltage

(c) the reverse biased current is strongly dependent on the applied voltage

(d) the forward biased current is very small in comparison to reverse biased current

(iv) In the middle of the depletion layer of a reverse biased p-n junction, the

(a) electric field is zero   (b) potential is maximum

(c) electric field is maximum   (d) potential is zero

OR

The dominant mechanism for the motion of charge carriers in forward and reverse biased silicon junctions are

(a) drift in forward bias, diffusion in reverse bias

(b) diffusion in forward bias, drift in reverse bias

(c) diffusion in both forward and reverse bias

(d) drift in both forward and reverse bias

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

(i) How will the power of lens affected with an increase of wavelength of light ?

(a) increases   (b) decreases

(c) first increases then decreases   (d) first decreases then increases

(ii) The radius of curvatures of two surface of a convex lens is R. For what value of μ of its material will its focal length become equal to R ?

(a) 1   (b) 1.5   (c) 2   (d) infinite

(iii) An object is immersed in a fluid. In order that the object becomes invisible, it should

(a) behave as perfect reflector

(b) absorb all the light falling on it

(c) have refractive index 1

(d) have refractive index exactly matching with that of the surrounding fluid

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

(a) –40 cm   (b) 40 cm   (c) –80 cm   (d) 80 cm

OR

The focal length of a concave lens of $\mu = 1.5$ is 20 cm is air. It is completely immersed in water $\mu = \dfrac{4}{3}$. Its focal length in water will be

(1) 20 cm   (2) 40 cm   (3) 60 cm   (4) 80 cm

31. With the help of a ray diagram, show the formation of image of a point object due to refraction of light at a spherical surface separating two media of refractive indices n_1 and n_2 $(n_2 > n_1)$ respectively. Using this diagram, derive the relation

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

Write the sign conventions used. What happens to the focal length of convex lens when it is immersed in water ?

OR

(i) Define a wavefront. How is it different from a ray ?

(ii) Using Huygens's construction of secondary wavelets draw a diagram showing the passage of a plane wavefront from a denser to a rarer medium. Using it verify Snell's law.

(iii) In a double slit experiment using light of wavelength 600 nm and the angular width of the fringe formed on a distant screen is 0.1°. Find the spacing between the two slits.

(iv) Write two differences between interference pattern and diffraction pattern./

32. (i) Derive an expression for the capacitance of a parallel plate capacitor with air present between the two plates.

(ii) Obtain the equivalent capacitance of the network shown in figure. For a 300 V supply, determine the charge on each capacitor.
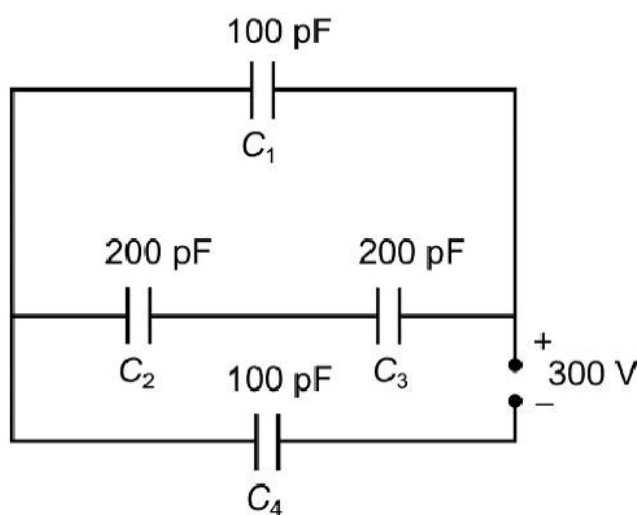

OR

(i) A dielectric slab of thickness 't' is kept between the plates of a parallel plate capacitor with plate separation 'd' (t < d). Derive the expression for the capacitance of the capacitor.

(ii) A capacitor of capacity C_1 is charged to the potential of V_0. On disconnecting with the battery, it is connected with an uncharged capacitor of capacity C_2 as shown in the adjoining figure. Find the ratio of energies before and after the connection of switch S.
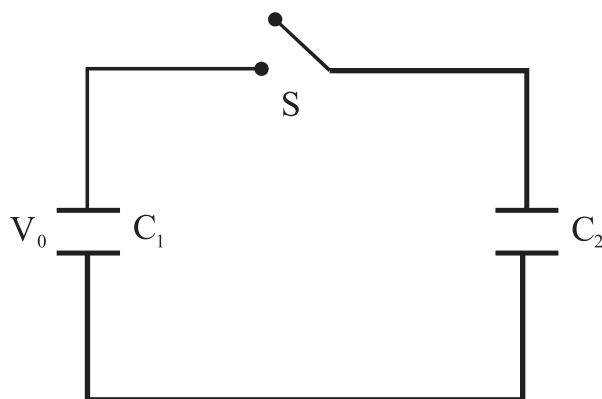
33. A device 'X' is connected to an ac source $V = V_0 \sin \omega t$. The variation of voltage, current and power in one cycle is shown in the following graph :
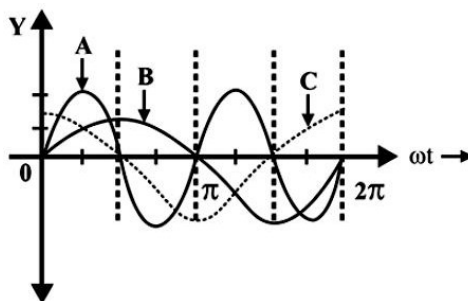
(a) Identify the device 'X'.

(b) Which of the curves, A, B and C represent the voltage, current and the power consumed in the circuit? Justify your answer.

(c) How does its impedance vary with frequency of the ac source ? Show graphically.

(d) Obtain an expression for the current in the circuit and its phase relation with ac voltage.

OR

(i) A series LCR circuit is connected to an ac source. Using the phasor diagram, derive the expression for the impedance of the circuit.

(ii) Plot a graph to show the variation of current with frequency of the ac source, explaining the nature of its variation for two different resistances R_1 and R_2 $(R_1 < R_2)$ at resonance.