

Question Paper

Conducted by the Central Board of Secondary Education (CBSE)



Time Allowed: 3 Hours

Maximum Marks: 70

General Instructions

- (i) This question paper contains **33 questions**. All questions are **compulsory**.
- (ii) The question paper is divided into Sections A, B, C, D, E.
- (iii) Section A - Questions 1 to 16 carry 1 mark each.
- (iv) Section B - Questions 17 to 21 carry 2 marks each.
- (v) Section C - Questions 22 to 28 carry 3 marks each.
- (vi) Section D - Questions 29 to 30 carry 4 marks each.
- (vii) Section E - Questions 31 to 33 carry 5 marks each.
- (viii) There is no overall choice. Where an internal choice is provided, attempt only one of the alternatives.

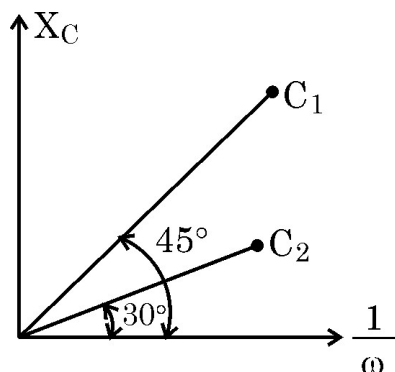
You may use the following values of physical constants wherever necessary:

$$\begin{aligned}c &= 3 \times 10^8 \text{ m/s} \\h &= 6.63 \times 10^{-34} \text{ Js} \\e &= 1.6 \times 10^{-19} \text{ C} \\\mu_0 &= 4\pi \times 10^{-7} \text{ T m A}^{-1} \\\epsilon_0 &= 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2} \\\frac{1}{4\pi\epsilon_0} &= 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}\end{aligned}$$

$$\begin{aligned}\text{Mass of electron } (m_e) &= 9.1 \times 10^{-31} \text{ kg} \\\text{Mass of neutron} &= 1.675 \times 10^{-27} \text{ kg} \\\text{Mass of proton} &= 1.673 \times 10^{-27} \text{ kg} \\\text{Avogadro's number} &= 6.023 \times 10^{23} \text{ per gm mole} \\\text{Boltzmann constant} &= 1.38 \times 10^{-23} \text{ JK}^{-1}\end{aligned}$$

Section A

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



- (A) 5
(C) $\sqrt{3}$
(B) 2
(D) $\frac{1}{\sqrt{3}}$

2. 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) Wb s^2 , Wb s
(C) Wb s^{-2} , Wb s^{-1}
(B) Wb s^{-1} , Wb
(D) Wb s^{-1} , Wb s^{-2}

3. A galvanometer of resistance 27Ω is converted into an ammeter of range (0-10 mA) using a resistance of 3Ω . The galvanometer will show full scale deflection for a current of about:

- (A) 10 mA
(C) 1 mA
(B) 100 mA
(D) 3 mA

4. Two metal spheres of radii r_1 and r_2 ($r_2 > r_1$) 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 $\frac{1}{4\pi\epsilon_0} \frac{(q_1 + q_2)}{(r_1 + r_2)}$.
(D) The final potential of the system equals $\frac{1}{4\pi\epsilon_0} \frac{(q_1 + q_2)(r_1 + r_2)}{r_1 r_2}$.

5. A person is standing facing geographic north and a vertical wire in front of him is carrying a current in downward direction. The direction of magnetic field at a point on the right side of wire is:

- (A) South
(C) West
(B) East
(D) North

6. Which one of the following materials has magnetic susceptibility χ in the range $-1 < \chi < 0$?

- (A) Aluminium
(C) Copper
(B) Copper chloride
(D) Nickel

7. The electric field and the magnetic field components of an electromagnetic wave travelling in vacuum are represented as $E = m \sin(\alpha z - \beta t)$ and $B = n \sin(\alpha z - \beta t)$, where m , n , α and β are constants characterising the wave. Then:

- (A) $\frac{m}{n} = \frac{\alpha}{\beta}$
(C) $\frac{n}{m} = \frac{\beta}{\alpha}$
(B) $\frac{m}{n} = \frac{\beta}{\alpha}$
(D) $\frac{n}{m} = \alpha\beta$

8. Two identical circular loops A and B of metal wire are arranged on a table close to each other. Loop A is connected to a battery and the current in it increases with time. In response, the loop B :

- (A) remains stationary (B) is attracted by loop A
(C) is repelled by loop A (D) rotates about its centre of mass which is fixed

9. In Bohr model of hydrogen atom, an electron is moving in an orbit, with total energy -3.4 eV. Its angular momentum will be:

- (A) 1.05×10^{-34} J s (B) 6.63×10^{-34} J s
(C) 3.31×10^{-34} J s (D) 2.1×10^{-34} J s

10. According to Bohr model of hydrogen atom, the time period of an electron in its n^{th} orbit is proportional to:

- (A) n (B) n^2
(C) n^3 (D) n^4

11. The equivalent mass of a photon of wavelength 100 nm is:

- (A) 2.21×10^{-35} kg (B) 6.63×10^{-33} kg
(C) 1.11×10^{-35} kg (D) 3.31×10^{-27} kg

12. A point charge of $5 \mu\text{C}$ is located at (1 cm, 1 cm) in x - y plane. A second charge of $6 \mu\text{C}$ is brought from infinity to point $(-3 \text{ cm}, 4 \text{ cm})$. The work done in the process is:

- (A) 0.54 J (B) 5.4 J
(C) -0.54 J (D) 10.8 J

Question numbers 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 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): 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 an electric device when connected to a dc source of voltage V is proportional to its resistance.

14. 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.

15. 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.

16. Assertion (A): On increasing the intensity of incident light of frequency ν ($> \nu_0$) on a photosensitive surface, the photocurrent increases.

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

Section B

17. Find the ratio (λ_α/λ_p) of the de Broglie wavelengths λ_α 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.

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

19(a). 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

19(b). 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.

20(a). Why is manganin used in wire-wound standard resistors? Calculate the temperature at which the resistance of a wire increases by 25% of its resistance at room temperature 27.5°C . The temperature coefficient of resistance of the material of the wire is 0.004°C^{-1} .

20(b). How does the resistivity of a semiconductor depend on temperature? Show it on a plot.

21. A ray of light is incident at an angle $2A$ on one of the faces of a glass prism of refracting angle A . After refraction from this face, the ray strikes the opposite face which is silvered. The reflected ray from this face retraces on its path. Trace the ray diagram and find the relation between the refractive index of material of prism and the angle of prism.

Section C

22(a). (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

22(b). Two long straight parallel conductors A and B carrying steady currents I_1 and I_2 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.

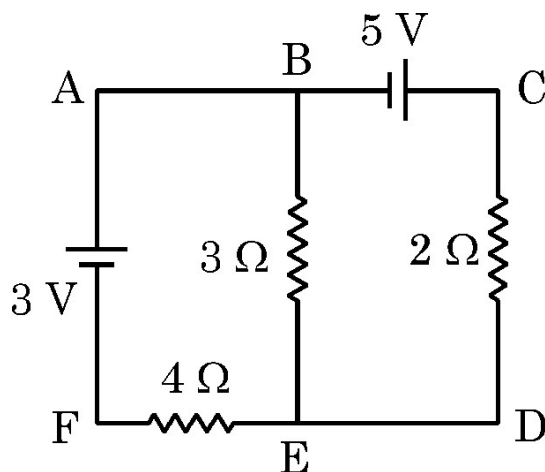
23. Derive an expression for the magnetic field $\vec{B}$, due to a circular coil of N turns, each of radius r carrying current I , at a distance x from the centre along its axis.

24. (a) Consider the following nuclides: $^{12}_6\text{C}$, $^{198}_{80}\text{Hg}$, $^{14}_6\text{C}$, $^{197}_{79}\text{Au}$. 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.

25. (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 $3\ \Omega$ resistor in the circuit shown in the figure:



26. (a) Draw electric field lines and equipotential surfaces for a system of two equal positive charges separated by some distance.

(b) Using the drawing in (a) above, explain that electric field need not be a constant over each point of an equipotential surface.

27. Name the electromagnetic waves which are (i) also known as 'heat waves', (ii) used in LASIK eye surgery, (iii) used to destroy cancer cells. Also write their wavelength range.

28(a). A particle of charge q and mass m is accelerated through a potential difference V . Deduce an expression for the de Broglie wavelength associated with the particle.

28(b). Plot a graph for a particle of charge q and mass m showing variation of de Broglie wavelength λ , as $\frac{1}{\lambda}$ with $\sqrt{V}$, where V is the potential difference through which the particle is accelerated.

Section D

Question numbers 29 and 30 are Case Study-based questions. Read the following paragraphs and answer the questions that follow.

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.

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

- | | |
|----------------|--------------|
| (A) Phosphorus | (B) Arsenic |
| (C) Boron | (D) Antimony |

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

- | | |
|---------------------------------------|---|
| (A) $5 \times 10^{22} \text{ m}^{-3}$ | (B) $1.5 \times 10^{16} \text{ m}^{-3}$ |
| (C) $9 \times 10^8 \text{ m}^{-3}$ | (D) $4.5 \times 10^9 \text{ m}^{-3}$ |

29(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. |

29(iv)(a). 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

29(iv)(b). 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 .

30(i). The value of d is:

- (A) $\sqrt{D(D - 4f)}$ (B) $\sqrt{D(D - 2f)}$
(C) $2\sqrt{Df}$ (D) $\sqrt{D(D - f)}$

30(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

30(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

30(iv)(a). Consider a convex lens of focal length 15 cm. 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

30(iv)(b). 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 2 D, the value of f is:

- (A) -15 cm (B) -10 cm
(C) -20 cm (D) -30 cm

Section E

31(a)(i). 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.

31(a)(ii). 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 be affected after the slab is introduced?

OR

31(b)(i). 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.

31(b)(ii). (i) This 'average velocity' is found to be a few mm s^{-1} 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.

32(a)(i). 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 .

32(a)(ii). Under what conditions:

- (i) the impedance of the circuit is minimum?
- (ii) wattless current flows in the circuit?

OR

32(b)(i). (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.

32(b)(ii). If T is the time period of the rotation of the coil, at what values of T in a cycle, the emf generated is maximum?

33(a)(i). What are coherent sources? Why are they 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 double-slit experiment.

33(a)(ii). 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

33(b)(i). 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.

33(b)(ii). (i) In a telescope the objective has much larger aperture than the eyepiece. Why?

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

- End of Question Paper -