INDIAN ASSOCIATION OF PHYSICS TEACHERS

National Graduate Physics Examination 2025

Day and Date of Examination: Sunday, January 19, 2025

Time : 10 AM to 1 PM

Instructions to Candidates

1. In addition to this question paper, you are given **answer sheet (OMR Sheet) for part A** and **answer paper for part B**.
2. On the answer sheet (OMR Sheet) for part A, fill up all the entries carefully in the space provided, **Only in block capital. Do write the name and PIN of your city.**

   Incomplete / incorrect / carelessly filled information may disqualify your candidature
3. On part A answer sheet, use only BLUE or BLACK BALL PEN for making entries and marking answers.
4. In Part A each question has **FOUR** alternatives. Any number of these (4, 3, 2 or 1) may be correct. You have to mark **ALL** correct alternatives and fill a bubble (●) for each, like

Q.No.	a	b	c	d
24	○	●	○	●

   Full marks are 6 for each question, you get them only when ALL correct answers are marked. The answers of part A shall be available on **www.indapt.org** on 1.2.2025.
5. Part A answer sheet will be collected at the end of one hour.
6. Any rough work should be done only on the sheets provided with part B answer paper.
7. Use of non-programmable calculator is allowed.
8. No candidate should leave the examination hall before the completion of the examination. You will take away the question paper with you.
9. Symbols used in the paper have their usual meaning unless specified otherwise.

PLEASE DO NOT MAKE ANY MARK OTHER THAN ● IN THE SPACE PROVIDED ON THE ANSWER SHEET OF PART A MEANS YO HAVE TO DARK THE CIRCLE.

Answer sheets for part A are to be evaluated with the help of a machine. Due to this, **CHANGE OF ENTRY IS NOT ALLOWED**

Scratching or overwriting may result in wrong score

DO NOT WRITE ANYTHING ON BACK SIDE OF ANSWER SHEET FOR PART A

INDIAN ASSOCIATION OF PHYSICS TEACHERS

National Graduate Physics Examination 2025

Day and Date of Examination : Sunday, January 19, 2025

Time : 10 AM to 1 PM

Part A- Maximum Marks: 150 — Time for Part A : 60 minutes

Part B- Maximum Marks: 150 — Time for Part B : 120 minutes

Part A

25 × 6 = 150

Mark the correct option/options (Any number of options may be correct).
Marks will be awarded only if all the correct options are marked. No negative marking.

1. The electric field E in a certain region of space is described by $E = \frac{-y\hat{x} + x\hat{y}}{x^2 + y^2}$ Here x and y are the usual space coordinates in meter. The magnitude of the flux of $\nabla \times E$ through a circular loop of radius r = 2 m centred at the origin and lying perpendicular to z-axis is
   (a) Zero
   (b) π
   (c) 2π
   (d) 4π\

2. A satellite moves in an elliptical orbit around the Earth (radius R = 6370 km). The minimum and the maximum distances of the satellite from the surface of the Earth are $r_1 = 6.3 \times 10^5$ m and $r_2 = 3.63 \times 10^6$ m respectively. The correct options are the
   (a) major axis of the path is $2a = 17 \times 10^6$ m
   (b) ratio of the speed of satellite at apogee to that at the perigee is 0.7
   (c) angular momentum of the satellite, at all points in its orbit, remains conserved
   (d) kinetic energy of the satellite, at all points in its orbit, remains conserved

3. A beam of unpolarized light of intensity I_0 is passed through three parallel ideal polarizing sheets. The polarizing directions of the first and the third sheets are inclined at 30° with respect to the middle one. The first being turned clockwise while the third being turned anti-clockwise. The emergent light
   (a) is unpolarized
   (b) is plane polarized
   (c) has intensity I_0
   (d) has intensity (9/32) I_0

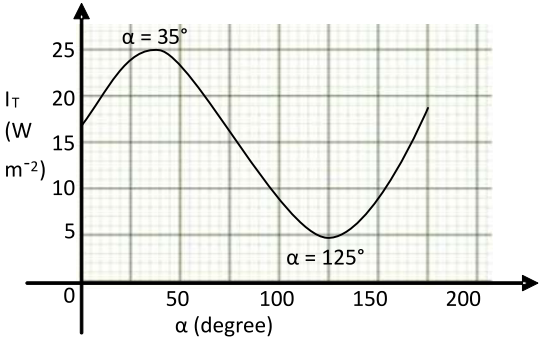
4. The maximum angular separation of the sodium doublet seen through a plane transmission diffraction grating having 10,000 lines per inch is
   (a) 8.69′
   (b) 4.13′
   (c) 3.25′
   (d) 1.45′

5. Helium-Neon LASER
   (a) is a four level LASER
   (b) has Neon as the active element
   (c) gives monochromatic light of $\lambda = 6328\ \text{Å}$
   (d) is for highly intense and directional light

6. The percentage contraction in the length of a rod moving with speed v = 0.8c in a direction making 60° angle with its own length is
   (a) 91.7 %
   (b) 81.7%
   (c) 8.35 %
   (d) 3.6 %

7. Knowing that the ground state wave function for a hydrogen atom, is $\psi_{100} = \frac{1}{\sqrt{\pi a_0^3}} e^{-\frac{r}{a_0}}$ the expectation value $<\frac{1}{r}>$ for a 1s electron in the hydrogen atom is
   (a) $\frac{\sqrt{2}}{a_0}$
   (b) $\frac{2}{a_0}$
   (c) $\frac{2\sqrt{2}}{a_0}$
   (d) $\frac{1}{a_0}$

8. A beam of light travelling horizontally consists of an un-polarized component of intensity I_0 and a polarized component of intensity I_P. The plane of vibration of the polarized component is oriented at an angle θ with vertical. The figure below depicts the total intensity I_T (Wm^{-2}) of light after the light beam has passed through a polarizer as a function of angle α that the polarizing axis of the polarizer subtends with vertical.



The values of I_0 and I_P may be

(a) $I_0 = 5\ W/m^2$

(b) $I_0 = 10\ W/m^2$

(c) $I_P = 20\ W/m^2$

(d) $I_P = 25\ W/m^2$

9. The path of a particle of mass m, moving under the influence of a central force, in plane polar coordinates is given by $r = r_0 e^{K\theta}$, where r_0 and K are positive constants of appropriate dimensions. The total energy of the particle throughout the motion is zero. In terms of mass m, angular momentum $L = mr^2\dot{\theta}$ and the constant K, the potential function V(r) and the particle velocity v(r) may be expressed as

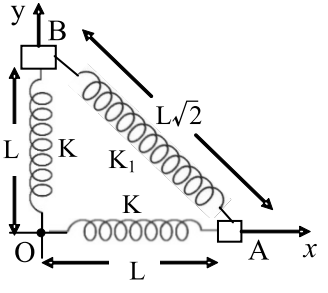
(a) $v(r) = Kr\dot{\theta}$

(b) $v(r) = \dfrac{K^2L^2}{2mr^2}$

(c) $v(r) = \dfrac{(K^2+1)\,L^2}{2mr^2}$

(d) $v(r) = \dfrac{KL}{mr}$

10. Each of the two small blocks A and B of mass m has been connected to a rigid support O (the Origin) through two identical springs (having equal un-stretched length L and equal force constant K). Initially the springs have been arranged perpendicular to each other as shown. The two blocks A and B are also joined by a third spring of spring constant K_1 and un-stretched length $L\sqrt{2}$. The motion of block A is constrained to be along x- axis and that of the B along y-axis. When displaced slightly,each block executes SHM. Choose the correct alternative(s)



(a) There are two normal modes of vibration

(b) Angular frequency may be $\omega = \sqrt{\dfrac{K}{m}}$

(c) Angular frequency may be $\omega = \sqrt{\dfrac{K+K_1}{m}}$

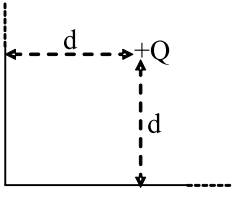
(d) Angular frequency may be $\omega = \sqrt{\dfrac{K+K_1}{2m}}$

11. A positive charge + Q is placed at a distance d from each of the two perpendicular semi-infinite metal plates as shown. The magnitude of the resultant force F acting on the charge +Q may be expressed as

(a) $F = \dfrac{Q^2}{16\pi\,\epsilon_0\,d^2}$

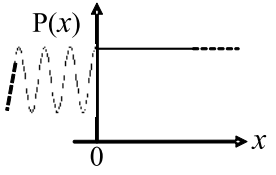
(b) $F = \dfrac{Q^2\sqrt{2}}{16\pi\,\epsilon_0\,d^2}$

(c) $F = \dfrac{Q^2\left(2\sqrt{2}-1\right)}{32\pi\,\epsilon_0\,d^2}$

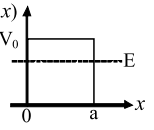


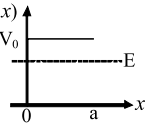
(d) None of these

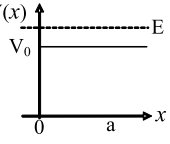
12. A particle moving from $-\infty$ along x-axis, with a total energy E, approaches to x = 0 where it is subjected to a potential field V(x). For time $t \to \infty$, the probability density P(x) is schematically shown in the figure below

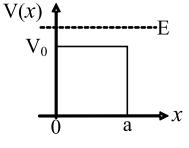


The correct shape of the potential V(x) is

(a) 

(b) 

(c) 

(d) 

13. A real gas obeys Vander Waal equation $\left(P + \frac{a}{V^2}\right)(V - b) = RT$, the critical constants of the gas are

(a) $P_C = \frac{a}{27b^2}, V_C = 3b$

(b) $RT_C = \frac{8a}{27b}$

(c) $\frac{P_C V_C}{RT_C} = \frac{8}{3}$

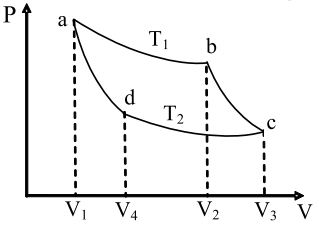
(d) The equation for n moles of the same gas is

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

14. The wavelength of K_α (x-ray line) for Tungsten (W) is 21nm. What would be its value for copper? Given that atomic number of Tungsten is 74 and that of copper is 29.
(a) 102.7nm
(b) 142.7nm
(c) 217.9nm
(d) 29nm

15. Two particles 1 and 2 with equal rest mass m_0 are moving along x axis of a frame which is at rest. The momenta of the two particles are observed to be $\frac{3}{4}m_0 c$ and $\frac{4}{3}m_0 c$ respectively then
(a) velocity of particle 1 is $v_1 = 0.6c$
(b) the kinetic energy of particle 1 is $\frac{1}{4}m_0 c^2$
(c) velocity of particle 2 as seen from particle 1 is $\frac{5}{13}c$
(d) $\frac{KE_{\text{faster moving}}}{KE_{\text{slower moving}}} = \frac{8}{3}$

16. Two identical Carnot engines 1 and 2 operate between the limits of maximum and minimum volume V_3 and V_1 and between maximum and minimum temperature T_1 and T_2 (see figure). Such that $\frac{V_3}{V_1} = e^3$ and $\frac{T_1}{T_2} = e$ (e being the base of natural logarithm). Engine 1 operates on monoatomic gas and engine 2 on an equal number of moles of a diatomic gas. Then



(a) For two engines ratio $\frac{V_{b\ \text{for engine}\ 1}}{V_{b\ \text{for engine}\ 2}} = e$

(b) Ratio of work done per cycle $\frac{W_1}{W_2} = \frac{5}{3}$

(c) Ratio of efficiency of two engines $\frac{\eta_1}{\eta_2} = 3$

(d) Ratio of efficiency of two engines $\frac{\eta_1}{\eta_2} = 1$

17. The magnetic susceptibility (χ) defines the extent of acquiring the magnetisation. The magnetic susceptibility (χ) may
    (a) be positive or negative.
    (b) have a value close to 1 for paramagnetic
    (c) increase with increasing magnetic field B
    (d) vary inversely to the absolute temperature

18. The ratio of surface energy (E_S) per nucleon contributing for the binding energy in the liquid drop model for two given / specified nuclides, $E_S(Z=13, N=14) : E_S(Z=27, N=37)$ is
    (a) 13 : 27
    (b) 9 : 16
    (c) 14 : 37
    (d) 4 : 3

19. In canonical ensemble, the expression for average energy in terms of partition function (Z) is expressed as
    (a) $< E > = -\left(\frac{1}{Z}\right)\frac{\partial z}{\partial \beta}$
    (b) $< E > = -\left(\frac{\partial}{\partial \beta}\right)(\beta\ \ell n\ Z)$
    (c) $< E > = -k_B T\, \ell n\, Z$
    (d) $< E > = -\frac{1}{\beta}\left(\frac{\partial Z}{\partial \beta}\right)$

20. The basis of sodium chloride structure consists of a Na atom and a Cl atom separated by….of the body diagonal of a unit cube/cell
    (a) $\frac{2}{3}$
    (b) $\frac{1}{2}$
    (c) $\frac{3}{4}$
    (d) $\frac{1}{2\sqrt{3}}$

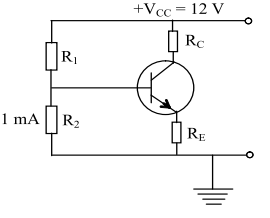
21. The average life time of a hydrogen atom in an excited state is given to be 2.5×10^{-14}s. The uncertainty in the measurement of the energy of this state is
    (a) 2.5 eV
    (b) 0.5 eV
    (c) 0.25 Ev
    (d) 0.026 eV

22. Gold has atomic weight M = 197 and density $\rho = 19.3 \times 10^3$ kg/m^3 the spacing between the atoms in solid gold is
    (a) 1.28 Å
    (b) 2.57 Å
    (c) 3.85 Å
    (d) 5.14 Å

23. In the famous Stern Gerlach experiment performed in 1921 in Frankfurt
    (a) a nonuniform magnetic field was employed
    (b) Silver ions were used
    (c) the electron spin was predicted
    (d) the concept of space quantization of angular momentum was conceived

24. During winters, the lakes often freeze because of the surrounding temperature being below the freezing temperature of water. Even when such freezing conditions persist for a long time say for days together complete freezing of water in the lake does not happen. This might be due to the fact that
    (a) the conductivity of ice decreases with time
    (b) the ice on the surface becomes too dense
    (c) the fishes and other aquatic animals start breathing fast
    (d) the heat is continuously conducted from the earth core

25. The figure shows a transistor circuit with voltage divider bias. The operating point of the transistor is to obtain (I_C, V_{CE}) ≡ (2 mA, 6 V). given that $V_E = 2$ volt, $V_{BE} = 0.6$ volt and $I_C \cong I_E$, the transistor parameters are
    (a) $R_E = 1\ k\Omega$
    (b) $V_C = 8$ volt
    (c) $V_B = 2.6$ volt
    (d) $R_1 = 9.4\ k\Omega$



Part B1

10 x 5 = 50

Answer all the following in brief (not more than 10 lines) with appropriate reasoning

B1. The precession of a rotating symmetric top takes place when the direction of its angular momentum does not coincide with its rotation axis. Defend or refute.

B2. The scaler triple product of three coplanar vectors is zero. Defend or refute.

B3. In steady state the amplitude and phase of the driven oscillator adjust themselves so that the average power supplied by the driving force just equals that being dissipated by the frictional force. Justify

B4. Heavier nuclei have tendency towards fission while lighter ones towards fusion. Explain why?

B5. The classical Physics is deterministic whereas the quantum Physics is purely probabilistic. Comment.

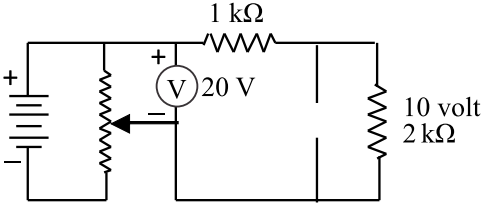
B6. Poynting Vector represents the amount of energy flowing per sec per unit area of cross section. Defend or refute.

B7. Debye theory of specific heat predicts that the specific heat of solids at low temperature varies proportional to T^3 and not as $T^{3/2}$. Defend or refute

B8. The equation of state for a gas with internal energy U is $PV = \frac{U}{3}$. The adiabatic process for the gas is represented by $PV^{\frac{4}{3}}$ = constant. Defend or refute.

B9. A direct band gap semiconductor is the one in which the conduction band minimum and valence band maximum occur at the same value of k. Defend or refute.

B10. When the supply voltage to a shunt zener regulator of zener voltage 10 V across the load of 2 kΩ changes from 20 volt to 40 volt, the zener current changes by 20 mA. Defend or refute. Given that the series resistance is 1 kΩ.



Part B2

10 x 10 = 100

Solve all Ten Problems

P1. What are conservative and non-conservative forces? Demonstrate that a conservative force can always be expressed as the negative gradient of a potential function. Show explicitly that the curl of a conservative force is zero.

P2. Enumerate the various forces acting on a body executing forced oscillations. Obtain the differential equation of forced oscillations in a mechanical system. Solve the differential equation to arrive at the equation of forced oscillations in mechanical systems. Discuss the transient part of the solution. Show mathematically that the velocity maximum occurs just when the frequency of applied periodic force equals the natural frequency of the vibrating body while the amplitude maximum occurs at frequencies slightly lower than that in realistic situations.

P3. Explain the concept of conduction current and the displacement current in electric circuits. Discuss the behaviour of a solid copper wire to the propagation of the e m waves of frequencies $\nu_1 = 5.0 \times 10^{15}$ Hz and the X- rays of $\nu_2 = 7.0 \times 10^{20}$ Hz through it. Given that for copper the electric conductivity is $\sigma = 5.8 \times 10^7\ \Omega^{-1}\ m^{-1}$ and the relative permittivity is $\varepsilon_r = 1.0$

P4. Knowing that the crystal structure of gold is quite similar to that of copper and that the speed of sound in gold is 2100 m/s while that in copper is 3800 m/s, estimate the Debye temperature (θ_D) of gold if that of copper is 348 K. The densities of gold and copper are 19.3 and 8.96 g/cc and their atomic weights are 197.0 and 63.5 respectively.

P5. The Fermi energy of copper is 7.0 eV. Estimate the average distance (mean free path) travelled by the conduction electrons between two successive collisions. Given that for copper the electric conductivity is $\sigma = 5.8 \times 10^{7}\ \Omega^{-1} m^{-1}$ and the concentration of valence electrons in conduction band is $n = 8.5 \times 10^{28}\ m^{-3}$; the charge and mass of electron are respectively $e = 1.6 \times 10^{-19}$ C and $m = 9.1 \times 10^{-31}$ kg.

P6. Rydberg constant is given by $R = \frac{mZ^2e^4}{8\varepsilon_0^2 h^3}$ where m is the mass of electron. In its reduced mass form the values of R for the hydrogen atom and singly ionized helium are $R_H = 10967757.6 m^{-1}$ & $R_{He} = 10972226.3\ m^{-1}$ respectively. The ratio of nuclear masses is given by $\frac{M_{He}}{M_H} = 3.9726$

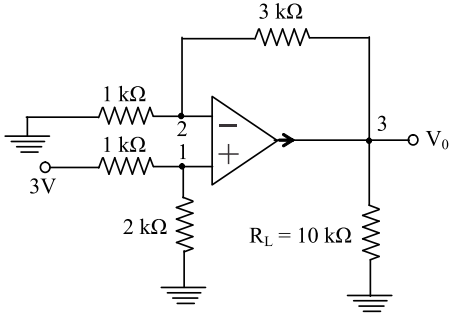
Using this information, calculate the ratio of proton mass to electron mass to four significant figures.

P7. A spherical metallic ball of radius R = 0.50 m carrying a charge q distributed uniformly over its surface is kept in space where the surrounding medium has a uniform charge density $\rho = \frac{\alpha}{r}$ with $2\pi\alpha = 10^{-4} Cm^{-2}$ is a constant and r is the distance from the centre of the ball. Find the value of charge q on the ball if the magnitude of the electric field in the surrounding space, outside the ball, is independent of r. How high is this field strength? The relative permittivity of the ball as well as that of the surrounding space is considered to be unity ($\varepsilon_r = 1.0$).

P8. Two convergent lenses of glass ($\mu = 3/2$) of focal lengths 20 cm and 10 cm separated by a distance of 30 cm constitute a coaxial optical system. A linear object of height 2.0 cm is placed perpendicular to the principal axis at a distance of 30 cm from the first lens in front of it, obtain the position and the size of the final image so formed. Comment on the nature of the final image and the practical utility of such a combination. How are the results affected if the space between the lenses is filled with water ($\mu = 4/3$).

P9. A particle of mass m is coupled to a 1D simple harmonic oscillator of angular frequency ω and characteristic distance x_0 such that $x_0^2 = \frac{\hbar}{m\omega}$
At time t = 0, the wave function $\Psi(x, t=0)$, of the particle is given by $\Psi(x,\ t=0) = \frac{1}{(\pi\sigma^2)^{\frac{1}{4}}} e^{-\frac{x^2}{2\sigma^2}}$
Compute the probability that an energy measurement at t = 0 yields the value $\frac{\hbar\omega}{2}$

P10. Assuming that the operational amplifier shown in the circuit below is an ideal one.



Calculate
(a) the output voltage V_0
(b) the magnitude and direction of current passing through the 3 $k\Omega$ resistor.