SECTION – A

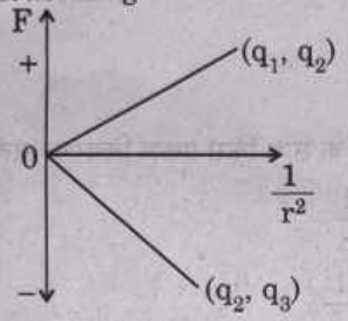
$16 \times 1 = 16$

1. Three point charges, each of charge q are placed on vertices of a triangle ABC, with AB = AC = 5L, BC = 6L. The electrostatic potential at midpoint of side BC will be 1

(A) $\frac{11}{48}\frac{q}{\pi\varepsilon_0 L}$ (B) $\frac{8q}{36\pi\varepsilon_0 L}$

(C) $\frac{5q}{24\pi\varepsilon_0 L}$ (D) $\frac{1}{16}\frac{q}{\pi\varepsilon_0 L}$

2. The Coulomb force (F) versus $(1/r^2)$ graphs for two pairs of point charges (q_1 and q_2) and (q_2 and q_3) are shown in figure. The charge q_2 is positive and has least magnitude. Then 1



(A) $q_1 > q_2 > q_3$ (B) $q_1 > q_3 > q_2$

(C) $q_3 > q_2 > q_1$ (D) $q_3 > q_1 > q_2$

3. The magnetic susceptibility for a diamagnetic material is 1

(A) small and negative (B) small and positive

(C) large and negative (D) large and positive

4. A circular loop A of radius R carries a current I. Another circular loop B of radius $r\left(=\frac{R}{20}\right)$ is placed concentrically in the plane of A. The magnetic flux linked with loop B is proportional to 1

(A) R (B) $\sqrt{R}$

(C) $R^{\frac{3}{2}}$ (D) R^2

5. A particle of mass m and charge q is moving with velocity $\vec{v} = v_x\hat{i} + v_y\hat{j}$. If it is subjected to a magnetic field $\vec{B} = B_0\hat{i}$, it will move in a – 1

(A) straight line path (B) circular path

(C) helical path (D) parabolic path

6. The quantum nature of light explains the observations on photoelectric effect as – 1

(A) there is a minimum frequency of incident radiation below which no electrons are emitted.

(B) the maximum kinetic energy of photoelectrons depends only on the frequency of incident radiation.

(C) when the metal surface is illuminated, electrons are ejected from the surface after sometime.

(D) the photoelectric current is independent of the intensity of incident radiation.

7. The phase difference between electric field $\vec{E}$ and magnetic field $\vec{B}$ in an electromagnetic wave propagating along z-axis is – 1

(A) zero (B) π

(C) $\frac{\pi}{2}$ (D) $\frac{\pi}{4}$

8. The radius (r_n) of n^{th} orbit in Bohr model of hydrogen atom varies with n as 1

(A) $r_n \propto n$ (B) $r_n \propto \frac{1}{n}$

(C) $r_n \propto n^2$ (D) $r_n \propto \frac{1}{n^2}$

9. An ac source V = 282 sin (100 t) volt is connected across a 1 μF capacitor. The rms value of current in the circuit will be (take $\sqrt{2} = 1.41$) 1

(A) 10 mA (B) 20 mA

(C) 40 mA (D) 80 mA

10. A galvanometer of resistance 100 Ω is converted into an ammeter of range (0 – 1 A) using a resistance of 0.1 Ω. The ammeter will show full scale deflection for a current of about 1

(A) 0.1 mA (B) 1 mA

(C) 10 mA (D) 0.1 A

11. In Balmer series of hydrogen atom, as the wavelength of spectral lines decreases, they appear 1

(A) equally spaced and equally intense.

(B) further apart and stronger in intensity.

(C) closer together and stronger in intensity.

(D) closer together and weaker in intensity.

12. A coil of N turns is placed in a magnetic field $\vec{B}$ such that $\vec{B}$ is perpendicular to the plane of the coil. $\vec{B}$ changes with time as $B = B_0 \cos\left(\frac{2\pi}{T}t\right)$ where T is time period. The magnitude of emf induced in the coil will be maximum at 1

(A) $t = \frac{nT}{8}$ (B) $t = \frac{nT}{4}$

(C) $t = \frac{nT}{2}$ (D) $t = nT$

Here, n = 1, 2, 3, 4, ...

Note : For questions number **13** to **16**, two statements are given – one labelled **Assertion (A)** and the other labelled **Reason (R)**. Select the correct answer to these questions from the codes **(A)**, **(B)**, **(C)** and **(D)** as given below :

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

(B) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).

(C) If Assertion (A) is true and Reason (R) is false.

(D) If both Assertion (A) and Reason (R) are false.

13. **Assertion (A) :** In interference and diffraction of light, light energy reduces in one region producing a dark fringe. It increases in another region and produces a bright fringe.

Reason (R) : This happens because energy is not conserved in the phenomena of interference and diffraction. 1

14. **Assertion (A) :** When electrons drift in a conductor, it does not mean that all free electrons in the conductor are moving in the same direction.

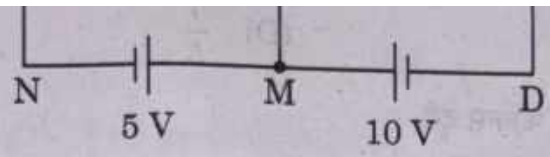
Reason (R) : The drift velocity is superposed over large random velocities of electrons. 1

15. **Assertion (A) :** Electrons are ejected from the surface of zinc when it is irradiated by yellow light.

Reason (R) : Energy associated with a photon of yellow light is more than the work function of zinc. 1

16. **Assertion (A) :** The temperature coefficient of resistance is positive for metals and negative for p-type semiconductors.

Reason (R) : The charge carriers in metals are negatively charged, whereas the majority charge carriers in p-type semiconductors are positively charged. 1



28. (a) (i) Define mutual inductance. Write its SI unit. **3**

(ii) Derive an expression for the mutual inductance of a system of two long coaxial solenoids of same length l, having turns N_1 and N_2 and of radii r_1 and r_2 ($> r_1$).

OR

(b) What are ferromagnetic materials ? Explain ferromagnetism with the help of suitable diagrams, using the concept of magnetic domain. **3**

SECTION – D

$2 \times 4 = 8$

Note : Questions number **29** to **30** are Case Study based questions. Read the following paragraph and answer the questions that follow.

29. A lens is a transparent optical medium bounded by two surfaces; at least one of which should be spherical. Applying the formula of image formation by a single spherical surface successively at the two surfaces of a thin lens, a formula known as lens maker's formula and hence the basic lens formula can be obtained. The focal length (or power) of a lens depends on the radii of its surfaces and the refractive index of its material with respect to the surrounding medium. The refractive index of a material depends on the wavelength of light used. Combination of lenses helps us to obtain diverging or converging lenses of desired power and magnification. **$4 \times 1 = 4$**

(i) A thin converging lens of focal length 20 cm and a thin diverging lens of focal length 15 cm are placed coaxially in contact. The power of the combination is

(A) $\frac{-5}{6}$ D

(B) $\frac{-5}{3}$ D

(C) $\frac{4}{3}$ D

(D) $\frac{3}{2}$ D

(ii) The radii of curvature of two surfaces of a convex lens are R and 2R. If the focal length of this lens is $\left(\frac{4}{3}\right)$R, the refractive index of the material of the lens is :

(A) $\frac{5}{3}$ (B) $\frac{4}{3}$

(C) $\frac{3}{2}$ (D) $\frac{7}{5}$

(iii) The focal length of an equiconvex lens

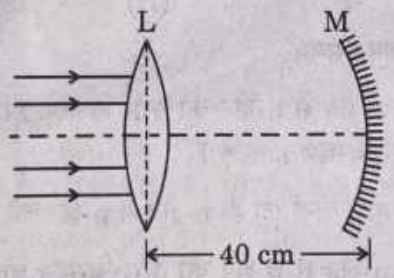
(A) increases when the lens is dipped in water.

(B) increases when the wavelength of incident light decreases.

(C) increases with decrease in radius of curvature of its surface.

(D) decreases when the lens is cut into two identical parts along its principal axis.

(iv) (a) A thin convex lens L of focal length 10 cm and a concave mirror M of focal length 15 cm are placed coaxially 40 cm apart as shown in figure. A beam of light coming parallel to the principal axis is incident on the lens. The final image will be formed at a distance of



(A) 10 cm, left of lens (B) 10 cm, right of lens

(C) 20 cm, left of lens (D) 20 cm, right of lens

OR

(iv) (b) A beam of light coming parallel to the principal axis of a convex lens L_1 of focal length 16 cm is incident on it. Another convex lens L_2 of focal length 12 cm is placed coaxially at a distance 40 cm from L_1. The nature and distance of the final image from L_2 will be

(A) real, 24 cm (B) virtual, 12 cm

(C) real, 32 cm (D) virtual, 18 cm

30. A pure semiconductor like Ge or Si, when doped with a small amount of suitable impurity, becomes an extrinsic semiconductor. In thermal equilibrium, the electron and hole concentration in it are related to the concentration of intrinsic charge carriers. A p-type or n-type semiconductor can be converted into a p-n junction by doping it with suitable impurity. Two processes, diffusion and drift take place during formation of a p-n junction. A semiconductor diode is basically a p-n junction with metallic contacts provided at the ends for the application of an external voltage. A p-n junction diode allows currents to pass only in one direction when it is forward biased. Due to this property, a diode is widely used to rectify alternating voltages, in half-wave or full wave configuration. $4 \times 1 = 4$

(i) When Ge is doped with pentavalent impurity, the energy required to free the weakly bound electron from the dopant is about

(A) 0.001 eV (B) 0.01 eV

(C) 0.72 eV (D) 1.1 eV

(ii) At a given temperature, the number of intrinsic charge carriers in a semiconductor is 2.0×10^{10} cm^{-3}. It is doped with pentavalent impurity atoms. As a result, the number of holes in it becomes 8×10^3 cm^{-3}. The number of electrons in the semiconductor is

(A) 2×10^{24} m^{-3} (B) 4×10^{23} m^{-3}

(C) 1×10^{22} m^{-3} (D) 5×10^{22} m^{-3}

(iii) (a) During the formation of a p-n junction –

(A) electrons diffuse from p-region into n-region and holes diffuse from n-region into p-region.

(B) both electrons and holes diffuse from n-region into p-region.

(C) electrons diffuse from n-region into p-region and holes diffuse from p-region into n-region.

(D) both electrons and holes diffuse from p-region into n-region.

OR

(iii) (b) Initially during the formation of a p-n junction –

(A) diffusion current is large and drift current is small.

(B) diffusion current is small and drift current is large.

(C) both the diffusion and the drift currents are large.

(D) both the diffusion and the drift currents are small.

(iv) An ac voltage V = 0.5 sin (100 πt) volt is applied, in turn, across a half-wave rectifier and a full-wave rectifier. The frequency of the output voltage across them respectively will be

(A) 25 Hz, 50 Hz (B) 25 Hz, 100 Hz

(C) 50 Hz, 50 Hz (D) 50 Hz, 100 Hz

SECTION – E

$3 \times 5 = 15$

31. (a) (i) Mention the factors on which the resonant frequency of a series LCR circuit depends. Plot a graph showing variation of impedance of a series LCR circuit with the frequency of the applied a.c. source.

(ii) With the help of a suitable diagram, explain the working of a step-up transformer.

(iii) Write two causes of energy loss in a real transformer. 5

OR

(b) (i) With the help of a diagram, briefly explain the construction and working of ac generator.

(ii) An electron is revolving around a proton in an orbit of radius r with