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

$h = 6{\cdot}63 \times 10^{-34}$ Js

$e = 1{\cdot}6 \times 10^{-19}$ C

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

$\varepsilon_0 = 8{\cdot}854 \times 10^{-12}$ 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) = $9{\cdot}1 \times 10^{-31}$ kg

Mass of neutron = $1{\cdot}675 \times 10^{-27}$ kg

Mass of proton = $1{\cdot}673 \times 10^{-27}$ kg

Avogadro's number = $6{\cdot}023 \times 10^{23}$ per gram mole

Boltzmann constant = $1{\cdot}38 \times 10^{-23}$ JK^{-1}

SECTION A

1. A wire of resistance R, connected to an ideal battery consumes a power P. If the wire is gradually stretched to double its initial length, and connected across the same battery, the power consumed will be :

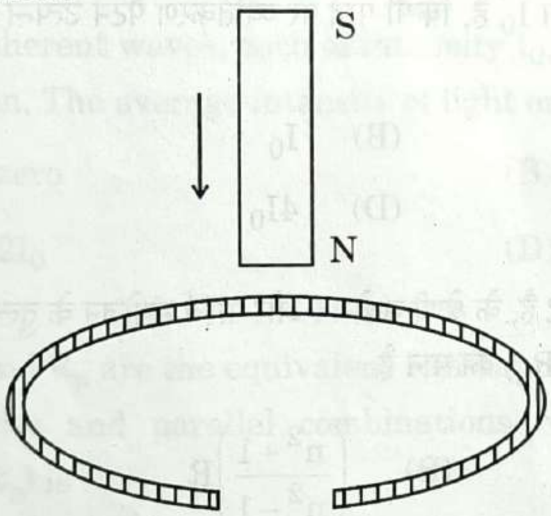
   (A) $\frac{P}{4}$

   (B) $\frac{P}{2}$

   (C) P

   (D) 2P

2. A vertically held bar magnet is dropped along the axis of a copper ring having a cut as shown in the diagram. The acceleration of the falling magnet is :



   (A) zero (B) less than g

   (C) g (D) greater than g

3. A straight conductor is carrying a current of 2 A in +x direction along it. A uniform magnetic field $\vec{B} = (0{\cdot}6\,\hat{j} + 0{\cdot}8\,\hat{k})$ T is switched on, in the region. The force acting on 10 cm length of the conductor is :

   (A) $(0{\cdot}12\,\hat{j} - 0{\cdot}16\,\hat{k})$ N (B) $(-0{\cdot}16\,\hat{j} + 0{\cdot}12\,\hat{k})$ N

   (C) $(-0{\cdot}12\,\hat{j} + 0{\cdot}16\,\hat{k})$ N (D) $(0{\cdot}16\,\hat{j} - 0{\cdot}12\,\hat{k})$ N

4. An ac source is connected to a resistor and an inductor in series. The voltage across the resistor and inductor are 8 V and 6 V respectively. The voltage of the source is :

(A) 10 V (B) 12 V

(C) 14 V (D) 16 V

5. A proton and an α-particle enter with the same velocity $\vec{v}$ in a uniform magnetic field $\vec{B}$ such that $\vec{v} \perp \vec{B}$. The ratio of the radii of their paths is :

(A) 2 (B) $\frac{1}{2}$

(C) $\frac{1}{4}$ (D) 4

6. Two coherent waves, each of intensity I_0, produce interference pattern on a screen. The average intensity of light on the screen is :

(A) zero (B) I_0

(C) $2I_0$ (D) $4I_0$

7. If R_s and R_p are the equivalent resistances of n resistors, each of value R, in series and parallel combinations respectively, then the value of $(R_s - R_p)$ is :

(A) $\left(\frac{n^2-1}{n^2}\right)R$ (B) $\left(\frac{n^2+1}{n^2-1}\right)R$

(C) $\left(\frac{n^2-1}{n}\right)R$ (D) $\frac{(n^2+1)R}{n^2}$

8. A galvanometer can be converted into an ammeter of desired range by connecting a :

(A) small resistance in series (B) large resistance in series

(C) small resistance in parallel (D) large resistance in parallel

9. Inside a nucleus, the nuclear forces between proton and proton, proton and neutron, neutron and neutron are F_{pp}, F_{pn} and F_{nn} respectively. Then :

(A) $F_{pp} > F_{pn} > F_{nn}$

(B) $F_{pn} > F_{nn} > F_{pp}$

(C) $F_{nn} > F_{pp} > F_{pn}$

(D) $F_{pp} = F_{pn} = F_{nn}$

10. The de Broglie wavelength associated with an electron moving with energy 5 eV is :

(A) 0·75 nm (B) 1·2 nm

(C) 2·4 nm (D) 0·55 nm

11. A piece of a diamagnetic material, free to move when placed in a uniform magnetic field :

(A) moves along the field

(B) moves opposite to the field

(C) moves perpendicular to the field

(D) does not move at all

12. The momentum (in kg m/s) of a photon of frequency 6.0×10^{14} Hz is :

(A) 6.63×10^{-25}

(B) 1.326×10^{-27}

(C) 2.652×10^{-26}

(D) 3.978×10^{-24}

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*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.

13. *Assertion (A) :* A hole is an apparent free particle with effective positive electronic charge.

Reason (R) : A hole is not necessarily a vacancy left behind by an electron in the valence band.

14. *Assertion (A) :* In a reflecting telescope, the image does not have chromatic aberration.

Reason (R) : Chromatic aberration occurs only due to refraction of light through an optical medium.

15. *Assertion (A) :* The binding energy per nucleon is practically constant for mass number in the range $(30 < A < 170)$.

Reason (R) : Nuclear forces between the nucleons for mass numbers in the range $(30 < A < 170)$ are not short-range.

16. *Assertion (A) :* X-rays are produced when slow moving electrons are stopped by a metal target of high atomic number.

Reason (R) : X-rays consist of low-energy photons.

SECTION B

17. A cell of emf E and internal resistance r is connected to an external variable resistance R. Plot a graph showing the variation of terminal voltage V of the cell as a function of current I, supplied by the cell. Explain how the emf of the cell and its internal resistance can be found from it. 2

18. In an n-type semiconductor electron-hole combination is a continuous process at room temperature. Yet the electron concentration is always greater than the hole concentration in it. Explain. 2

19. A laser beam of wavelength 500 nm and power 5 mW strikes normally on a perfectly reflecting surface of area 1 mm^2 of a body. It rebounds back from the surface. Find the force exerted by the laser beam on the body. 2

20. A ray of light is incident on face AB of a prism ABC with angle of prism A and emerges out from face AC. The prism is set in the position of minimum deviation with angle of deviation δ. Find (i) the angle of incidence and (ii) the angle of refraction on face AB. 2

21. (a) Find the intensity at a point on the screen in Young's double slit experiment, at which the interfering waves of intensity I_0 each, have a path difference of (i) $\frac{\lambda}{3}$, and (ii) $\frac{\lambda}{2}$. 2

OR

(b) A point source of light in air is kept at a distance of 12 cm in front of a convex spherical surface of glass of refractive index 1·5 and radius of curvature 30 cm. Find the nature and position of the image formed. 2

SECTION C

22. (a) Define the term 'drift velocity' of conduction electrons in a conductor.

(b) A conductor of length l and area of cross-section A is connected across an ideal battery of emf V. Derive the formula for the current density in terms of relaxation time τ. *3*

23. (a) State Lenz's law. A rod MN of length L is rotated about an axis passing through its end M perpendicular to its length, with a constant angular velocity ω in a uniform magnetic field $\vec{B}$ parallel to the axis. Obtain an expression for emf induced between its ends. *3*

OR

(b) Define 'self-inductance' of a coil. Derive an expression for self-inductance of a long solenoid of cross-sectional area A and length l, having n turns per unit length. *3*

24. A ray of light is incident at an angle i on a parallel sided glass slab of thickness 'd' and gets refracted into the slab at angle r. Draw a ray diagram to show its path as its emerges out of the slab. Hence, obtain an expression for the lateral shift of the ray. Under what condition will the shift be minimum ? *3*

25. Describe briefly Geiger-Marsden scattering experiment. Depict the graph showing the variation of number of scattered particles detected with the scattering angle. How did this graph lead to the discovery of the nucleus ? *3*

26. Find the Q value of the following nuclear reaction :

$${}^{12}_{6}C + {}^{12}_{6}C \longrightarrow {}^{20}_{10}Ne + {}^{4}_{2}He$$

Is this reaction exothermic or endothermic ? 3

Given :

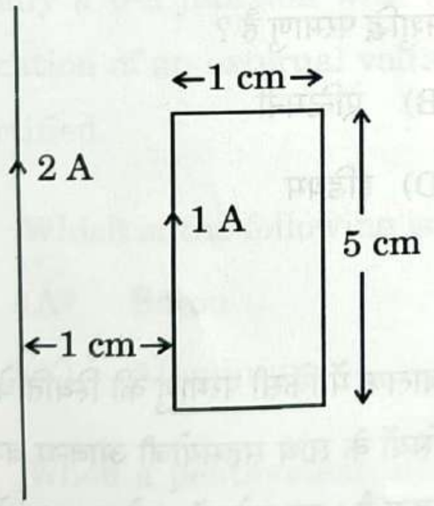
$$m\left({}^{12}_{6}C\right) = 12 \cdot 000000 \text{ u}$$

$$m\left({}^{20}_{10}Ne\right) = 19 \cdot 992439 \text{ u}$$

$$m\left({}^{4}_{2}He\right) = 4 \cdot 002603 \text{ u}$$

$$1 \text{ u} = 931 \text{ MeV}/c^2$$

27. A rectangular loop carries a current of 1 A. A straight long wire carrying 2 A current is kept near the loop in the same plane as shown in the figure.



Find : 3

(i) the torque acting on the loop, and

(ii) the magnitude and direction of the net force on the loop.

28. Name the electromagnetic wave used (i) in radar, (ii) in eye surgery and (iii) as diagnostic tool in medicine. Write their wavelength range also. 3

SECTION D

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

29. Extrinsic semiconductors are made by doping pure or intrinsic semiconductors with suitable impurity. There are two type of dopants used in doping, Si or Ge, and using them p-type and n-type semiconductors can be obtained. A p-n junction is the basic building block of many semiconductor devices. Two important processes occur during the formation of a p-n junction : diffusion and drift. When such a junction is formed, a 'depletion layer' is created consisting of immobile ion-cores. This is responsible for a junction potential barrier. The width of a depletion layer and the height of potential barrier changes when a junction is forward-biased or reverse-biased. A semiconductor diode is basically a p-n junction with metallic contacts provided at the ends for application of an external voltage. Using diodes, alternating voltages can be rectified.

(i) Which of the following is a donor impurity atom for Ge ? *1*

(A) Boron (B) Antimony

(C) Aluminium (D) Indium

(ii) When a pentavalent atom occupies the position of an atom in the crystal lattice of Si, four of its electrons form covalent bonds with four silicon neighbours, while the fifth remains bound to the parent atom. The energy required to set this electron free is about : *1*

(A) 0·5 eV (B) 0·1 eV

(C) 0·05 eV (D) 0·01 eV

(iii) During formation of a p-n junction : 1

(A) a layer of negative charge on n-side and a layer of positive charge on p-side appear.

(B) a layer of positive charge on n-side and a layer of negative charge on p-side appear.

(C) the electrons on p-side of the junction move to n-side initially.

(D) initially diffusion current is small and drift current is large.

(iv) (a) In reverse-biased p-n junction : 1

(A) the drift current is of the order of few mA.

(B) the applied voltage mostly drops across the depletion region.

(C) the depletion region width decreases.

(D) the current increases with increase in applied voltage.

OR

(b) The output frequency of a full-wave rectifier with 50 Hz as input frequency is : 1

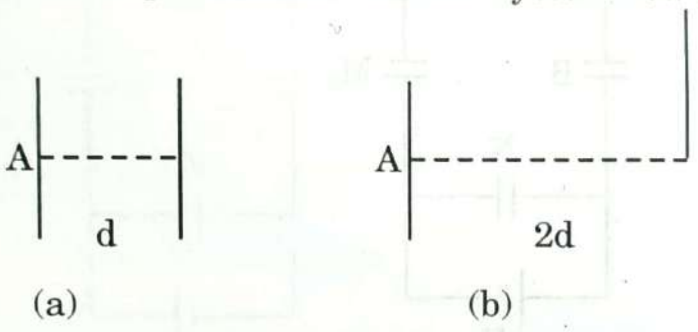
(A) 25 Hz (B) 50 Hz

(C) 100 Hz (D) 200 Hz

30. A capacitor is a system of two conductors separated by an insulator. In practice, the two conductors have charges Q and – Q with potential difference $V = V_1 - V_2$ between them. The ratio $\frac{Q}{V}$ is a constant, denoted by C and is called the capacitance of the capacitor. It is independent of Q or V. It depends only on the geometrical configuration (shape, size, separation) of the two conductors and the medium separating the conductors. When a parallel plate capacitor is charged, the electric field E_0 is localised between the plates and is uniform throughout. When a slab of a dielectric is inserted between the charged plates (charge density σ), the dielectric is polarised by the field. Consequently opposite charges appear on the faces of the slab, near the plates, with surface charge density of magnitude σ_p. For a linear dielectric σ_p is proportional to E_0. Introduction of a dielectric changes the electric field, and hence, the capacitance of a capacitor, and hence, the energy stored in the capacitor.

Like resistors, capacitors can also be arranged in series or in parallel or in a combination of series and parallel.

(i) Consider a capacitor of capacitance C, with plate area A and plate separation d, filled with air [Fig. (a)]. The distance between the plates is increased to 2d and one of the plates is shifted as shown in Fig. (b). The capacitance of the new system now is : *1*



(A) $\frac{C}{4}$ (B) $\frac{C}{2}$

(C) 2C (D) 4C

(ii) A slab (area A and thickness d_1) of a linear dielectric of dielectric constant K is inserted between charged plates (charge density σ) of a parallel plate capacitor [plate area A and plate separation d (> d_1)] and opposite charges with charge density of magnitude σ_p appear on the faces of the slab. The dielectric constant K is given by : *1*

(A) $\frac{\sigma + \sigma_p}{\sigma}$ (B) $\frac{\sigma}{\sigma - \sigma_p}$

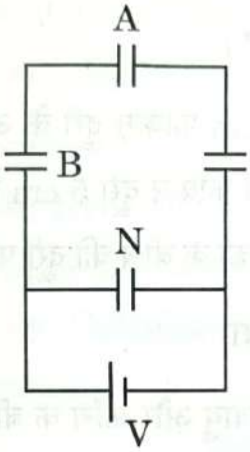
(C) $\frac{\sigma + \sigma_p}{\sigma_p}$ (D) $\frac{\sigma}{\sigma_p}$

(iii) An electric field E is established between the plates of an air filled parallel plate capacitor, with charges Q and – Q. V is the volume of the space enclosed between the plates. The energy stored in the capacitor is : *1*

(A) $\frac{1}{2} \varepsilon_0 E^2$ (B) $\varepsilon_0 Q^2 E$

(C) $\frac{1}{2} \varepsilon_0 E^2 V$ (D) $\varepsilon_0 E Q V$

(iv) (a) Three capacitors A, B and M, each of capacitance C are connected to a capacitor N of capacitance 2C and a battery as shown in the figure. If the charges on A and N are Q and Q′ respectively, then $\frac{Q'}{Q}$ is : 1



(A) $\frac{1}{6}$ (B) $\frac{1}{3}$

(C) 3 (D) 6

OR

(b) A slab (area A and thickness $\frac{d}{2}$) of dielectric constant K is inserted in a parallel plate capacitor of plate area A and plate separation d. If C and C_0 are the capacitances of the capacitors with and without the dielectric, then $\frac{C}{C_0}$ is : 1

(A) $\frac{K+1}{2K}$ (B) $\frac{2K}{K+1}$

(C) $\frac{K}{K-1}$ (D) $\frac{K-1}{K}$

SECTION E

31. (a) (i) Draw a ray diagram to show the image formation by a compound microscope. Obtain the expression for the total magnification of the microscope when the final image is formed at infinity.

(ii) In a compound microscope, an object is placed at a distance of 1·5 cm from the objective of focal length 1·25 cm. The eyepiece has a focal length of 5 cm. The final image is formed at infinity. Calculate the distance between the objective and the eyepiece. 5

OR

(b) (i) Using Huygens' principle, explain the refraction of a plane wavefront, propagating in air, at a plane interface between air and glass. Hence verify Snell's law.

(ii) Use mirror formula to deduce that a convex mirror always produces a virtual image of an object kept in front of it. 5

32. (a) (i) The electric field in a region is given by $\vec{E} = 40x\ \hat{i}$ N/C. Find the amount of work done in taking a unit positive charge from a point (0, 3m) to the point (5m, 0).

(ii) A charge Q is distributed over two concentric hollow spheres of radii r and R (> r) such that their surface charge densities are equal. Find :

(I) the electric field, and

(II) the potential

at their common centre. 5

OR

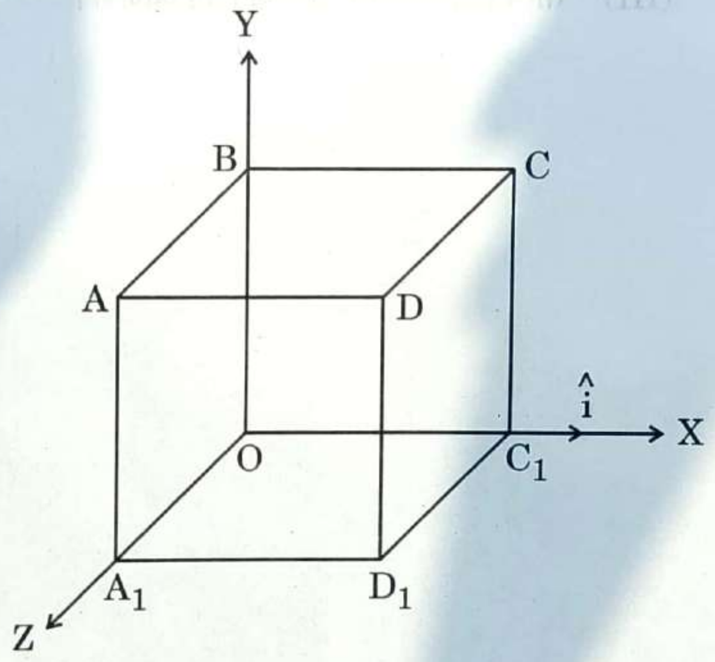
(b) (i) Obtain an expression for the electric field $\vec{E}$ due to a dipole of dipole moment $\vec{p}$ at a point on its equatorial plane and specify its direction. Hence, find the value of electric field :

(I) at the centre of the dipole ($r = 0$), and

(II) at a point $r >> a$,

where 2a is the length of the dipole.

(ii) An electric field $\vec{E} = (10x + 5)\hat{i}$ N/C exists in a region in which a cube of side L is kept as shown in the figure. Here x and L are in metres. Calculate the net flux through the cube. 5



33. (a) (i) Write the principle of working of an ac generator. Draw its labelled diagram and explain its working.

(ii) A resistor of 400 Ω, an inductor of $\left(\frac{5}{\pi}\right)$ H and a capacitor of $\left(\frac{50}{\pi}\right)$ μF are joined in series across an ac source $v = 140 \sin (100\pi)t$ V. Find the rms voltages across these three circuit elements. The algebraic sum of these voltages is more than the rms voltage of source. Explain. 5

OR

(b) (i) Write the principle of working of a transformer. With the help of a labelled diagram, explain the working of a step-up transformer.

(ii) An ideal transformer is designed to convert 50 V into 250 V. It draws 200 W power from an ac source whose instantaneous voltage is given by $v_i = 20 \sin (100\pi)t$ V.

Find :

(I) rms value of input current.

(II) expression for instantaneous output voltage.

(III) expression for instantaneous output current. 5