SECTION A

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

   (A) $\frac{\lambda}{2\varepsilon_0 R}$ (B) Zero (C) $\frac{\lambda}{4\pi\varepsilon_0 R}$ (D) $\frac{\lambda}{4\varepsilon_0 R}$

2. A charged sphere of radius r has surface charge density σ. The electric field on its surface is E. If the radius of the sphere is doubled, keeping charge density the same, the ratio of the electric field on the old sphere to that on the new sphere will be :

   (A) 1 (B) $\frac{1}{2}$ (C) $\frac{1}{4}$ (D) 4

3. A student is asked to connect four cells, each of emf E and internal resistance r, in series. But she/he connects one cell wrongly in series with the other cells. The equivalent emf and the equivalent internal resistance of the combination will be :

   (A) 4E and 2r (B) 4E and 3r
   (C) 3E and 4r (D) 2E and 4r

4. A piece of wire bent in the form of a circular loop A carries a current I. The wire is then bent into a circular loop B of two turns and carries the same current. The ratio of magnetic fields at the centre of loop A to that of loop B will be :

   (A) $\frac{1}{16}$ (B) 16
   (C) 4 (D) $\frac{1}{4}$

5. A 10 cm long wire lies along y-axis. It carries a current of 1·0 A in positive y-direction. A magnetic field $\vec{B} = (5\text{ mT})\hat{j} - (8\text{ mT})\hat{k}$ exists in the region. The force on the wire is :

   (A) $(0{\cdot}8\text{ mN})\hat{i}$ (B) $-(0{\cdot}8\text{ mN})\hat{i}$
   (C) $(80\text{ mN})\hat{i}$ (D) $-(80\text{ mN})\hat{i}$

6. A galvanometer of resistance G Ω is converted into an ammeter of range 0 to I A. If the current through the galvanometer is 0·1% of I A, the resistance of the ammeter is :

(A) $\frac{G}{999}$ Ω (B) $\frac{G}{1000}$ Ω (C) $\frac{G}{1001}$ Ω (D) $\frac{G}{100 \cdot 1}$ Ω

7. A conducting circular loop is placed in a uniform magnetic field B = 50 mT with its plane perpendicular to the magnetic field. The radius of the loop is made to shrink at a constant rate of 1 mm s^{-1}. At the instant the radius of the loop is 4 cm, the induced emf in the loop is :

(A) π μV (B) 2π μV

(C) 4π μV (D) 8π μV

8. The electric and magnetic fields of electromagnetic waves are :

(A) In the same phase and perpendicular to each other.

(B) In the same phase and not perpendicular to each other.

(C) Not in the same phase but are perpendicular to each other.

(D) Neither in the same phase nor perpendicular to each other.

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

(A) 3 (B) 9 (C) $\frac{1}{3}$ (D) $\frac{1}{9}$

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

(A) momentum (B) angular momentum

(C) speed (D) energy

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

(A) the structure of Ge lattice is distorted.

(B) the number of conduction electrons increases.

(C) the number of holes increases.

(D) the number of conduction electrons decreases.

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

(A) $n_f = 2$ and $n_i = 3$

(B) $n_f = 3$ and $n_i = 4$

(C) $n_f = 2$ and $n_i = 4$

(D) $n_f = 2$ and $n_i = \infty$

*Questions number **13** to **16** are Assertion (A) and Reason (R) type questions. Two statements are given — one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (A), (B), (C) and (D) as given below.*

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

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

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

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

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

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

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

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

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

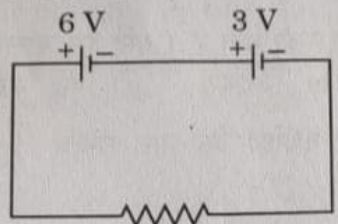
Reason (R) : Photoelectric current depends on the wavelength of the incident light.

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

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

SECTION B

17. Two batteries of emfs 6 V and 3 V and internal resistances 0·8 Ω and 0·2 Ω respectively are connected in series to an external resistance R, as shown in figure. Find the value of R so that the potential difference across the 6 V battery be zero. 2



18. Consider a neutron (mass m) of kinetic energy E and a photon of the same energy. Let λ_n and λ_p be the de Broglie wavelength of neutron and the wavelength of photon respectively. Obtain an expression for $\frac{\lambda_n}{\lambda_p}$. 2

19. (a) Monochromatic light of frequency $5 \cdot 0 \times 10^{14}$ Hz passes from air into a medium of refractive index 1·5. Find the wavelength of the light (i) reflected, and (ii) refracted at the interface of the two media. 2

OR

(b) A plano-convex lens of focal length 16 cm is made of a material of refractive index 1·4. Calculate the radius of the curved surface of the lens. 2

20. An object is placed 30 cm in front of a concave mirror of radius of curvature 40 cm. Find the (i) position of the image formed and (ii) magnification of the image. 2

21. How does the conductivity of an intrinsic semiconductor vary with temperature ? Explain. Show the variation in a plot. 2

SECTION C

22. Three point charges Q_1, Q_2 and Q_3 are located in $x - y$ plane at points $(-d, 0)$, $(0, 0)$ and $(d, 0)$ respectively. Q_1 and Q_3 are identical and Q_2 is positive. What will be the nature and value of Q_1 so that the potential energy of the system is zero ? *3*

23. (a) Define 'current density'. Is it a scalar or a vector ? An electric field $\vec{E}$ is maintained in a metallic conductor. If n be the number of electrons (mass m, charge $-e$) per unit volume in the conductor and τ its relaxation time, show that the current density $\vec{j} = \alpha \vec{E}$, where $\alpha = \left(\frac{ne^2}{m}\right)\tau$. *3*

OR

(b) What is a Wheatstone bridge ? Obtain the necessary conditions under which the Wheatstone bridge is balanced. *3*

24. A bar magnet of magnetic moment $2 \cdot 5\ JT^{-1}$ lies aligned with the direction of a uniform magnetic field of $0 \cdot 32$ T.

(a) Find the amount of work done to turn the magnet so as to align its magnetic moment (i) normal to the field direction, and (ii) opposite to the field direction.

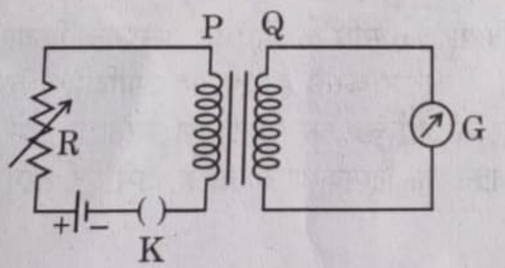
(b) What is the torque on the magnet in above cases (i) and (ii) ? 3

25. Consider the arrangement of two coils P and Q shown in the figure. When current in coil P is switched on or switched off, a current flows in coil Q.

(a) Explain the phenomenon involved in it.

(b) Mention two factors on which the current produced in coil Q depends.

(c) Give the direction of current in coil Q when there is a current in the coil P and (i) R is increased, and (ii) R is decreased. 3



26. Write the drawbacks of Rutherford's atomic model. How did Bohr remove them ? Show that different orbits in Bohr's atom are not equally spaced. 3

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

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

(ii) Optical and radio telescopes are built on the ground, but X-ray astronomy is possible only from satellites orbiting the Earth. Why ? 3

28. (a) Write two characteristic properties of nuclear force.

(b) Draw a plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions that can be drawn from the plot. 3

SECTION D

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

29. Junction Diode as a Rectifier :

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

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

(i) The root mean square value of an alternating voltage applied to a full-wave rectifier is $\frac{V_0}{\sqrt{2}}$. Then the root mean square value of the rectified output voltage is : *1*

(A) $\frac{V_0}{\sqrt{2}}$ (B) $\frac{V_0^2}{\sqrt{2}}$

(C) $\frac{2V_0}{\sqrt{2}}$ (D) $\frac{V_0}{2\sqrt{2}}$

(ii) In a full-wave rectifier, the current in each of the diodes flows for : *1*

(A) Complete cycle of the input signal

(B) Half cycle of the input signal

(C) Less than half cycle of the input signal

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

(iii) In a full-wave rectifier : *1*

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

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

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

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

(iv) (a) An alternating voltage of frequency of 50 Hz is applied to a half-wave rectifier. Then the ripple frequency of the output will be : *1*

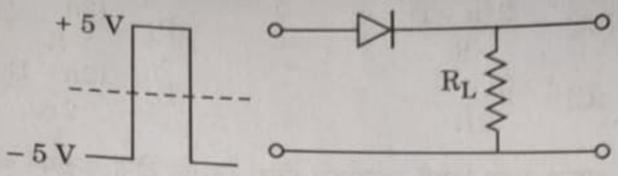
(A) 100 Hz (B) 50 Hz

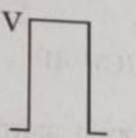
(C) 25 Hz (D) 150 Hz

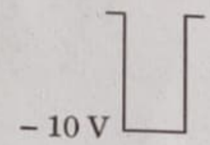
OR

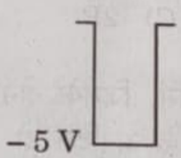
1

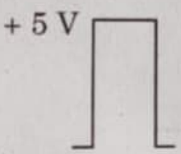
(b) A signal, as shown in the figure, is applied to a p-n junction diode. Identify the output across resistance R_L : 1



(A) 

(B) 

(C) 

(D) 

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

(i) A double-convex lens, with each face having same radius of curvature R, is made of glass of refractive index n. Its power is : 1

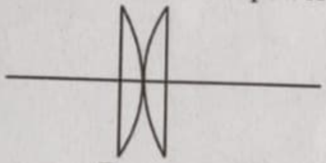
(A) $\frac{2(n-1)}{R}$ (B) $\frac{(2n-1)}{R}$

(C) $\frac{(n-1)}{2R}$ (D) $\frac{(2n-1)}{2R}$

(ii) A double-convex lens of power P, with each face having same radius of curvature, is cut into two equal parts perpendicular to its principal axis. The power of one part of the lens will be : 1

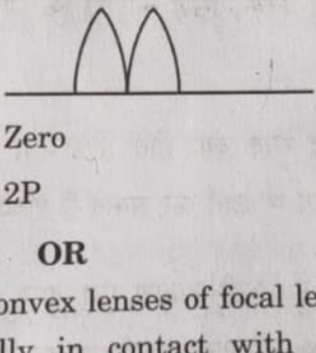
(A) 2P (B) P (C) 4P (D) $\frac{P}{2}$

(iii) The above two parts are kept in contact with each other as shown in the figure. The power of the combination will be : 1



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

(iv) (a) A double-convex lens of power P, with each face having same radius of curvature, is cut along its principal axis. The two parts are arranged as shown in the figure. The power of the combination will be : 1



(A) Zero (B) P

(C) 2P (D) $\frac{P}{2}$

OR

(b) Two convex lenses of focal lengths 60 cm and 20 cm are held coaxially in contact with each other. The power of the combination is : 1

(A) 6·6 D (B) 15 D

(C) $\frac{1}{15}$ D (D) $\frac{1}{80}$ D

SECTION E

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

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

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

(1) Angle of minimum deviation, and

(2) Angle of incidence. 5

OR

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

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

(iii) A beam of light consisting of a known wavelength 520 nm and an unknown wavelength λ, used in Young's double slit experiment produces two interference patterns such that the fourth bright fringe of unknown wavelength coincides with the fifth bright fringe of known wavelength. Find the value of λ. 5

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

(ii) An electric dipole consists of point charges $-1{\cdot}0$ pC and $+1{\cdot}0$ pC located at (0, 0) and (3 mm, 4 mm) respectively in $x-y$ plane. An electric field $\vec{E} = \left(\frac{1000\ \text{V}}{\text{m}}\right)\hat{i}$ is switched on in the region. Find the torque $\vec{\tau}$ acting on the dipole. 5

OR

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

(ii) Two isolated metallic spheres S_1 and S_2 of radii 1 cm and 3 cm respectively are charged such that both have the same charge density $\left(\frac{2}{\pi}\times 10^{-9}\right) \text{C}/\text{m}^2$. They are placed far away from each other and connected by a thin wire. Calculate the new charge on sphere S_1. 5

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

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

(iii) An electric lamp is designed to operate at 110 V dc and 11 A current. If the lamp is operated on 220 V, 50 Hz ac source with a coil in series, then find the inductance of the coil. 5

OR

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

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

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

(1) The output voltage across the secondary coil

(2) The current in the primary coil if the current in the secondary coil is 2·0 A. 5