

Questions
40 MCQs (25 + 15)

Marks
150 (75 + 75)

Time
3 hours

Negative marking
–1 in Section A only

Part	Section	Questions	Q. No.
Section A (25 questions, +3 / –1)	Section A: Basic Topics	25	1 to 25
Section B (15 questions, +5 / no negative)	Section B: PhD Level	15	26 to 40

Instructions

1. This paper has two sections. Section A has 25 questions on basic topics. Section B has 15 questions that need somewhat more thought or knowledge.
2. All questions are multiple-choice with four options, and only one option is correct.
3. Section A: +3 marks for a correct answer, –1 mark for a wrong answer, 0 if not attempted. Section B: +5 marks for a correct answer and no negative marking, so attempt every Section B question.
4. You have 3 hours for the whole paper. The real test is online and gives an on-screen calculator, so a basic calculator is fine here. If your answer does not match an option exactly, choose the closest one.
5. Use only the values in the Useful Data box printed before Question 1 wherever an answer is numerical.
6. In the GS-2026 Physics test, Section A was common to everyone and the second section was different for PhD and Integrated PhD applicants. The Section B in this paper is at PhD (MSc) level.
7. The answer key and short solutions are at the end. Check them only after you finish.

This is an AglaSem practice paper with original questions written on the official TIFR GS Physics screening-test pattern and syllabus (Classical Mechanics; Mathematics relevant to Physics; Electricity and Magnetism; Quantum Mechanics; Heat, Thermodynamics and Statistical Physics; General and Modern Physics; Electronics and Experimental Physics). It is not an official TIFR paper.

Section A (25 questions, +3 / –1)

Section A: Basic Topics

Useful Data (use these values in numerical questions)

Quantity	Value
Speed of light, c	3.00×10^8 m/s
Planck's constant, h	6.63×10^{-34} J s
Electron charge, e	1.60×10^{-19} C
Electron mass, m_e	9.11×10^{-31} kg
Permittivity of free space, ϵ_0	8.85×10^{-12} F/m
Permeability of free space, μ_0	$4\pi \times 10^{-7}$ H/m
1 eV	1.60×10^{-19} J
Specific heat of water	4186 J/(kg K)
0 °C	273 K

1. A uniform solid sphere rolls without slipping down a rough inclined plane of angle θ . The acceleration of its centre of mass is:
 (A) $(1/2) g \sin \theta$ (B) $g \sin \theta$
 (C) $(2/3) g \sin \theta$ (D) $(5/7) g \sin \theta$

2. A body is projected vertically upward from the surface of the Earth (radius R , no air) with a speed equal to the orbital speed of a satellite skimming the surface. The maximum height it reaches above the surface is:
- (A) $2R$ (B) R
(C) $R/\sqrt{2}$ (D) $R/2$
3. A particle of mass m moves in one dimension in the potential $V(x) = kx^4$ ($k > 0$). If the amplitude of oscillation is A , the period T depends on A as:
- (A) $T \propto A$ (B) $T \propto A^2$
(C) T is independent of A (D) $T \propto 1/A$
4. The eigenvalues of the matrix
- | | | |
|---|---|---|
| 0 | 1 | 0 |
| 1 | 0 | 1 |
| 0 | 1 | 0 |
- are:
- (A) $0, 2, -2$ (B) $0, \sqrt{2}, -\sqrt{2}$
(C) $1, \sqrt{2}, -\sqrt{2}$ (D) $0, 1, -1$
5. The contour integral $\oint e^z/(z - 1) dz$, taken anticlockwise around the circle $|z| = 2$ in the complex plane, equals:
- (A) 0 (B) $2\pi i e$
(C) $2\pi i$ (D) $\pi i e$
6. Using the Fourier series of $f(x) = x^2$ on $(-\pi, \pi)$, one can show that $\sum_{n=1}^{\infty} 1/n^2 = \pi^2/6$. The value of $1 - 1/2^2 + 1/3^2 - 1/4^2 + \dots$ is:
- (A) $\pi^2/12$ (B) $\pi^2/8$
(C) $\pi^2/6$ (D) $\pi/4$
7. X and Y are independent random variables, each uniformly distributed on $[0, 1]$. The probability that $X + Y < 1/2$ is:
- (A) $1/8$ (B) $1/16$
(C) $1/4$ (D) $1/2$
8. An isolated parallel-plate capacitor of capacitance C carries charge Q . The work needed to slowly pull the plates apart until their separation is doubled is:
- (A) Zero (B) $Q^2/(4C)$
(C) $Q^2/(2C)$ (D) Q^2/C
9. A square loop of side a carries a steady current I . The magnitude of the magnetic field at the centre of the loop is:
- (A) $\mu_0 I/(2a)$ (B) $4\mu_0 I/(\pi a)$
(C) $2\sqrt{2} \mu_0 I/(\pi a)$ (D) $\sqrt{2} \mu_0 I/(\pi a)$
10. A plane electromagnetic wave in vacuum has an electric field amplitude of 100 V/m . Its time-averaged intensity is closest to:
- (A) 6.6 W/m^2 (B) 13 W/m^2
(C) 27 W/m^2 (D) 1.3 W/m^2
11. An electron is confined in a one-dimensional infinite square well of width 1.0 nm . Its ground-state energy is closest to:
- (A) 1.5 eV (B) 0.38 eV
(C) 3.8 eV (D) 0.094 eV

12. For a particle in one dimension, the commutator $[\hat{x}, \hat{p}^2]$ equals:
 (A) $i\hbar \hat{p}$ (B) 0
 (C) $2i\hbar \hat{p}$ (D) $-2i\hbar \hat{p}$
13. The Lyman- α line ($n = 2 \rightarrow n = 1$) of atomic hydrogen has wavelength 121.6 nm. The corresponding line of singly ionised helium, He^+ , has wavelength closest to:
 (A) 30.4 nm (B) 60.8 nm
 (C) 486.4 nm (D) 121.6 nm
14. An ideal monatomic gas is compressed reversibly and adiabatically to one-eighth of its initial volume. Its absolute temperature increases by a factor of:
 (A) 2 (B) 4
 (C) $2\sqrt{2}$ (D) 8
15. 1 kg of water is heated from 0 °C to 100 °C at constant pressure. The increase in its entropy is closest to:
 (A) 0.42 kJ/K (B) 4.19 kJ/K
 (C) 1.31 kJ/K (D) 1.53 kJ/K
16. A two-level system has energies 0 and ϵ . At a temperature T such that $kT = \epsilon/\ln 3$, the probability of finding the system in the upper level is:
 (A) $1/3$ (B) $3/4$
 (C) $1/4$ (D) $1/2$
17. According to classical statistical mechanics, the average total energy of a three-dimensional isotropic harmonic oscillator in equilibrium at temperature T is:
 (A) $(3/2)kT$ (B) $3kT$
 (C) kT (D) $6kT$
18. X-rays are Compton-scattered by free electrons. The increase in wavelength of the radiation scattered at 90° is closest to:
 (A) 1.2 pm (B) 2.4 pm
 (C) 0.24 pm (D) 4.9 pm
19. Muons with a mean lifetime of 2.2 μs (in their rest frame) move through the laboratory at 0.99c. The mean distance they travel in the laboratory before decaying is closest to:
 (A) 4.6 km (B) 0.09 km
 (C) 0.65 km (D) 46 km
20. A radioactive sample has mean life τ . The fraction of the original nuclei that decay between $t = \tau$ and $t = 2\tau$ is closest to:
 (A) 0.50 (B) 0.23
 (C) 0.37 (D) 0.14
21. An ideal op-amp is used as a non-inverting amplifier with feedback resistor $R_f = 47 \text{ k}\Omega$ and resistor $R_1 = 10 \text{ k}\Omega$ from the inverting input to ground. For an input of 0.20 V, the output is:
 (A) -1.14 V (B) -0.94 V
 (C) 1.14 V (D) 0.94 V
22. The Boolean expression $(A + B)(A + C)$ simplifies to:
 (A) $A + B + C$ (B) ABC
 (C) $AB + C$ (D) $A + BC$

23. The resistivity of a wire is found from $\rho = \pi d^2 R / (4L)$. The diameter d , resistance R and length L are measured with errors of 1%, 2% and 1% respectively. The maximum possible percentage error in ρ is:
 (A) 6% (B) 4%
 (C) 5% (D) 3%
24. Light of wavelength 600 nm falls normally on a single slit of width 0.10 mm. On a screen 2.0 m away, the width of the central bright fringe is:
 (A) 12 mm (B) 24 mm
 (C) 6 mm (D) 48 mm
25. A string of length 1.0 m and linear mass density 0.010 kg/m is fixed at both ends and kept under a tension of 100 N. Its fundamental frequency is:
 (A) 50 Hz (B) 200 Hz
 (C) 100 Hz (D) 25 Hz

Section B (15 questions, +5 / no negative)

Section B: PhD Level

26. A one-dimensional harmonic oscillator of mass m and angular frequency ω is perturbed by $H' = \lambda x^2$. To first order in λ , the shift in its ground-state energy is:
 (A) $\lambda \hbar / (4m\omega)$ (B) $\lambda \hbar / (m\omega)$
 (C) Zero (D) $\lambda \hbar / (2m\omega)$
27. A spin- $1/2$ particle is in the eigenstate of S_z with eigenvalue $+\hbar/2$. Its spin component is then measured along a unit vector in the xz -plane that makes an angle of 60° with the z -axis. The probability of getting $+\hbar/2$ is:
 (A) $3/4$ (B) $1/2$
 (C) $1/4$ (D) $\sqrt{3}/2$
28. Three non-interacting spin- $1/2$ fermions of mass m are placed in a one-dimensional infinite square well. If $E_1 = \pi^2 \hbar^2 / (2mL^2)$ is the single-particle ground-state energy, the ground-state energy of the three-particle system is:
 (A) $6E_1$ (B) $14E_1$
 (C) $9E_1$ (D) $3E_1$
29. A particle of mass m moves in the attractive one-dimensional potential $V(x) = -\alpha \delta(x)$, with $\alpha > 0$. The energy of its only bound state is:
 (A) $-2m\alpha^2/\hbar^2$ (B) $-m\alpha^2/\hbar^2$
 (C) $-m\alpha^2/(4\hbar^2)$ (D) $-m\alpha^2/(2\hbar^2)$
30. A particle moves in the central potential $V(r) = kr^2$ ($k > 0$). For an orbit that is close to circular, the ratio of the angular frequency of small radial oscillations to the angular frequency of revolution is:
 (A) 1 (B) $\sqrt{2}$
 (C) $\sqrt{3}$ (D) 2
31. Two identical masses m move on a frictionless line. They are joined to each other by a spring of constant k , and each is joined to a fixed wall on its own side by an identical spring k (wall- k - m - k - m - k -wall). The normal-mode angular frequencies are:
 (A) $\sqrt{k/2m}$ and $\sqrt{3k/2m}$ (B) $\sqrt{2k/m}$ and $\sqrt{3k/m}$
 (C) $\sqrt{k/m}$ and $\sqrt{3k/m}$ (D) $\sqrt{k/m}$ and $\sqrt{2k/m}$

32. A dielectric sphere has a uniform, permanent polarisation P (no free charge). The electric field inside the sphere is:
- (A) $-P/(3\epsilon_0)$ (B) $-2P/(3\epsilon_0)$
 (C) Zero (D) $-P/\epsilon_0$
33. A thin spherical shell of radius R carries a total charge Q spread uniformly over its surface and spins with angular velocity ω about a diameter. The magnitude of its magnetic dipole moment is:
- (A) $QR^2\omega/5$ (B) $QR^2\omega/2$
 (C) $2QR^2\omega/3$ (D) $QR^2\omega/3$
34. For a single band in a one-dimensional tight-binding chain with lattice spacing a , the dispersion is $E(k) = E_0 - 2t \cos(ka)$, with $t > 0$. The effective mass of an electron at the bottom of the band is:
- (A) $\hbar^2/(ta^2)$ (B) $\hbar^2/(4ta^2)$
 (C) $\hbar^2/(2ta^2)$ (D) $2\hbar^2/(ta^2)$
35. A two-dimensional gas of non-interacting spin- $1/2$ fermions of mass m has N particles in area A . With $n = N/A$, its Fermi energy at $T = 0$ is:
- (A) $2\pi\hbar^2 n/m$ (B) $\pi\hbar^2 n/(2m)$
 (C) $\pi\hbar^2 n/m$ (D) $\hbar^2(3\pi^2 n)^{2/3}/(2m)$
36. The temperature of a cavity containing black-body radiation is doubled while its volume is kept fixed. Its entropy increases by a factor of:
- (A) 2 (B) 16
 (C) 4 (D) 8
37. N independent spin- $1/2$ particles, each with magnetic moment μ , are in a weak magnetic field B at temperature T , with $\mu B \ll kT$. The magnetisation (total moment along B) is approximately:
- (A) $N\mu^2 B/(kT)$ (B) $N\mu^2 B/(2kT)$
 (C) $N\mu^2 B/(3kT)$ (D) $2N\mu^2 B/(kT)$
38. The value of the integral $\int dx/(x^2 + 1)^2$, taken from $x = -\infty$ to $x = +\infty$, is:
- (A) $\pi/2$ (B) π
 (C) $\pi/4$ (D) 2π
39. The Fourier transform $F(k) = \int e^{(-a|x|)} e^{(-ikx)} dx$, taken over all x ($a > 0$), is:
- (A) $2/(a + k)^2$ (B) $1/(a^2 + k^2)$
 (C) $a/(a^2 + k^2)$ (D) $2a/(a^2 + k^2)$
40. Which one of the following processes is forbidden for free particles in the Standard Model?
- (A) $\pi^0 \rightarrow \gamma + \gamma$ (B) $\pi^+ \rightarrow \mu^+ + \nu_\mu$
 (C) $n \rightarrow p + e^- + \bar{\nu}_e$ (D) $\mu^- \rightarrow e^- + \gamma$

Answer Key

1	D	2	B	3	D	4	B	5	B	6	A	7	A	8	C	9	C	10	B
11	B	12	C	13	A	14	B	15	C	16	C	17	B	18	B	19	A	20	B
21	C	22	D	23	C	24	B	25	A	26	D	27	A	28	A	29	D	30	D
31	C	32	A	33	D	34	C	35	C	36	D	37	A	38	A	39	D	40	D

Solutions

Section A: Basic Topics

- (D)** $a = g \sin \theta / (1 + I/MR^2)$ and $I/MR^2 = 2/5$ for a solid sphere, so $a = (5/7) g \sin \theta$. The value $2/3$ is for a solid cylinder and $1/2$ for a ring.
- (B)** With $v^2 = GM/R$, energy conservation gives $\frac{1}{2}GM/R - GM/R = -GM/r$, so $r = 2R$ and the height is $r - R = R$.
- (D)** The only time scale from m , k and A is $\sqrt{(m/k)/A}$ (since k has units of energy/length⁴). Physically, a larger amplitude means a steeper restoring force and faster motion, so $T \propto 1/A$.
- (B)** $\det(M - \lambda I) = -\lambda(\lambda^2 - 1) + \lambda = -\lambda^3 + 2\lambda = 0$, so $\lambda = 0, \pm\sqrt{2}$.
- (B)** The only singularity inside $|z| = 2$ is the simple pole at $z = 1$ with residue $e^1 = e$, so the integral is $2\pi i e$.
- (A)** The alternating sum equals $(1 - 2^{-1/4}) \sum 1/n^2 = \frac{1}{2} \times \pi^2/6 = \pi^2/12$.
- (A)** The region $X + Y < 1/2$ in the unit square is a right triangle with legs $1/2$, of area $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = 1/8$.
- (C)** Q stays fixed and the capacitance halves, so the energy $Q^2/2C'$ rises from $Q^2/2C$ to Q^2/C . The work done is the increase, $Q^2/(2C)$.
- (C)** Each side gives $\mu_0 I (\sin 45^\circ + \sin 45^\circ) / (4\pi \cdot a/2) = \sqrt{2} \mu_0 I / (2\pi a)$. Four sides add: $2\sqrt{2} \mu_0 I / (\pi a)$.
- (B)** $I = \frac{1}{2} \epsilon \epsilon_0 E_0^2 = 0.5 \times 3.00 \times 10^8 \times 8.85 \times 10^{-12} \times 10^4 \approx 13.3 \text{ W/m}^2$.
- (B)** $E_1 = \hbar^2 / (8mL^2) = (6.63 \times 10^{-34})^2 / (8 \times 9.11 \times 10^{-31} \times 10^{-18}) \approx 6.03 \times 10^{-20} \text{ J} \approx 0.38 \text{ eV}$.
- (C)** $[x, p^2] = p[x, p] + [x, p]p = 2i\hbar p$, using $[x, p] = i\hbar$.
- (A)** Hydrogen-like energy levels scale as Z^2 . For He^+ ($Z = 2$) the photon energy is 4 times larger, so $\lambda = 121.6/4 = 30.4 \text{ nm}$.
- (B)** $TV^{\gamma-1}$ is constant with $\gamma - 1 = 2/3$, so $T_2/T_1 = 8^{3/5} = 4$.
- (C)** $\Delta S = mc \ln(T_2/T_1) = 4186 \times \ln(373/273) \approx 4186 \times 0.312 \approx 1.31 \text{ kJ/K}$.
- (C)** $P(\text{upper}) = e^{-(\epsilon/kT)} / (1 + e^{-(\epsilon/kT)})$ and $e^{-(\epsilon/kT)} = 1/3$, so $P = (1/3)/(4/3) = 1/4$.
- (B)** There are six quadratic terms (three kinetic, three potential), each contributing $\frac{1}{2}kT$, so $\langle E \rangle = 3kT$.
- (B)** $\Delta\lambda = (h/m_e c)(1 - \cos 90^\circ) = 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 3.00 \times 10^8) \approx 2.43 \times 10^{-12} \text{ m}$.
- (A)** $\gamma = 1/\sqrt{1 - 0.99^2} \approx 7.09$. Distance $= \gamma v \tau = 7.09 \times 0.99 \times 3.00 \times 10^8 \times 2.2 \times 10^{-6} \approx 4.6 \times 10^3 \text{ m}$.
- (B)** $N(\tau) - N(2\tau) = N_0(e^{-1} - e^{-2}) = N_0(0.368 - 0.135) \approx 0.23 N_0$.
- (C)** Gain $= 1 + R_f/R_1 = 1 + 4.7 = 5.7$, so $V_{\text{out}} = 5.7 \times 0.20 = 1.14 \text{ V}$ (same sign as the input).
- (D)** $(A + B)(A + C) = A + AC + AB + BC = A(1 + B + C) + BC = A + BC$.
- (C)** Maximum relative error $= 2(\Delta d/d) + \Delta R/R + \Delta L/L = 2 + 2 + 1 = 5\%$. (Adding in quadrature would give 3% , but that is not the maximum.)
- (B)** The first minima are at $y = \pm \lambda D/a = \pm 600 \times 10^{-9} \times 2/10^{-4} = \pm 12 \text{ mm}$, so the central maximum is 24 mm wide.
- (A)** Wave speed $v = \sqrt{T/\mu} = \sqrt{(100/0.01)} = 100 \text{ m/s}$ and $f_1 = v/2L = 50 \text{ Hz}$.

Section B: PhD Level

- (D)** $\Delta E = \lambda \langle x^2 \rangle_0$ and $\langle x^2 \rangle_0 = \hbar/(2m\omega)$. Check: the exact frequency is $\sqrt{(\omega^2 + 2\lambda/m)} \approx \omega + \lambda/(m\omega)$, and $\frac{1}{2}\hbar$ times the change is $\lambda\hbar/(2m\omega)$.
- (A)** The probability is $\cos^2(\theta/2) = \cos^2 30^\circ = 3/4$.

- 28. (A)** Two particles (opposite spins) fill $n = 1$ and the third goes to $n = 2$ with energy $4E_1$: total $2E_1 + 4E_1 = 6E_1$.
- 29. (D)** With $\psi \propto e^{(-\kappa|x|)}$, the derivative jump at $x = 0$ gives $\kappa = ma/\hbar^2$, so $E = -\hbar^2\kappa^2/2m = -ma^2/(2\hbar^2)$.
- 30. (D)** For $V \propto r^n$, $\omega_r/\omega_\phi = \sqrt{(n+2)}$. With $n = 2$ this is 2, so the orbit closes after half a revolution per radial cycle (an ellipse centred on the origin).
- 31. (C)** In-phase motion leaves the middle spring unstretched: $\omega^2 = k/m$. Opposite-phase motion stretches the middle spring twice as much: $\omega^2 = (k + 2k)/m = 3k/m$.
- 32. (A)** The bound surface charge $\sigma = P \cos \theta$ produces a uniform field $-P/(3\epsilon_0)$ inside the sphere.
- 33. (D)** A ring at polar angle θ carries current $(Q/2) \sin \theta \, d\theta \cdot \omega/2\pi$ and encloses area $\pi R^2 \sin^2\theta$. Integrating gives $m = (Q\omega R^2/4) \int \sin^3\theta \, d\theta = (Q\omega R^2/4)(4/3) = QR^2\omega/3$. ($QR^2\omega/5$ is for a uniformly charged solid sphere.)
- 34. (C)** Near $k = 0$, $E \approx E_0 - 2t + ta^2k^2$. Comparing with $\hbar^2k^2/2m^*$ gives $m^* = \hbar^2/(2ta^2)$.
- 35. (C)** $N = 2 \times A \pi k_F^2/(2\pi)^2$, so $k_F^2 = 2\pi n$ and $E_F = \hbar^2k_F^2/2m = \pi\hbar^2n/m$. The last option is the three-dimensional result.
- 36. (D)** For a photon gas $S = (4/3)aVT^3$ (since $U = aVT^4$), so doubling T multiplies S by $2^3 = 8$. The energy rises by 16.
- 37. (A)** Exactly $M = N\mu \tanh(\mu B/kT)$, and $\tanh x \approx x$ for small x . The factor $1/3$ belongs to classical dipoles (Langevin), not to two-state spins.
- 38. (A)** Close the contour in the upper half-plane. The double pole at $z = i$ has residue $d/dz[(z+i)^{-2}]$ at $z = i = -2/(2i)^3 = 1/(4i)$, so the integral is $2\pi i/(4i) = \pi/2$.
- 39. (D)** Splitting at $x = 0$ gives $1/(a+ik) + 1/(a-ik) = 2a/(a^2+k^2)$.
- 40. (D)** $\mu^- \rightarrow e^- \gamma$ would change muon and electron lepton numbers separately and has never been seen. The other three are the main observed decays of the π^+ , the free neutron and the π^0 .