भौतिक विज्ञान (सैद्धांतिक)

PHYSICS (Theory)

निर्धारित समय : 3 घण्टे
Time allowed : 3 hours

अधिकतम अंक : 70
Maximum Marks : 70
General Instructions :

(i) All questions are compulsory. There are 27 questions in all.

(ii) This question paper has four sections: Section A, Section B, Section C and Section D.

(iii) Section A contains five questions of one mark each, Section B contains seven questions of two marks each, Section C contains twelve questions of three marks each, Section D contains three questions of five marks each.

\[ c = 3 \times 10^8 \text{ m/s} \]
\[ h = 6.63 \times 10^{-34} \text{ Js} \]
\[ e = 1.6 \times 10^{-19} \text{ C} \]
\[ \mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1} \]
\[ \varepsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2} \]
\[ \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2} \]

इलेक्ट्रॉन का द्रव्यमान \((m_e) = 9.1 \times 10^{-31} \text{ kg} \]

न्यूट्रॉन का द्रव्यमान = \(1.675 \times 10^{-27} \text{ kg} \]

प्रोटॉन का द्रव्यमान = \(1.673 \times 10^{-27} \text{ kg} \]

आवोगाड्डो संख्या = \(6.023 \times 10^{23} \) प्रति ग्राम मोल

बॉल्ट्जमान नियतांक = \(1.38 \times 10^{-23} \text{ JK}^{-1} \)
(iv) There is no overall choice. However, an internal choice (s) has been provided in two questions of one mark, two questions of two marks, four questions of three marks and three questions of five marks weightage. You have to attempt only one of the choices in such questions.

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

\[ \begin{align*}
    c &= 3 \times 10^8 \text{ m/s} \\
    h &= 6.63 \times 10^{-34} \text{ Js} \\
    e &= 1.6 \times 10^{-19} \text{ C} \\
    \mu_0 &= 4\pi \times 10^{-7} \text{ T m A}^{-1} \\
    \varepsilon_0 &= 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2} \\
    \frac{1}{4\pi\varepsilon_0} &= 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2} \\
    \text{Mass of electron (} m_e \text{)} &= 9.1 \times 10^{-31} \text{ kg} \\
    \text{Mass of neutron} &= 1.675 \times 10^{-27} \text{ kg} \\
    \text{Mass of proton} &= 1.673 \times 10^{-27} \text{ kg} \\
    \text{Avogadro’s number} &= 6.023 \times 10^{23} \text{ per gram mole} \\
    \text{Boltzmann constant} &= 1.38 \times 10^{-23} \text{ JK}^{-1}
\end{align*} \]

### SECTION A

1. किसी वैद्युत दिशांक के लिए समविभाजित पृष्ठ खींचिए।

   Draw equipotential surfaces for an electric dipole.

2. किसी प्रोटॉन को उसके वेग की दिशा के अन्तरगत एकसमान चुम्बकीय क्षेत्र में प्रवेश कराने से पूर्व विभवात्तर \( V \) तक तृतीय किया गया। यदि विभवात्तर को दुगुना कर दिया जाए, तो चुम्बकीय क्षेत्र में प्रोटॉन द्वारा चले गए वृत्ताकार पथ की त्रिज्या किस प्रकार परिवर्तित होगी?

   A proton is accelerated through a potential difference \( V \), subjected to a uniform magnetic field acting normal to the velocity of the proton. If the potential difference is doubled, how will the radius of the circular path described by the proton in the magnetic field change?
3. The magnetic susceptibility of magnesium at 300 K is $1.2 \times 10^5$. At what temperature will its magnetic susceptibility become $1.44 \times 10^5$?

A or B

The magnetic susceptibility $\chi$ of a given material is $-0.5$. Identify the magnetic material.

4. Identify the semiconductor diode whose V-I characteristics are as shown.
5. Which part of the electromagnetic spectrum is used in RADAR? Give its frequency range.

OR

How are electromagnetic waves produced by accelerating charges?

6. A capacitor made of two parallel plates, each of area ‘A’ and separation ‘d’ is charged by an external dc source. Show that during charging, the displacement current inside the capacitor is the same as the current charging the capacitor.

7. A photon and a proton have the same de-Broglie wavelength \( \lambda \). Prove that the energy of the photon is \((2m\lambda c/h)\) times the kinetic energy of the proton.
8. A photon emitted during the de-excitation of electron from a state \( n \) to the first excited state in a hydrogen atom, irradiates a metallic cathode of work function 2 eV, in a photo cell, with a stopping potential of 0·55 V. Obtain the value of the quantum number of the state \( n \).

OR

A hydrogen atom in the ground state is excited by an electron beam of 12·5 eV energy. Find out the maximum number of lines emitted by the atom from its excited state.

9. Draw the ray diagram of an astronomical telescope showing image formation in the normal adjustment position. Write the expression for its magnifying power.

OR

Draw a labelled ray diagram to show image formation by a compound microscope and write the expression for its resolving power.
10. Write the relation between the height of a TV antenna and the maximum range up to which signals transmitted by the antenna can be received. How is this expression modified in the case of line of sight communication by space waves? In which range of frequencies, is this mode of communication used?

11. Under which conditions can a rainbow be observed? Distinguish between a primary and a secondary rainbow.

12. Explain the following:

(a) Sky appears blue.

(b) The Sun appears reddish at (i) sunset, (ii) sunrise.
A capacitor (C) and resistor (R) are connected in series with an ac source of voltage of frequency 50 Hz. The potential difference across C and R are respectively 120 V, 90 V, and the current in the circuit is 3 A. Calculate (i) the impedance of the circuit (ii) the value of the inductance, which when connected in series with C and R will make the power factor of the circuit unity.

OR

A capacitor (C) and resistor (R) are connected in series with an ac source of voltage of frequency 50 Hz. The potential difference across C and R are respectively 120 V, 90 V, and the current in the circuit is 3 A. Calculate (i) the impedance of the circuit (ii) the value of the inductance, which when connected in series with C and R will make the power factor of the circuit unity.
The figure shows a series LCR circuit connected to a variable frequency 230 V source.

![Circuit Diagram]

(a) Determine the source frequency which drives the circuit in resonance.

(b) Calculate the impedance of the circuit and amplitude of current at resonance.

(c) Show that potential drop across LC combination is zero at resonating frequency.

14. Explain why n and p regions of a Zener diode are heavily doped. Find the current through the Zener diode in the circuit given below: (Zener breakdown voltage is 15 V)
15. Draw a labelled diagram of cyclotron. Explain its working principle. Show that cyclotron frequency is independent of the speed and radius of the orbit.

OR

(a) Derive, with the help of a diagram, the expression for the magnetic field inside a very long solenoid having n turns per unit length carrying a current I.

(b) How is a toroid different from a solenoid?

16. Prove that the magnetic moment of the electron revolving around a nucleus in an orbit of radius r with orbital speed v is equal to evr/2. Hence using Bohr’s postulate of quantization of angular momentum, deduce the expression for the magnetic moment of hydrogen atom in the ground state.

17. σ and −2σ C/m² are two equal and opposite uniform charges. Two charges are separated by a distance d. Use Coulomb’s law to find the magnitude and direction of the electric force on each charge. 

OR

(a) A charged particle is placed on the axis of a long uniform solenoid. The solenoid has n turns per unit length and carries a current I. Derive the expression for the magnetic field inside the solenoid.

(b) How is a toroid different from a solenoid?

18. A charged particle is placed on the axis of a long uniform solenoid. The solenoid has n turns per unit length and carries a current I. Derive the expression for the magnetic field inside the solenoid.
Two large charged plane sheets of charge densities $\sigma$ and $-2\sigma$ C/m$^2$ are arranged vertically with a separation of $d$ between them. Deduce expressions for the electric field at points (i) to the left of the first sheet, (ii) to the right of the second sheet, and (iii) between the two sheets.

OR

A spherical conducting shell of inner radius $r_1$ and outer radius $r_2$ has a charge $Q$.

(a) A charge $q$ is placed at the centre of the shell. Find out the surface charge density on the inner and outer surfaces of the shell.

(b) Is the electric field inside a cavity (with no charge) zero; independent of the fact whether the shell is spherical or not? Explain.

A signal of low frequency $f_m$ is to be transmitted using a carrier wave of frequency $f_c$. Derive the expression for the amplitude modulated wave and deduce expressions for the lower and upper sidebands produced. Hence, obtain the expression for modulation index.
19. Draw a plot of \( \alpha \)-particle scattering by a thin foil of gold to show the variation of the number of the scattered particles with scattering angle. Describe briefly how the large angle scattering explains the existence of the nucleus inside the atom. Explain with the help of impact parameter picture, how Rutherford scattering serves a powerful way to determine an upper limit on the size of the nucleus.

20. A 200 \( \mu \text{F} \) parallel plate capacitor having plate separation of 5 mm is charged by a 100 V dc source. It remains connected to the source. Using an insulated handle, the distance between the plates is doubled and a dielectric slab of thickness 5 mm and dielectric constant 10 is introduced between the plates. Explain with reason, how the (i) capacitance, (ii) electric field between the plates, (iii) energy density of the capacitor will change?

21. \( \beta \)-decay की अवधि में परतिञ्ज्ञातियन की संस्थिति का समूचा गठन क्यों है? किसी रेडियोऐक्टिव नामिक के क्षयांक पद की परिभाषा लिखिए तथा क्षयांक के पदों में इस नामिक की माध्यम आयु के लिए व्यंजक न्युट्रल क्लीजिए।

अथवा

(a) नामिकीय बल के दो विभेदनकारी लक्षण लिखिए।
(b) न्यूक्लिया के बीच पुरूषक को फलन मानकर न्यूक्लिया के किसी युगल की स्थितिज़ ऊर्जा के विचरण को दर्शाने के लिए ग्राफ़ खींचिए। ग्राफ़ पर उस क्षेत्र को अंकित कीजिए जहाँ पर नामिकीय बल (i) आकर्ष, तथा (ii) प्रतिकर्ष खिला।
Why is it difficult to detect the presence of an anti-neutrino during $\beta$-decay? Define the term decay constant of a radioactive nucleus and derive the expression for its mean life in terms of the decay constant.

OR

(a) State two distinguishing features of nuclear force.

(b) Draw a plot showing the variation of potential energy of a pair of nucleons as a function of their separation. Mark the regions on the graph where the force is (i) attractive, and (ii) repulsive.

22. $2/\sqrt{3}$ अपवर्तनांक के पारदर्शी माध्यम से बने किसी त्रिभुजाकार प्रिज्म का अपवर्तन कोण 60° है। आरेख में दर्शाए अनुसार कोई प्रकाश किरण इस प्रिज्म के फलक KL पर अभिलम्बवत्तू आपत्ति करती है। प्रिज्म में इस किरण का पथ आरेखित कीजिए तथा निर्गत कोण व विचलन कोण परिकलित कीजिए।

A triangular prism of refracting angle 60° is made of a transparent material of refractive index $2/\sqrt{3}$. A ray of light is incident normally on the face KL as shown in the figure. Trace the path of the ray as it passes through the prism and calculate the angle of emergence and angle of deviation.
23. Prove that in a common-emitter amplifier, the output and input differ in phase by 180°.

In a transistor, the change of base current by 30 μA produces change of 0.02 V in the base-emitter voltage and a change of 4 mA in the collector current. Calculate the current amplification factor and the load resistance used, if the voltage gain of the amplifier is 400.

24. Show, on a plot, variation of resistivity of (i) a conductor, and (ii) a typical semiconductor as a function of temperature.

Using the expression for the resistivity in terms of number density and relaxation time between the collisions, explain how resistivity in the case of a conductor increases while it decreases in a semiconductor, with the rise of temperature.
25. (a) Derive an expression for the induced emf developed when a coil of $N$ turns, and area of cross-section $A$, is rotated at a constant angular speed $\omega$ in a uniform magnetic field $B$.

(b) A wheel with 100 metallic spokes each 0·5 m long is rotated with a speed of 120 rev/min in a plane normal to the horizontal component of the Earth’s magnetic field. If the resultant magnetic field at that place is $4 \times 10^{-4}$ T and the angle of dip at the place is $30^\circ$, find the emf induced between the axle and the rim of the wheel.

OR
(a) Derive the expression for the magnetic energy stored in an inductor when a current \( I \) develops in it. Hence, obtain the expression for the magnetic energy density.

(b) A square loop of sides 5 cm carrying a current of 0.2 A in the clockwise direction is placed at a distance of 10 cm from an infinitely long wire carrying a current of 1 A as shown. Calculate (i) the resultant magnetic force, and (ii) the torque, if any, acting on the loop.

![Diagram of a square loop and a wire](attachment:image.png)
Explain, with the help of a diagram, how plane polarized light can be produced by scattering of light from the Sun.

Two polaroids $P_1$ and $P_2$ are placed with their pass axes perpendicular to each other. Unpolarised light of intensity $I$ isincident on $P_1$. A third polaroid $P_3$ is kept between $P_1$ and $P_2$ such that its pass axis makes an angle of 45° with that of $P_1$. Calculate the intensity of light transmitted through $P_1$, $P_2$ and $P_3$.

**OR**

(a) Why cannot the phenomenon of interference be observed by illuminating two pin holes with two sodium lamps?

(b) Two monochromatic waves having displacements $y_1 = \cos \omega t$ and $y_2 = \cos (\omega t + \phi)$ from two coherent sources interfere to produce an interference pattern. Derive the expression for the resultant intensity and obtain the conditions for constructive and destructive interference.

(c) Two wavelengths of sodium light of 590 nm and 596 nm are used in turn to study the diffraction taking place at a single slit of aperture $2 \times 10^{-6}$ m. If the distance between the slit and the screen is 1.5 m, calculate the separation between the positions of the second maxima of diffraction pattern obtained in the two cases.

27. (a) परिपथ आरेख की सहायता से किसी सेल के आंतरिक प्रतिरोध को मापने की विधि का संक्षेप में वर्णन कीजिए।

(b) कारण दीजिए कि किसी सेल के विभ. बल (emf) की माप के लिए वोल्टमीटर की तुलना में पोटेंशियमीटर के उपयोग को वरीयता क्यों दी जाती है।

(c) नीचे दिए गए पोटेंशियमीटर परिपथ में संतुलन लम्बाई $l$ परिकलित कीजिए। कारण देखते स्पष्ट कीजिए कि यदि सभी अन्य कारकों को अपरिवर्तित रखते हुए, 5 V विभ. बल (emf) के परिचालक सेल को 2 V के सेल द्वारा प्रतिस्थापित कर दिया जाए, तो यह परिपथ कार्य करेगा अथवा नहीं।

![Diagram of a circuit with voltages and resistances](image-url)
(a) Describe briefly, with the help of a circuit diagram, the method of measuring the internal resistance of a cell.

(b) Give reason why a potentiometer is preferred over a voltmeter for the measurement of emf of a cell.

(c) In the potentiometer circuit given below, calculate the balancing length \( l \). Give reason, whether the circuit will work, if the driver cell of emf 5 V is replaced with a cell of 2 V, keeping all other factors constant.

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OR

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(a) State the working principle of a meter bridge used to measure an unknown resistance.

(b) Give reason
(i) why the connections between the resistors in a metre bridge are made of thick copper strips,
(ii) why is it generally preferred to obtain the balance length near the mid-point of the bridge wire.

(c) Calculate the potential difference across the 4 Ω resistor in the given electrical circuit, using Kirchhoff’s rules.