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JEST Physics

Question Paper -2025

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Section A (MCQ)

Correct answer: +1, wrong answer: −1/3.

Q1. For a relativistic point particle, the momentum is $\vec{p} = \frac{m_0 \vec{v}}{\sqrt{1 - v^2/c^2}}$, where $\vec{v}$ is its velocity as measured by an inertial observer. Then the acceleration is in the same direction as the applied force

(a) always

(b) never

(c) only when force is neither parallel nor perpendicular to the velocity

(d) only when force is parallel or perpendicular to the velocity

Ans.: (d)

Q2. A boat is floating in a pond with still water. There is a heavy stone on the boat. If the stone is dropped gently into the water, what happens to the water level in the pond after the stone sinks completely?

(a) The level goes down

(b) The level goes up

(c) The level goes up or down depending on the size of the stone

(d) The level remains the same

Ans.: (a)

Q3. Consider a quantum system that is evolved sequentially with a finite sequence of Hermitian Hamiltonians $\{H_0, H_1, ...H_n\}$. The full evolution operator is written as:

$$\mathrm{O} = U_n U_{n-1} ... U_1 U_0 = e^{-i\mathrm{H}}, \text{ with } U_j = e^{-i\mathrm{H}_j} \text{ and, } j = 0,1,...n$$

Then H is

(a) undefined (b) a Hermitian operator

(c) a unitary operator (d) None of the others

Ans.: (b)

Q4. Suppose the mass of the Sun is reduced to half of its original value very slowly, e.g., over a billion years, what will be the effect of this on the Earth's orbit?

(a) The earth flies away

(b) Orbit remains closed but not elliptical

(c) Remains elliptical with the same mean radius

(d) Remains elliptical, but the mean radius changes

Ans.: (d)

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Q5. If the lattice contribution to the C_V of a solid crystal at temperature $2K$ is found to be $0.5mJ\ \text{mole}^{-1}K^{-1}$, what will be the corresponding contribution at temperature $4K$?

(a) $2mJ\ \text{mole}^{-1}K^{-1}$ (b) $1mJ\ \text{mole}^{-1}K^{-1}$ (c) $4mJ\ \text{mole}^{-1}K^{-1}$ (d) $8mJ\ \text{mole}^{-1}K^{-1}$

Ans.: (c)

Q6. A particle is moving under the force field given by $\vec{F}=k\vec{r}$, where k is a positive constant. The difference in work done (in arbitrary units) if the particle moves from point $A(-1,0,0)$ to point $B(1,0,0)$ following semi-circular paths in the clockwise and anti-clockwise directions on the $X-Y$ plane will be

(a) $2\pi k$ (b) 0 (c) πk (d) $\frac{1}{2}\pi k$

Ans.: (b)

Q7. For a plane electromagnetic wave propagating with wave vector $\vec{k}$ in a homogeneous and isotropic medium, which of the following holds?

(a) $\vec{E}\times\vec{B}=\vec{0}$ (b) None of the others (c) $\vec{E}\cdot\vec{B}=0$ (d) $\vec{k}\cdot\left(\vec{E}\times\vec{B}\right)=0$

Ans.: (c)

Q8. A quantum mechanical system is spanned by the eigenstates $|a_1\rangle$ and $|a_2\rangle$ of a Hermitian operator A with eigenvalues a_1 and a_2 respectively. If there is no degeneracy, what is the expectation value of the operator $(A-a_1)(A-a_2)$ in the state $\frac{|a_1\rangle+|a_2\rangle}{\sqrt{2}}$?

(a) 1 (b) 0 (c) $(a_2-a_1)(a_1-a_2)$ (d) $\frac{(a_2-a_1)(a_1-a_2)}{2}$

Ans.: (b)

Q9. Three observers successively measure the spin of a given proton along z-axis, x-axis and again z-axis, respectively. The first observer finds the projection to be $+\frac{1}{2}$. Assuming no other factors, what is the probability that the third observer finds the spin projection to be $-\frac{1}{2}$?

(a) 0 (b) 1 (c) 0.5 (d) None of the others

Ans.: (c)

Q10. One mole of ideal gas with a constant C_V undergoes a reversible adiabatic expansion. Which one of the following equations is valid? $\left[\gamma = \frac{C_P}{C_V} \text{ for the gas}\right]$

(a) $P^{1-\gamma}T^{\gamma}$ = constant (b) $V^{\gamma}T$ = constant

(c) $P^{\gamma-1}T^{\gamma}$ = constant (d) VT^{γ} = constant

Ans.: (a)

Q11. Consider two identical charged balls, each of mass m and charge q. One of them is initially held fixed on a frictionless insulating horizontal surface and the other is carefully placed above the first one at a height h from the surface, such that the gravitational force on it is balanced by the Coulomb repulsion. The upper ball is now shifted horizontally by a distance $d\left(d << h\right)$ to the right and then both the balls are released. Which way will the balls move immediately after this?

(a) ball on the surface moves towards right and ball above moves upwards

(b) ball on the surface moves towards left, ball above moves downwards

(c) both balls oscillate around their original positions

(d) both balls remains static at their new positions

Ans.: (b)

Q12. A wire of length $0.01mm$ is placed perpendicular to the axis of a thin convex lens, $30cm$ from its center. If the focal length of the lens is $20cm$, what is the length of the image of the wire?

(a) $0.02mm$ (b) $0.01mm$ (c) $1mm$ (d) $0.03mm$

Ans.: (a)

Q13. The electric dipole moment of a charge distribution is independent of the choice of the origin of coordinates only if

(a) the charge distribution is discrete (b) the total charge adds up to zero

(c) there is no magnetic field present (d) the charge distribution is not time-dependent

Ans.: (b)

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Q14. Consider the time-independent Schrodinger equation with a real potential and suppose $\psi(x)$ is a solution of this equation. Which of the following is true?

(a) ψ^* is a solution of the same equation

(b) ψ^* is never a solution of the same equation

(c) is a solution of the same equation only if the potential is symmetric about $x=0$

(d) is a solution of the same equation only if the potential vanishes at infinity

Ans.: (a)

Q15. Calculate the partition function for two indistinguishable bosonic particles at a temperature T, which can be distributed in two single-particle energy levels $\in_1$ and $\in_2$. Consider $\beta = \frac{1}{k_B T}$.

(a) $\left(e^{-\beta\in_1} + e^{-\beta\in_2}\right)^2$ (b) $e^{-2\beta\in_1} + e^{-2\beta\in_2} + e^{-\beta(\in_1+\in_2)}$

(c) $e^{-2\beta\in_1} + e^{-2\beta\in_2} + e^{-2\beta(\in_1+\in_2)}$ (d) $\frac{1}{2!}\left(e^{-\beta\in_1} + e^{-\beta\in_2}\right)^2$

Ans.: (b)

Q16. Consider the standard notation of discrete finite groups with Z_n corresponding to the rotation by $2\pi/n$ about a given axis, S_n corresponding to the permutation group of the set S having n elements, i.e. $S=\{1,2,3,...,n\}$, and the Dihedral group D_n corresponding to the reflection and rotation symmetries of a regular polygon with n number of sides. Which of the following is the smallest non-abelian group?

(a) S_3 (b) Z_3 (c) S_4 (d) D_4

Ans.: (a)

Q17. Given the differential operator: $D \equiv \frac{d^2}{dx^2} + P\frac{d}{dx} + Q$, where P and Q are constants, what is the eigenvalue corresponding to the eigenfunction $y = e^x$?

(a) $(P+Q)$ (b) $(1+Q)$ (c) $(P+Q-1)$ (d) $(1+P+Q)$

Ans.: (d)

Q18. The Fraunhofer diffraction pattern formed by an elliptical aperture will be

(a) circular

(b) elliptical with the semi-major axis parallel to that of the aperture

(c) hyperbolic

(d) elliptical with the semi-major axis perpendicular to that of the aperture

Ans.: (d)

Q19. Match the following statements

A1	Photoelectric effect	B1	Involves loosely bound or free electrons
A2	Compton scattering	B2	Inverse photoelectric effect
A3	Pair production	B3	Needs a minimum of 1.02 MeV of energy for the incident radiation
A4	Bremsstrahlung	B4	Involves bound electrons and depends on the specifics of the material

(a) A1-B3, A2-B4, A3-B2, A4-B1 (b) A1-B3, A2-B2, A3-B1, A4-B4

(c) A1-B4, A2-B1, A3-B3, A4-B2 (d) A1-B4, A2-B3, A3-B2, A4-B1

Ans.: (c)

Q20. The Lagrangian of a two-dimensional system is given by

$$L=\frac{1}{2}m\left(\dot{x}^2+\dot{y}^2\right)-k\left(x^2+y^2\right)^{-1.5}$$

Which of the following is/are the constant(s) of motion?

(a) Energy only (b) None of the others

(c) Angular momentum only (d) Energy and angular momentum

Ans.: (d)

Q21. Which of the following thermodynamic variables is not a function of state for an ideal gas?

(a) Entropy (b) None of the others (c) Temperature (d) Pressure

Ans.: (b)

Q22. A slide calipers instrument has smallest main scale division of $0.4\,mm$ and 40 vernier divisions match with 38 main scale divisions. The vernier constant of this instrument is

(a) $0.05\,mm$ (b) $0.01\,mm$ (c) $0.02\,mm$ (d) $0.1\,mm$

Ans.: (c)

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Q23. A capacitor with capacitance C is connected in series with a resistor of resistance R and an ideal DC source with voltage V_S. At one instant during the charging of the capacitor if the resistor is replaced by a wire of zero resistance, which of the following statements is true?

(a) None of the others is true

(b) The voltage across the capacitor will increase slowly

(c) The voltage across the capacitor will drop immediately to zero

(d) The capacitor immediately attains the source voltage V_S

Ans.: (d)

Q24. The number of independent real numbers that parameterize any (3×3) Hermitian matrix is

(a) 3 (b) 8 (c) 9 (d) 6

Ans.: (c)

Q25. Consider a 2×2 matrix $A=\begin{bmatrix}0 & 1\\ 1 & 1\end{bmatrix}$ which has eigenvalues $\lambda_1=\frac{1+\sqrt{5}}{2}$ and $\lambda_2=\frac{1-\sqrt{5}}{2}$.

For any natural number n which of the following is correct?

(a) $A^n=\frac{1}{\sqrt{5}}\begin{bmatrix}\lambda_1^{n-1}-\lambda_2^{n-1} & \lambda_1^{n}-\lambda_2^{n}\\ \lambda_1^{n}-\lambda_2^{n} & \lambda_1^{n+1}-\lambda_2^{n+1}\end{bmatrix}$

(b) $A^n=\frac{1}{\sqrt{5}}\begin{bmatrix}\lambda_1^{n-1}-\lambda_2^{n-1} & \lambda_1^{n}+\lambda_2^{n}\\ \lambda_1^{n}+\lambda_2^{n} & \lambda_1^{n+1}-\lambda_2^{n+1}\end{bmatrix}$

(c) $A^n=\frac{1}{\sqrt{5}}\begin{bmatrix}\lambda_1^{n-1}+\lambda_2^{n-1} & \lambda_1^{n}+\lambda_2^{n}\\ \lambda_1^{n}+\lambda_2^{n} & \lambda_1^{n+1}+\lambda_2^{n+1}\end{bmatrix}$

(d) $A^n=\frac{1}{\sqrt{5}}\begin{bmatrix}\lambda_1^{n-1}+\lambda_2^{n-1} & \lambda_1^{n}-\lambda_2^{n}\\ \lambda_1^{n}-\lambda_2^{n} & \lambda_1^{n+1}+\lambda_2^{n+1}\end{bmatrix}$

Ans.: (a)

Section B (MCQ)

Correct answer: +3, wrong answer: −1.

Q1. A circular loop of radius a, carrying a current I in an anticlockwise direction (when seen downwards from the positive Z axis), is placed on the $X-Y$ plane centered at the origin. What is the magnetic field on the $X-Y$ plane at $r>>a$?

(a) $\frac{\mu_0 I}{4}\frac{a^2}{r^3}$ in the negative Z direction

(b) $\frac{\mu_0 I}{4}\frac{a^2}{r^3}\hat{r}$

(c) 0

(d) $\frac{\mu_0 I}{4\pi}\frac{a^2}{r^3}$ in the positive Z direction

Ans.: (a)

Q2. Evaluate $\vec{\nabla}\cdot\left(r^4\vec{r}\right)$, where $\vec{r}$ represents a three-dimensional position vector.

(a) $4r^4$ (b) 0 (c) $5r^4$ (d) $7r^4$

Ans.: (d)

Q3. The volume of a nucleus, treated as a Fermi gas in three-dimensional space, is proportional to the number of fermions presents in it. If the total number of fermions is changed from N to $2N$, the total energy of the system will

(a) be doubled

(b) be half of its original value

(c) remain the same

(d) be 4 times its original value

Ans.: (b)

Q4. Consider a two-dimensional Fermi gas at $0K$ with Fermi energy $\in_F$. The average energy per particle of this gas is

(a) $\frac{3\in_F}{5}$ (b) $\frac{\in_F}{4}$ (c) $\frac{\in_F}{2}$ (d) $\frac{\in_F}{3}$

Ans.: (c)

Q5. For a particle in a one-dimensional box of width L, the uncertainty Δp in momentum in the n-th eigenstate of energy for large n is

(a) $\frac{n\pi\hbar}{L}$ (b) $\frac{\hbar}{n\pi L}$ (c) $\frac{2n\hbar}{L}$ (d) $\frac{2n\pi\hbar}{L}$

Ans.: (a)

Q6. Consider the group S_4 corresponding to the permutations of the set S having four elements, say $S=\{1,2,3,4\}$. How many non-identity self-inverse (i.e. order 2) elements does S_4 have?

(a) 8 (b) 12 (c) 9 (d) 6

Ans.: (c)

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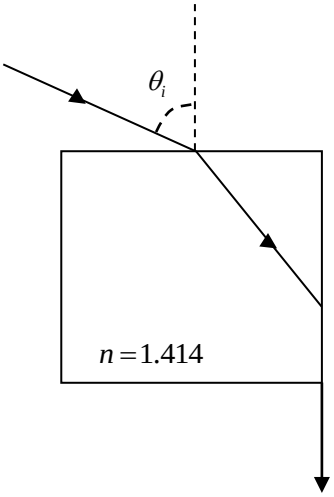
Q7. Consider a circular disk of radius R and mass M in the $X-Y$ plane, with a surface mass density $\sigma(r)=\sigma_0 e^{-r^2/a^2}$, where r is the distance from the center of the disk. What is the moment of inertia around the Z-axis through the center of the disk? [consider $R>>a$]

(a) $\frac{1}{2}Ma^2$ (b) $6Ma^2$ (c) Ma^2 (d) $\frac{1}{3}Ma^2$

Ans.: (c)

Q8. A ray of light is incident on a glass cube of refractive index 1.414 as shown in the figure. Find the angle of incidence θ_i, such that the ray grazes down the side of the glass cube.



(a) $\pi/3$

(b) $\pi/4$

(c) 0

(d) $\pi/2$

Ans.: (d)

Q9. A block, suspended from a massless spring, is fully immersed in a liquid contained in a reservoir. What is the time period of small oscillations of the block?

[Given: Mass of the block m, density of the block ρ_b, natural length of the spring L, spring constant k, acceleration due to gravity g, density of the liquid ρ_l, damping coefficient of the liquid i.e., damping per unit mass per unit velocity γ]

(a) $2\pi\sqrt{\frac{m}{k}}$ (b) $2\pi\sqrt{\frac{L}{(1-\rho_l/\rho_b)g}}$ (c) $2\pi\sqrt{\frac{1}{k/m+\gamma^2/4}}$ (d) $2\pi\sqrt{\frac{1}{k/m-\gamma^2/4}}$

Ans.: (d)

Q10. A silicon $p-n$ junction diode operates at 27^0 C. The current I is doubled when the forward bias is increased. The increase in the forward bias is closest to:

[Assume $I>>I_s$, where I_s is the reverse saturation current and the emission coefficient $\eta_{Si}=2$]

(a) $18\,mV$ (b) $36\,mV$ (c) $54\,mV$ (d) $72\,mV$

Ans.: (b)

Q11. The time averaged electrostatic potential of a neutral H-atom is given by

$$\Phi(\vec{r}) = \frac{q}{4\pi \in_0} \frac{e^{-\alpha r}}{r}\left(1+\frac{\alpha r}{2}\right)$$

The classical charge distribution corresponding to this is

(a) $-\frac{q}{8\pi}\alpha^3 e^{-\alpha r}$

(b) $-\frac{q}{8\pi}\alpha^3 e^{-\alpha r} + q\delta^3(\vec{r})$

(c) $\frac{q}{8\pi}\alpha^3 e^{-\alpha r}\left(1+\frac{\alpha r}{2}\right) - q\delta^3(\vec{r})$

(d) $qe^{-\alpha r}\left(1+\frac{\alpha r}{2}\right)$

Ans.: (b)

Q12. Given an isolated thermodynamic system with a total energy E, total volume V and total number of particles N, then condition for stable thermal equilibrium, in terms of its entropy S under small changes ΔE and ΔV, is given by

(a) $S(E+\Delta E, V+\Delta V, N) + S(E-\Delta E, V-\Delta V, N) + 2S(E,V,N) < 0$

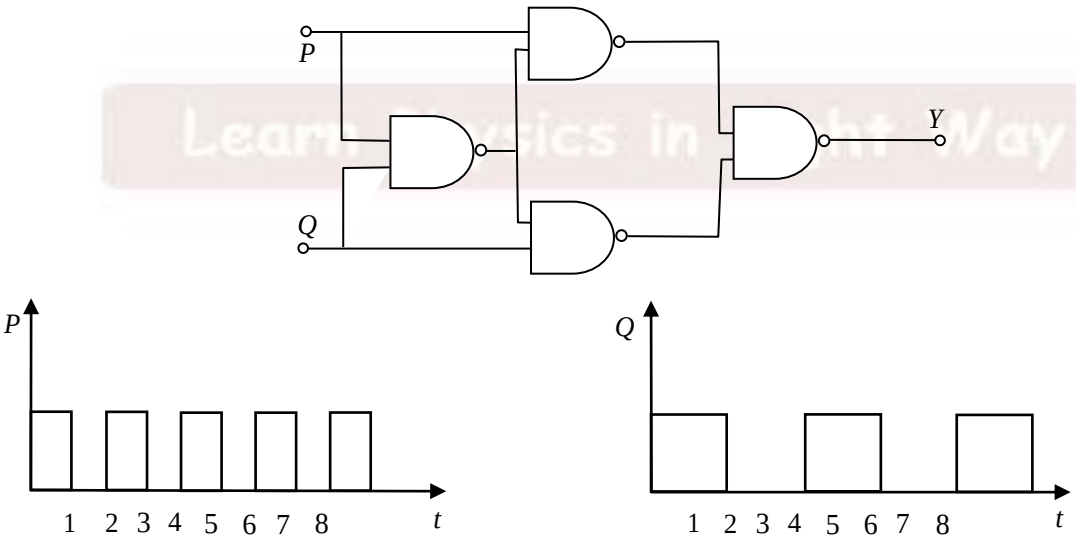
(b) $S(E+\Delta E, V+\Delta V, N) - S(E-\Delta E, V-\Delta V, N) - 2S(E,V,N) < 0$

(c) $-S(E+\Delta E, V+\Delta V, N) + S(E-\Delta E, V-\Delta V, N) - 2S(E,V,N) < 0$

(d) $S(E+\Delta E, V+\Delta V, N) + S(E-\Delta E, V-\Delta V, N) - 2S(E,V,N) < 0$

Ans.: (d)

Q13. For the circuit and the inputs P and Q shown, which of the following is the correct output Y ?



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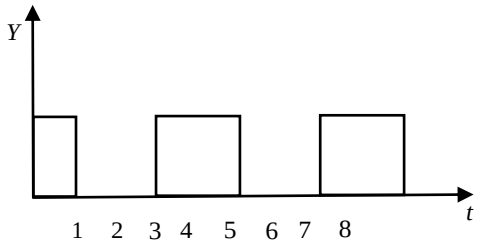
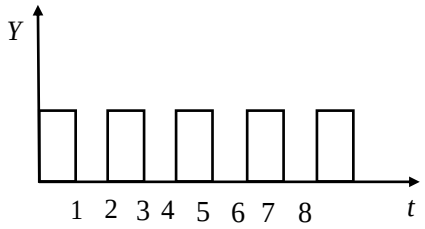
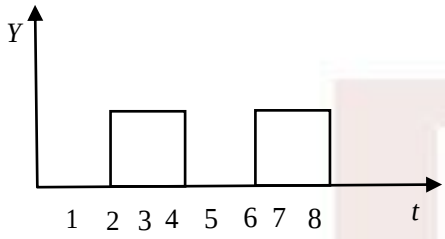
(a)



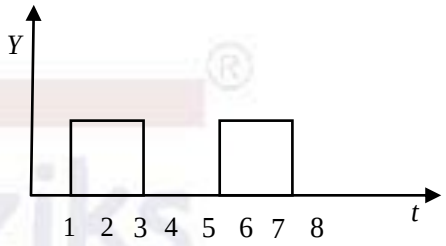
(b)



(c)



(d)



Ans.: (d)

Q14. A particle is moving with velocity $v_x = v_y = v_z = c/2$ in frame S. The ratio of velocity component v_y to the velocity component $v_{y'}$ as measured in frame S' moving with velocity $c/2$ with respect to frame S along the common x direction is

(a) $\cos(\pi/3)$

(b) $\sin(\pi/6)$

(c) $\cos(\pi/6)$

(d) $\sin(\pi/3)$

Ans.: (c)

Q15. For a one-dimensional simple harmonic oscillator with mass m and angular frequency ω, consider a perturbation λx^4 in the Hamiltonian $(\lambda > 0)$. What is the lowest order correction to the ground state energy?

[The position operator expressed in terms of the raising and lowering operators is $\hat{x} = \sqrt{\frac{\hbar}{2m\omega}}\left(\hat{a} + \hat{a}^\dagger\right)$]

(a) $\frac{3\lambda}{2}\left(\frac{\hbar}{m\omega}\right)^2$ (b) $\frac{5\lambda}{4}\left(\frac{\hbar}{m\omega}\right)^2$ (c) $\frac{3\lambda}{4}\left(\frac{\hbar}{m\omega}\right)^2$ (d) $\frac{5\lambda}{2}\left(\frac{\hbar}{m\omega}\right)^2$

Ans.: (c)

Section C (NAT)

Correct answer: +3, wrong answer: 0.

Q1. Given the mass of the proton $m_p \approx 1836\, m_e$ and mass of the deuteron $m_d \approx 3670\, m_e$, where m_e is the electron mass, find the fractional shift (in parts per million, to the nearest integer) of the ground state energy of the deuterium atom as compared to H-atom.

Ans.: 272

Q2. If a resistor of $10\,k\Omega$ and a capacitor of $0.5\,\mu F$ are connected in series across an AC supply of $220V$ (rms) at $50\,Hz$, what is the average power (in mW, to the nearest integer) dissipated in the circuit?

Ans.: 3444

Q3. The average lifetime of a muon in its rest frame is $2200\,ns$. What will be the average distance (in meters, to the nearest integer) travelled by it, which created with a velocity of $\frac{1}{3}c$, before it decays? Here c is the speed of light.

Ans.: 233

Q4. The Fraunhofer diffraction intensity pattern for light of wavelength λ by a single slit of width a is given by

$$I = A_0^2 \left(\frac{\sin \beta}{\beta} \right)^2$$

where A_0 is the intensity of the central maximum and $\beta = \frac{\pi a \sin \theta}{\lambda}$, where θ is the angle with the incident beam. What is the angular separation in milli-radians, between the two first minima on two sides of the central beam, if $a = 1mm$ and $\lambda = 5000\,\text{Å}$?

Ans.: 1

Q5. A current of $10A$ is maintained for $1s$ in a resistor of resistance 25Ω, which is thermally insulated. The initial temperature of the resistor is 23°C. The resistor has a mass of $10\,gm$ and a specific heat of $836\,Jkg^{-1}K^{-1}$. What is the entropy change of the resistor, rounding off to the nearest while number in units of JK^{-1}?

Ans.: 6

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Q6. A simple pendulum with effective length l and a bob of mass m has a time period T_1. Suppose now that the bob is given an electric charge $+Q$. It is made to oscillate just above a two dimensional infinite sheet with surface charge density $+\sigma$, where $\frac{Q\sigma}{mg\in_0}=\frac{3}{2}$, $\in_0$ being the permittivity of free space and g being the acceleration due to gravity. If the period of oscillation in this case is T_2, determine $\frac{T_2}{T_1}$. [Neglect radiation from the charge]

Ans.: 2

Q7. What is the value of the integral

$$I=\frac{3}{2\pi}\oint_C\frac{dz}{1+z^2},$$

where the contour C is a circle of radius 2 centered at the origin?

Ans.: 0

Q8. Suppose the wave function of a free particle in one dimension obeys $\frac{d^2\psi}{dx^2}=-4\psi$ in units where $\hbar=1$. What is the magnitude of the momentum of the particle?

Ans.: 2

Q9. A 3×3 matrix M satisfies $M^2-3M+2I=0$. Find the determinant of the matrix M if its trace is 6.

Ans.: 6

Q10. A heat engine works between a high temperature source and a sink at 27°C. If the maximum efficiency possible for it to achieve is 50%, what is the temperature of the source in °C?

Ans.: 327