CAREER ENDEAVOUR
Best Institute for IIT-JAM, NET & GATE

IIT JAM PHYSICS 2023

UNIT TEST - I: Quantum Mechanics (ONLINE BATCH)

Time : 60 Minutes **Date : 01-10-2022**

M.M. : 40

INSTRUCTIONS

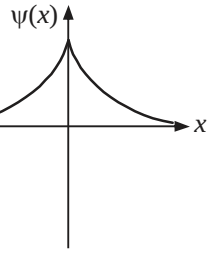
- This question booklet contains 20 questions and is divided into 3 parts.
  PART - A contains **10 Multiple Choice Questions (MCQ).** 2 marks will be awarded for a right answer and (–0.5) marks will be awarded for a wrong answer.
  PART - B contains **3 Multiple Select Questions (MSQ).** 2 marks will be awarded for a right answer and there will be no negative marks for a wrong answer.
  PART - C contains **7 Numerical Answer Type (NAT) Questions.** 2 marks will be awarded for a right answer and there will be no negative marks for a wrong answer.

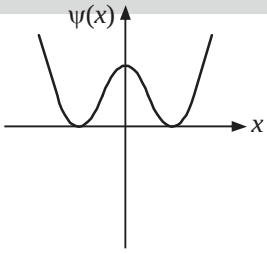
PART A: MULTIPLE CHOICE QUESTIONS (MCQ)

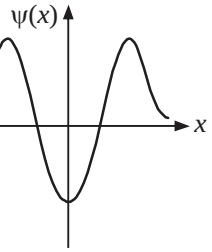
1. Consider a relativistic electron (e) and a relativistic proton (p) travelling with speeds $4c/5$ and $3c/5$, respectively. The ratio of de-Broglie wavelength of electron to that of proton is (Assume that $m_p \approx 1000\, m_e$ where m_p and m_e are rest mass of proton and electron respectively)

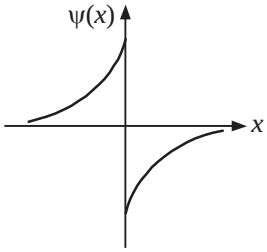
   (a) 1125 : 1 (b) 1125 : 2 (c) 750 : 1 (d) 750 : 2

2. A particle is moving along x-axis under the influence of a continuous one dimensional potential $V(x)$. Which of the following graphs may possibly represent a physically acceptable wave function of the particle?

(a) 

(b) 

(c) 

(d) 

3. The group velocity of a relativistic free particle of rest mass m is equal to half of its phase velocity. The value of the group velocity of the particle is

(a) $c/2$ (b) $c/3$ (c) $c/\sqrt{2}$ (d) $c/\sqrt{3}$

4. In 1974, a new particle was discovered which had a rest mass energy 3097 MeV and the uncertainty of measurement being 0.063 MeV. The mean lifetime of such particle will be

(a) $0.82\times10^{-20}\ s$ (b) $3.14\times10^{-20}\ s$ (c) $2.26\times10^{-20}\ s$ (d) $1.05\times10^{-20}\ s$

5. The wavefunction of the particle moving along x-axis, is given as following:

$$\psi(x) = Ax\exp\left(-\frac{m\omega x^2}{2\hbar}\right);\ (\omega > 0)$$

The value of the normalization constant A is equal to

(a) $\sqrt{2}\left(\frac{m^3\omega^3}{\pi\hbar^3}\right)^{1/4}$ (b) $2\left(\frac{m^3\omega^3}{\pi\hbar^3}\right)^{1/2}$ (c) $\left(\frac{m^3\omega^3}{2\pi\hbar^3}\right)^{1/4}$ (d) $\left(\frac{m^3\omega^3}{2\pi\hbar^3}\right)^{1/2}$

6. To get the information about the structure of a nucleus, proton beam is used. The approximate kinetic energy of proton, if the size of nucleus of the order of 10^{-15} m is

(a) 518.2 MeV (b) 618.2 MeV (c) 938.3 MeV (d) 1500 MeV

7. The normalized wavefunction of the particle (moving along x-axis) is given as following:

$$\varphi(x) = \sqrt{\frac{a}{\pi}}\frac{1}{\sqrt{x^2+a^2}}e^{i\frac{p_0}{\hbar}x}\quad(-\infty < x < \infty)$$

(where a and p_0 are positive real constants). The probability of finding the particle between $x = \pm\frac{a}{\sqrt{3}}$ will be

(a) 1/3 (b) 1/2 (c) 1/4 (d) 1/5

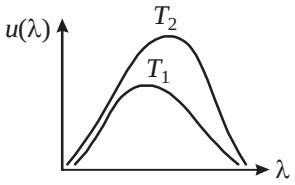
8. Light described by the equation

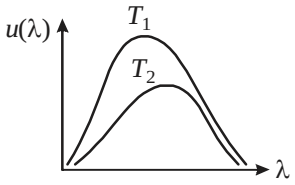
$$E = (100\ V/m)\left[\sin^3\left(1\times10^{15}\ s^{-1}\right)t\right]$$

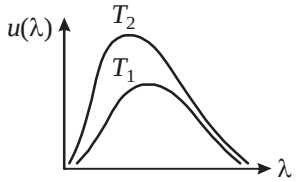
is incident on a metal surface having work function 1 eV. The maximum kinetic energy of the emitted photoelectrons will be about

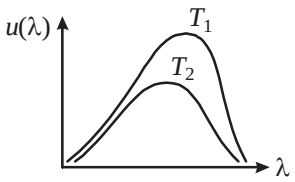
(a) 2.48 eV (b) 1.97 eV (c) 0.98 eV (d) 0.52 eV

9. If the temperature of two blackbody A and B are T_1 and T_2 respectively where $T_1 < T_2$. The energy radiated by the black bodies per unit area per unit time per unit solid angle in the wavelength range λ to $\lambda + d\lambda$ is $u(\lambda)\,d\lambda$. Which of the following graphs represent the variation u_λ as a function of λ?

(a) 

(b) 

(c) 

(d) 

10. A photon of wavelength 10 Å collides with an electron at rest. If it scattered at angle 150^0 from its initial direction, then the wavelength of photon after collision is

(a) 10.050 Å (b) 10.045 Å (c) 10.040 Å (d) 10.035 Å

PART B: MULTIPLE SELECT QUESTIONS (MSQ)

11. An electron has de-Broglie wavelength 1.5×10^{-12} m. Which of the following statement is/are **CORRECT**?

(a) The kinetic energy of electron is 0.46 MeV.
(b) The kinetic energy of electron is 1.46 MeV.
(c) Group velocity of the particle is 0.75 *c*.
(d) Group velocity of the particle is 0.85 *c*.

12. Consider a Compton scattering phenomena in which a photon of frequency $\nu = \frac{m_e c^2}{2h}$ scatters off an electron at rest (where m_e is the rest mass of electron) in a manner that maximum amount of energy is transferred to the electron. Which of the following statement(s) is/are **CORRECT**?

(a) The photon is scattered at an angle $\phi = \pi$ with respect to the initial line of approach of the incident photon.
(b) The kinetic energy of the electron becomes $m_e c^2/4$.
(c) The de-Broglie wavelength of the recoil electron is $4h/3mc$.
(d) The recoil angle of the electron is $\theta = \frac{\pi}{2}$ with respect to the initial line of approach of the incident photon.

13. Which of the following functions represents acceptable realistic bound state wave function of a particle in the specified range of *x*? (Here α and *A* are positive real constants)

(a) $\psi(x) = Ax^2 \exp(-\alpha x^2) \quad (-\infty < x < \infty)$ (b) $\psi(x) = Ax^2 \exp(-\alpha x) \quad (-\infty < x < \infty)$
(c) $\psi(r) = Ar^2 \exp(-\alpha r) \quad (0 < r < \infty)$ (d) $\psi(x) = A\exp(-\alpha |x|) \quad (-\infty < x < \infty)$

PART C: NUMERICAL ANSWER TYPE (NAT) QUESTIONS

14. The minimum energy required for a photon to cause photo-electric emission from a metal surface is 4 eV. When a photon beam of wavelength 248 nm is incident on the metal surface, the anode potential at which photocurrent becomes zero is _____ V.

[YOUR ANSWER SHOULD BE AN INTEGER]

15. Consider a nucleus of mass number A = 64 and radius R = 4.8 fm. Using uncertainty principle i.e. $\Delta r \, \Delta p \approx \hbar$, the minimum kinetic energy of a nucleon can be estimated to be _____ MeV.

[YOUR ANSWER SHOULD BE UPTO ONE DECIMAL PLACES]

16. A homogeneous light beam of wavelength 300 *nm* and intensity $500\,W/m^2$ falls on a Sodium surface. The average number of photons falling on the Sodium surface, is _____ $\times 10^{20}\ m^{-2}s^{-1}$.

[YOUR ANSWER SHOULD BE UPTO ONE DECIMAL PLACES]

17. The energy of a photon, emitted with the wavelength at which the intensity of Blackbody radiation is maximum at 750 K, is 0.31 eV. The wavelength, at which the intensity of Blackbody radiation at 3000 K, will be maximum is _____ μm.

[YOUR ANSWER SHOULD BE AN INTEGER]

18. The state of the system at t = 0, is given as following:

$$|\varphi\rangle = 3i|\psi_1\rangle - 2|\psi_2\rangle + 2\sqrt{3}|\psi_3\rangle$$

where $|\psi_1\rangle, |\psi_2\rangle$ and $|\psi_3\rangle$ forms an orthonormal set. If there are 10000 identical particles and each of them in the state $|\varphi\rangle$, then the number of particles which will be found in the state $|\psi_3\rangle$ will be _____

[YOUR ANSWER SHOULD BE AN INTEGER]

19. If *v* be the velocity of a thermal neutron at temperature *T* = 27°C, then the de-Broglie wavelength of neutron is _____ Å.

[YOUR ANSWER SHOULD BE UPTO TWO DECIMAL PLACES]

20. The number of photons emitted per second by 10 W sodium vapour lamp with wavelength of light 590 nm, (Assume that only 60% consumed energy converted into light) is _____ $\times 10^{19}$.

[YOUR ANSWER SHOULD BE UPTO TWO DECIMAL PLACES]

CAREER ENDEAVOUR
Best Institute for IIT-JAM, NET & GATE

IIT JAM PHYSICS 2023

UNIT TEST - I: QUANTUM MECHANICS (ONLINE BATCH)

Time : 60 Minutes **Date : 01-10-2022**

M.M. : 40

Answer Key (Mathematical Physics)

PART A: MULTIPLE CHOICE QUESTIONS (MCQ)

1. (b)	2. (c)	3. (c)	4. (d)	5. (a)
6. (b)	7. (a)	8. (c)	9. (c)	10. (b)

PART B: MULTIPLE SELECT QUESTIONS (MSQ)

11. (a,c)	12. (a, b, c)	13. (a, c, d)

PART C: NUMERICAL ANSWER TYPE (NAT) QUESTIONS

14. (1)	15. (14.1 to 14.7)	16. (7.4 to 7.8)	17. (1)
18. (4800)	19. (1.30 to 1.40)	20. (1.73 to 1.83)	