

CANDIDATE'S NAME: _____

SIGNATURE: _____

M.Phil Physics Entrance Test

**Department of Physics
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Instructions

- Answer all 20 questions or as many as you can.
- Each question carries equal marks. Circle only the right answer. If you do not know the answer, do not circle any answer.
- Wrong answers will be negatively marked. Your total marks will be reduced if you circle the wrong answer.
- If you make a mistake, make your choice clear by writing out the correct answer in full or indicating it clearly. Marking two choices will be considered as a wrong answer.
- Any attempt to copy answers from another candidate will result in permanent disbarment from the university for all purposes.
- No books or calculators are allowed.

Q.1. A block of mass M , at rest on a horizontal, frictionless table, is attached to a rigid support by a spring of force constant k . A bullet of mass m and speed v strikes the block as shown below. The bullet remains embedded in the block. The amplitude of the resulting harmonic motion is,

a) $\sqrt{\frac{M+m}{k}}v$

b) $(M+m)v\sqrt{\frac{1}{k(M+m)}}$

c) $(M+m)v\sqrt{\frac{1}{kM}}$

d) $mv\sqrt{\frac{1}{k(M+m)}}$

e) $mv\sqrt{\frac{1}{km}}$



Q.2 Consider the Hamiltonian of a system of mass m ,

$$H = \frac{1}{2m}(p_x^2 + p_y^2 + p_z^2) + V(x, y)$$

For this system,

- a) x and y components of momentum are constants of motion
- b) z component of momentum is a constant of motion
- c) x component of momentum is a constant of motion
- d) y component of momentum is a constant of motion
- e) none of the above

Q.3 For a conservative force F , which one of the following is true

a) $\nabla \times F = 0$

b) $\oint F \cdot dl = 0$

c) There exists a scalar function V such that $F = -\nabla V$

d) None of the above

e) a, b and c are all true

Q.4 A man stands on a frictionless platform that is rotating with an angular speed of 1.22 rev/s; his arms are outstretched and he holds a weight in each hand. With his hands in this position the total rotational inertia of the man, the weights, and the platform is $6.13 \text{ kg}\cdot\text{m}^2$. If by moving the weights the man decreases the rotational inertia to $1.97 \text{ kg}\cdot\text{m}^2$, the resulting angular speed is

- a) 3.8 rev/sec
- b) 1.9 rev/sec
- c) 7.6 rev/sec
- d) 1.1 rev/sec
- e) 9.8 rev/sec

Q.5 A car of mass m starts at rest and is driven with constant power. After it covers a distance x , the speed v is,

a) $\frac{1}{\sqrt{3}}\left(\frac{xP}{m}\right)^{1/3}$

b) $\left(\frac{xP}{m}\right)^{1/3}$

c) $\frac{1}{\sqrt{2}}\left(\frac{xP}{m}\right)^{1/3}$

d) $\sqrt{2}\left(\frac{xP}{m}\right)^{1/3}$

e) $\left(\frac{3xP}{m}\right)^{1/3}$

Q.6 A sphere of radius R carries a non-uniform charge distribution $\rho = \alpha r$, where α is a constant and r is the distance from the center of the sphere. The electric field E inside the sphere is proportional to,

- a) $\frac{1}{r^2}$
- b) $\frac{1}{r}$
- c) $\log r$
- d) r
- e) r^2

Q.7 Use Gauss' law to determine the electric field between two coaxial cylinders of infinite length and of radii a and $b > a$. If the inner one has a total charge per unit length of $-Q_L$ while the outer cylinder has a charge per unit length Q_L the capacitance is proportional to,

a) $\left(\ln \frac{b}{a}\right)^{-1}$

b) $\ln \frac{b}{a}$

c) $\frac{a}{b}$

d) $\frac{b}{a}$

e) $\sqrt{a^2 + b^2}$

Q.8 Two point charges are located on the x-axis. The first is $-e$ at $x=0$ and the second is $+e$ at $x = a$. The potential energy in this system of charges is proportional to,

a) $\frac{e^2}{a^2}$

b) $\frac{-e^2}{a^2}$

c) $\frac{e^2}{a^3}$

d) $\frac{e^2}{a}$

e) $-\frac{e^2}{a}$

Q.9 A charge $+2e$ moves in a magnetic field of 2 Tesla at speed 3 m/sec. The work done per second on the charge by the field,

- a) $4e$
- b) $12e$
- c) $12e^2$
- d) $16e$
- e) zero

Q.10 Two parallel wires separated by a distance r carry a current I in opposite directions. The force between them is proportional to,

a) $\frac{I^2}{r^2}$

b) $\frac{I^2}{r}$

c) $I^2 r$

d) $I^2 r^2$

e) None of the above

Q.11 Consider the wavefunction $\Psi(x,t) = \frac{1}{\sqrt{2}}[\psi_n(x)e^{-iE_n t/\hbar} + \psi_m(x)e^{-iE_m t/\hbar}]$, where ψ_n and ψ_m are normalized energy eigenstates. The expectation value of energy in this state is,

- (a) $\frac{E_n + E_m}{2}$
- (b) E_n
- (c) $E_n + E_m$
- (d) E_m
- (e) $2(E_n + E_m)$

Q.12 A particle that was known to be in a momentum state with $P = P_0$ is found in a subsequent position measurement at the origin, $x = 0$. What is its momentum?

- (a) P_0
- (b) 0
- (c) It is not possible to say
- (d) $2P_0$
- (e) $\frac{P_0}{2}$

Q.13 Consider a system which is in the state,

$$\Psi(\theta, \phi) = \frac{1}{\sqrt{5}} Y_1^{-1}(\theta, \phi) + \sqrt{\frac{3}{5}} Y_1^0(\theta, \phi) + \frac{1}{\sqrt{5}} Y_1^1(\theta, \phi),$$

where $Y_l^m(\theta, \phi)$ are the spherical harmonics. If \hat{L}_z is measured what possible values can be obtained?

- (a) $-\hbar, 0, \hbar$
- (b) $+\hbar, 2\hbar, -\hbar$
- (c) $+\hbar, 3\hbar, -\hbar$
- (d) $+\hbar, -\hbar$
- (e) $3\hbar, 2\hbar$

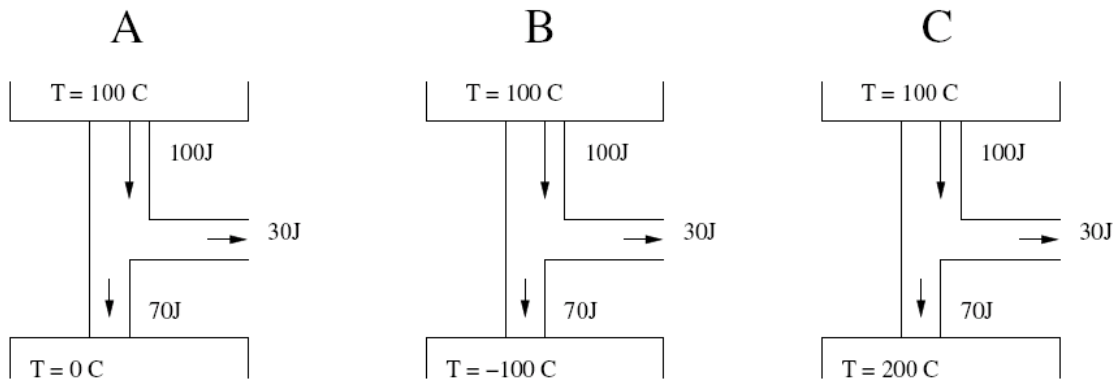
Q.14 Consider an operator $H = -\frac{d^2}{dx^2} + x^2$. The eigenvalue of H in the state $xe^{-x^2/2}$ is,

- (a) 0
- (b) 1
- (c) 2
- (d) 3
- (e) 4

Q.15 An electron is trapped in a semiconductor quantum dot, which is a very small cubical region of volume V . The smallest energy that the electron can have is proportional to,

- a) V
- b) $\frac{1}{V}$
- c) $V^{2/3}$
- d) $V^{-2/3}$
- e) $\ln V$

Q.16 Which of the following heat engines violate the laws of thermodynamics?
 (Arrows show the direction of energy flow.)



- a) A and B
- b) A and C
- c) B and C
- d) C
- e) None

Q.17 A thin sheet of metal has length L_0 and width W_0 . It is heated through an amount ΔT . If the coefficient of linear expansion is α , and ΔT is small, find ΔA , the increase in area of the plate.

- a) $\alpha L_0 W_0 \Delta T$
- b) $\alpha^2 L_0 W_0 \Delta T$
- c) $\alpha L_0 W_0 \Delta T^2$
- d) $\alpha L_0 W_0 \Delta T^2$
- e) None of the above

Q.18 The lowest energy level of O_2 is threefold degenerate. The next level is doubly degenerate and lies at energy ε above the lowest level. Take the lowest level to have zero energy. The partition function at temperature T is,

a) $2e^{\frac{-3\varepsilon}{kT}}$

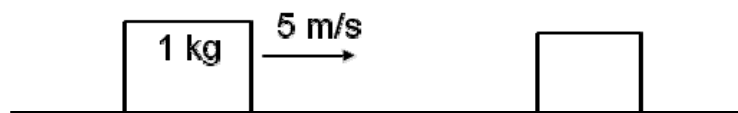
b) $3+2e^{\frac{-\varepsilon}{kT}}$

c) $3+e^{\frac{-\varepsilon}{kT}}$

d) $3e^{\frac{-3\varepsilon}{kT}}$

e) $e^{\frac{-2\varepsilon}{kT}}$

Q.19 A block of mass 1kg moving on a frictionless surface at the speed of 5 m/s collides with another block of the same mass. The two stick together and travel together.



How much thermal energy is generated during the collision?

- (a) 0.25 J
- (b) 2.25 J
- (c) 6.25 J
- (d) 16.25 J
- (e) 27.25 J

Q.20 The Maxwell velocity distribution for a low density gas is,

$$p(v) dv = 4\pi \left(\frac{1}{2\pi\tau/m} \right)^{\frac{3}{2}} e^{-mv^2/2\tau} v^2 dv .$$

The most probable speed (the speed at which the probability density is maximum) is,

- a) $\sqrt{2\tau/m}$
- b) $\sqrt{8\tau/m}$
- c) $\sqrt{3\tau/m}$
- d) $3\tau/m$
- e) $\tau/3m$

ANSWERS:

1. d
2. b
3. e
4. a
5. e
6. e
7. a
8. e
9. e
10. b
11. a
12. c
13. a
14. d
15. d
16. d
17. e
18. b
19. c
20. a