

SET ~ 3

Q.P. Code 55/4/3

Candidates must write the Q.P. Code on the title page of the answer-book. *



PHYSICS (Theory)

निर्धारित समय : 3 घण्टे

अधिकतम अंक : 70

Time allowed : 3 hours

Maximum Marks : 70

नोट / NOTE :

(i)

Please check that this question paper contains **27** printed pages.

(ii)

Q.P. Code given on the right hand side of the question paper should be written on the title page of the answer-book by the candidate.

(iii)

Please check that this question paper contains **35** questions.

(iv)

Please write down the serial number of the question in the answer-book before attempting it.

(v)

15 minute time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the students will read the question paper only and will not write any answer on the answer-book during this period.

General Instructions :

Read the following instructions very carefully and strictly follow them :

- (i) *This question paper contains **35** questions. **All** questions are **compulsory**.*
- (ii) *This question paper is divided into **five** Sections – **A, B, C, D** and **E**.*
- (iii) *In **Section A** – Questions no. **1** to **18** are Multiple Choice (MCQ) type questions, carrying **1** mark each.*
- (iv) *In **Section B** – Questions no. **19** to **25** are Very Short Answer (VSA) type questions, carrying **2** marks each.*
- (v) *In **Section C** – Questions no. **26** to **30** are Short Answer (SA) type questions, carrying **3** marks each.*
- (vi) *In **Section D** – Questions no. **31** to **33** are Long Answer (LA) type questions carrying **5** marks each.*
- (vii) *In **Section E** – Questions no. **34** and **35** are case-based questions carrying **4** marks each.*
- (viii) *There is no overall choice. However, an internal choice has been provided in 2 questions in Section B, 2 questions in Section C, 3 questions in Section D and 2 questions in Section E.*
- (ix) *Use of calculators is **not** allowed.*

Use the following values of physical constants, if required :

$$c = 3 \times 10^8 \text{ m/s}$$

$$h = 6.63 \times 10^{-34} \text{ Js}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

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

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$$

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$$

$$\text{Mass of electron (} m_e \text{)} = 9.1 \times 10^{-31} \text{ kg}$$

$$\text{Mass of neutron} = 1.675 \times 10^{-27} \text{ kg}$$

$$\text{Mass of proton} = 1.673 \times 10^{-27} \text{ kg}$$

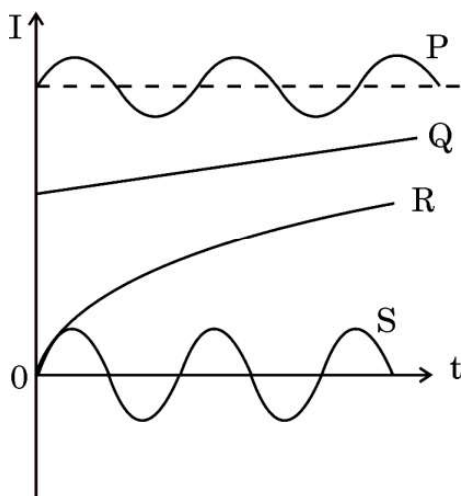
$$\text{Avogadro's number} = 6.023 \times 10^{23} \text{ per gram mole}$$

$$\text{Boltzmann constant} = 1.38 \times 10^{-23} \text{ JK}^{-1}$$

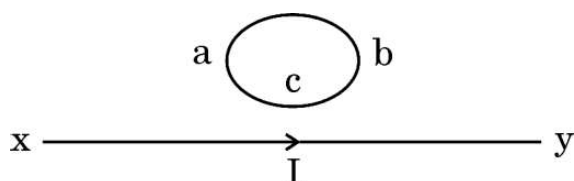
SECTION A

1. In a Young's double-slit experiment, the fringe width is found to be β . If the entire apparatus is immersed in a liquid of refractive index μ , the new fringe width will be :
- (a) β (b) $\mu\beta$ (c) $\frac{\beta}{\mu}$ (d) $\frac{\beta}{\mu^2}$
2. A light of frequency ν is incident on a metal surface whose work function is W_0 . The kinetic energy of emitted electron is K . If the frequency of the incident light is doubled then the kinetic energy of emitted electron will be :
- (a) $2K$ (b) more than $2K$
(c) between K and $2K$ (d) less than K
3. Which of the following statements is **not** true for nuclear forces ?
- (a) They are stronger than Coulomb forces.
(b) They have about the same magnitude for different pairs of nucleons.
(c) They are always attractive.
(d) They saturate as the separation between two nucleons increases.
4. A particle of mass m and charge $-q$ is moving with a uniform speed v in a circle of radius r , with another charge q at the centre of the circle. The value of r is :
- (a) $\frac{1}{4\pi\epsilon_0 m} \left(\frac{q}{v}\right)$ (b) $\frac{1}{4\pi\epsilon_0 m} \left(\frac{q}{v}\right)^2$
(c) $\frac{m}{4\pi\epsilon_0} \left(\frac{q}{v}\right)$ (d) $\frac{m}{4\pi\epsilon_0} \left(\frac{q}{v}\right)^2$
5. Photons of energy 3.2 eV are incident on a photosensitive surface. If the stopping potential for the emitted electrons is 1.5 V, the work function for the surface is :
- (a) 1.5 eV (b) 1.7 eV (c) 3.2 eV (d) 4.7 eV
6. Which one of the following has relative magnetic permeability between 0 and 1 ?
- (a) Aluminium (b) Alnico
(c) Water (d) Sodium

7. The figure shows variation of current (I) with time (t) in four devices P, Q, R and S. The device in which an alternating current flows is :



- (a) P (b) Q (c) R (d) S
8. Name the electromagnetic waves also known as 'heat waves'.
- (a) Radio waves (b) Microwaves
(c) X-rays (d) Infrared waves
9. A plane wavefront is incident on a concave mirror of radius of curvature R. The radius of the refracted wavefront will be :
- (a) $2R$ (b) R (c) $\frac{R}{2}$ (d) $\frac{R}{4}$
10. A proton and an alpha particle have the same kinetic energy. The ratio of de Broglie wavelengths associated with the proton to that with the alpha particle is :
- (a) 1 (b) 2 (c) $2\sqrt{2}$ (d) $\frac{1}{2}$
11. The direction of induced current in the loop abc is :

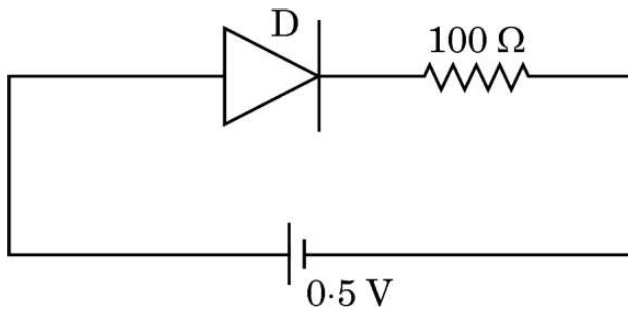


- (a) along abc if I decreases
(b) along acb if I increases
(c) along abc if I is constant
(d) along abc if I increases

12. An ac voltage $v = v_0 \sin \omega t$ is applied to a series combination of a resistor R and an element X . The instantaneous current in the circuit is $I = I_0 \sin (\omega t + \frac{\pi}{4})$. Then which of the following is correct ?

- (a) X is a capacitor and $X_C = \sqrt{2} R$
- (b) X is an inductor and $X_L = R$
- (c) X is an inductor and $X_L = \sqrt{2} R$
- (d) X is a capacitor and $X_C = R$

13. The threshold voltage for a p-n junction diode used in the circuit is 0.7 V . The type of biasing and current in the circuit are :



- (a) Forward biasing, 0 A
 - (b) Reverse biasing, 0 A
 - (c) Forward biasing, 5 mA
 - (d) Reverse biasing, 2 mA
14. The potential energy of an electron in the second excited state in hydrogen atom is :
- (a) -3.4 eV
 - (b) -3.02 eV
 - (c) -1.51 eV
 - (d) -6.8 eV
15. The difference in mass of ${}^7\text{X}$ nucleus and total mass of its constituent nucleons is 21.00 u . The binding energy per nucleon for this nucleus is equal to the energy equivalent of :

- (a) 3 u
- (b) 3.5 u
- (c) 7 u
- (d) 21 u

Questions number **16** to **18** 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.

16. *Assertion (A) :* In 'n' type semiconductor, number density of electrons is greater than the number density of holes but the crystal maintains an overall charge neutrality.

Reason (R) : The charge of electrons donated by donor atoms is just equal and opposite to that of the ionised donor.

17. *Assertion (A) :* When three electric bulbs of power 200 W, 100 W and 50 W are connected in series to a source, the power consumed by the 50 W bulb is maximum.

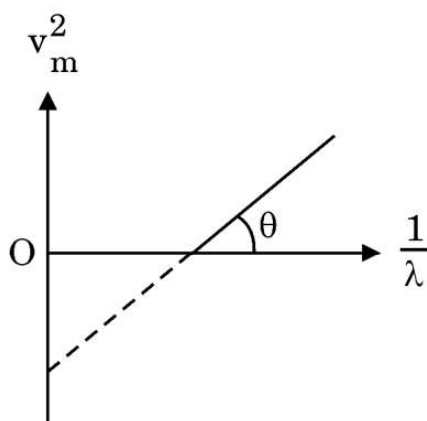
Reason (R) : In a series circuit, current is the same through each bulb, but the potential difference across each bulb is different.

18. *Assertion (A) :* A current carrying square loop made of a wire of length L is placed in a magnetic field. It experiences a torque which is greater than the torque on a circular loop made of the same wire carrying the same current in the same magnetic field.

Reason (R) : A square loop occupies more area than a circular loop, both made of wire of the same length.

SECTION B

19. The figure shows v_m^2 versus $\frac{1}{\lambda}$ graph for photoelectrons emitted from a surface where v_m is the maximum speed of electrons and λ is the wavelength of incident radiation. Using this graph and Einstein's photoelectric equation, obtain the expression for Planck's constant and work function of the surface. 2



20. Briefly describe the multi-step process involved in the generation of energy in the Sun. 2
21. Use Gauss's law to obtain the expression for electric field due to a thin infinitely long straight uniformly charged wire. 2
22. A cell of emf E and internal resistance r is connected to a variable resistance R . Draw plots showing the variation of (a) terminal voltage V with R , and (b) V with current I , in the circuit. 2
23. A particle of charge q and mass m starts moving with uniform velocity $v_0 \hat{i}$. Specify the direction of magnetic field which should be set up in the region so that the particle moves (a) straight undeviated, and (b) in a circle. Justify your answers. 2
24. (a) Obtain an expression for electrostatic potential energy of a system of three charges q , $2q$ and $-3q$ placed at the vertices of an equilateral triangle of side a . 2

OR

- (b) Two small conducting balls A and B of radius r_1 and r_2 have charges q_1 and q_2 respectively. They are connected by a wire. Obtain the expression for charges on A and B, in equilibrium. 2

25. (a) What is a displacement current ? How is it different from a conduction current ? 2

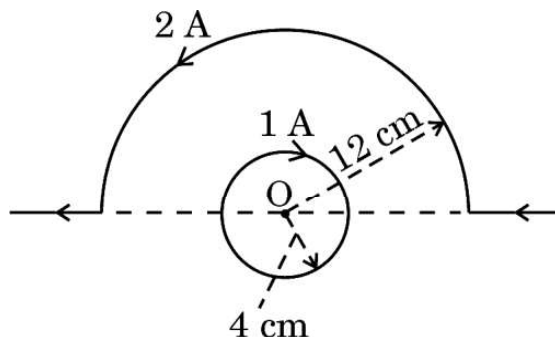
OR

- (b) Write any two characteristics of an electromagnetic wave. Why are microwaves used in radar systems ? 2

SECTION C

26. Draw a plot showing the variation of potential energy of two nucleons as a function of distance between them. Identify the regions in which the force between the nucleons is (i) attractive, and (ii) repulsive. Justify your answers. 3

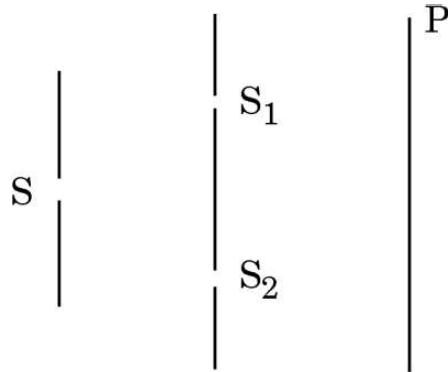
27. A current carrying circular loop and a straight wire bent partly in the form of a semicircle are placed as shown in the figure. Find the magnitude and direction of net magnetic field at point O. 3



28. (a) (i) In diffraction due to a single slit, the phase difference between light waves reaching a point on the screen is 5π . Explain whether a bright or a dark fringe will be formed at the point. 3
- (ii) What should the width (a) of each slit be to obtain eight maxima of two double-slit patterns (slit separation d) within the central maximum of the single slit pattern ?
- (iii) Draw the plot of intensity distribution in a diffraction pattern due to a single slit.

OR

- (b) (i) In a Young's double-slit experiment $SS_2 - SS_1 = \frac{\lambda}{4}$, where S_1 and S_2 are the two slits as shown in the figure. Find the path difference ($S_2P - S_1P$) for constructive and destructive interference at P.



- (ii) What is the effect on the interference fringes in a Young's double-slit experiment, if the monochromatic source S is replaced by a source of white light ?

3

- 29.** (a) A resistor of 30Ω and a capacitor of $\frac{250}{\pi} \mu\text{F}$ are connected in series to a 200 V, 50 Hz ac source. Calculate (i) the current in the circuit, and (ii) voltage drops across the resistor and the capacitor. (iii) Is the algebraic sum of these voltages more than the source voltage ? If yes, solve the paradox.

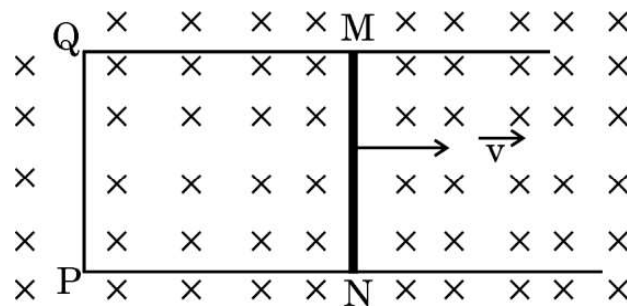
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OR

- (b) A series LCR circuit with $R = 20 \Omega$, $L = 2 \text{ H}$ and $C = 50 \mu\text{F}$ is connected to a 200 volts ac source of variable frequency. What is (i) the amplitude of the current, and (ii) the average power transferred to the circuit in one complete cycle, at resonance ? (iii) Calculate the potential drop across the capacitor.

3

- 30.** A rectangular conductor MNPQ with a movable arm MN (resistance r) is kept in a uniform magnetic field as shown in the figure. Resistance of arms MQ, QP and PN are negligible. Obtain the expression for the : 3
- (a) current induced in the loop specifying its direction, and
- (b) power required to move the arm.



SECTION D

- 31.** (a) (i) A germanium crystal is doped with antimony. With the help of energy-band diagram, explain how the conductivity of the doped crystal is affected.
- (ii) Briefly explain the two processes involved in the formation of a p-n junction.
- (iii) What will the effect of (1) forward biasing, and (2) reverse biasing be on the width of depletion layer in a p-n junction diode ? 5

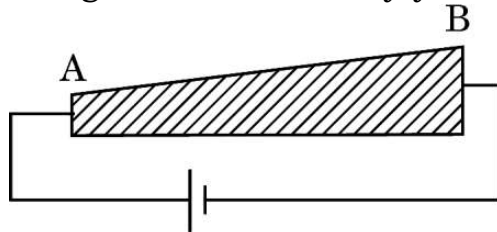
OR

- (b) (i) With the help of a circuit diagram, briefly explain the working of a full-wave rectifier using p-n junction diodes.

- (ii) Draw $V - I$ characteristics of a p-n junction diode. Explain how these characteristics make a diode suitable for rectification.
- (iii) Carbon and silicon have the same lattice structure. Then why is carbon an insulator but silicon a semiconductor ?

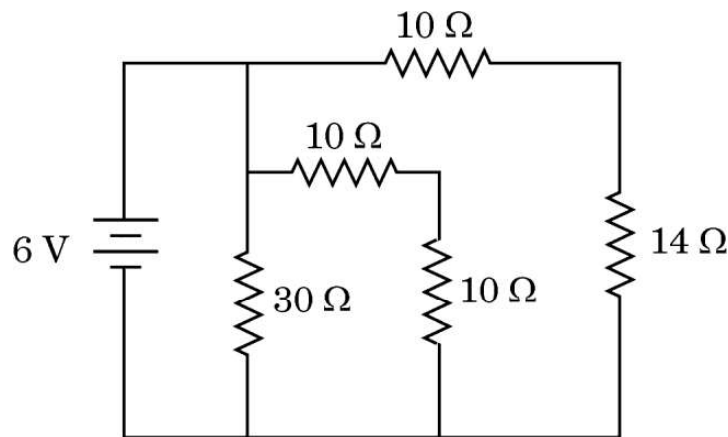
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- 32.** (a) (i) Define mobility of electrons. Give its SI units.
- (ii) A steady current flows through a wire AB, as shown in the figure. What happens to the electric field and the drift velocity along the wire ? Justify your answer.



- (iii) Consider the circuit shown in the figure. Find the effective resistance of the circuit and the current drawn from the battery.

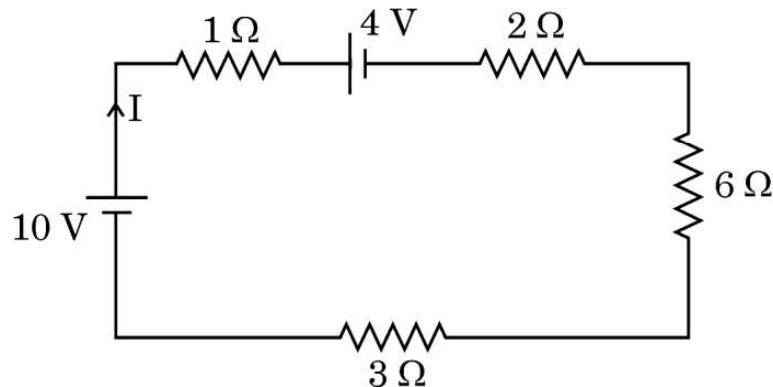
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OR

- (b) (i) Define electrical conductivity of a wire. Give its SI unit.
- (ii) High current is to be drawn safely from (1) a low-voltage battery, and (2) a high-voltage battery. What can you say about the internal resistance of the two batteries ?

- (iii) Calculate the total energy supplied by the batteries to the circuit shown in the figure, in one minute. 5



- 33.** (a) (i) Draw a ray diagram to show how the final image is formed at infinity in an astronomical refracting telescope. Obtain an expression for its magnifying power.

- (ii) Two thin lenses L_1 and L_2 , L_1 being a convex lens of focal length 24 cm and L_2 a concave lens of focal length 18 cm are placed coaxially at a separation of 45 cm. A 1 cm tall object is placed in front of the lens L_1 at a distance of 36 cm. Find the location and height of the image formed by the combination. 5

OR

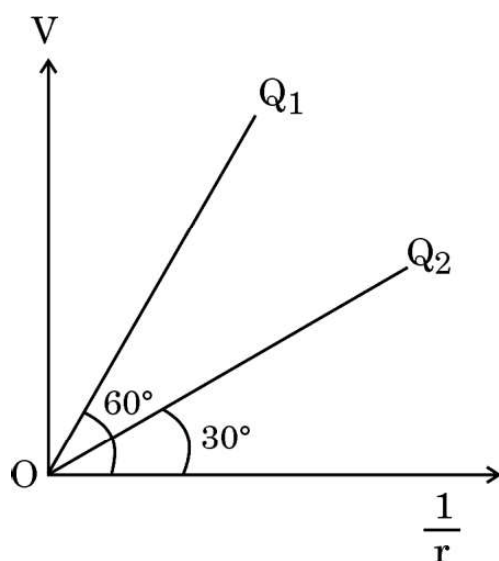
- (b) (i) Explain the working principle of an optical fibre with the help of a diagram. Mention one use of a light pipe.
- (ii) A ray of light is incident at an angle of 60° on one face of a prism with the prism angle $A = 60^\circ$. The ray passes symmetrically through the prism. Find the angle of minimum deviation (δ_m) and refractive index of the material of the prism. If the prism is immersed in water, how will δ_m be affected? Justify your answer. 5

SECTION E

- 34.** Electrostatics deals with the study of forces, fields and potentials arising from static charges. Force and electric field, due to a point charge is basically determined by Coulomb's law. For symmetric charge configurations, Gauss's law, which is also based on Coulomb's law, helps us to find the electric field. A charge/a system of charges like a dipole experience a force/torque in an electric field. Work is required to be done to provide a specific orientation to a dipole with respect to an electric field.

Answer the following questions based on the above :

- (a) Consider a uniformly charged thin conducting shell of radius R . Plot a graph showing the variation of $|\vec{E}|$ with distance r from the centre, for points $0 \leq r \leq 3R$. 1
- (b) The figure shows the variation of potential V with $\frac{1}{r}$ for two point charges Q_1 and Q_2 , where V is the potential at a distance r due to a point charge. Find $\frac{Q_1}{Q_2}$. 1



- (c) An electric dipole of dipole moment of 6×10^{-7} C-m is kept in a uniform electric field of 10^4 N/C such that the dipole moment and the electric field are parallel. Calculate the potential energy of the dipole.

2

OR

- (c) An electric dipole of dipole moment $\vec{p}$ is initially kept in a uniform electric field $\vec{E}$ such that $\vec{p}$ is perpendicular to $\vec{E}$. Find the amount of work done in rotating the dipole to a position at which $\vec{p}$ becomes antiparallel to $\vec{E}$.

2

- 35.** 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.

Answer the following questions based on the above :

- (a) How will the power of a lens be affected with an increase of wavelength of light ?
- (b) The radius of curvature of two surfaces of a convex lens is R each. For what value of μ of its material will its focal length become equal to R ?
- (c) The focal length of a concave lens of $\mu = 1.5$ is 20 cm in air. It is completely immersed in water of $\mu = \frac{4}{3}$. Calculate its focal length in water.

1

1

2

OR

- (c) An object is placed in front of a lens which forms its erect image of magnification 3. The power of the lens is 5 D. Calculate the distance of the object and the image from the lens.

2