REV-00
MPH/68/80

2017/12

M. Sc. Physics
FIRST SEMESTER
QUANTUM MECHANICS -I
MPH - 103

Duration: 3 Hrs. **Marks: 70**

PART : A (OBJECTIVE) = 20
PART : B (DESCRIPTIVE) = 50

[PART-B : Descriptive]

Duration: 2 Hrs. 40 Mins. **Marks: 50**

[Answer question no. One (1) & any four (4) from the rest]

1. a) Explain with proper examples the meaning of wave particle duality. Discuss how Schrodinger established the validity of it. 3+2=5

b) (i) Show that the wavelength of the quantum wave associated with the electron accelerated through a potential difference of 150 volts lies in X-ray range.

(ii)Calculate momentum of the electron of 100 electron volt energy. 2+3=5

2. Write down the Schrodinger wave equation for a particle of mass 'm' confined in a box of length 'a' such that V=0 for $0 \leq x \leq a$ and v=α for $x \leq 0$ and $\geq a$. Deduce the expression for wave function and energy. Calculate ground state energy of the electron in a box of size 10^{-14} meter in S.I unit. 2+3+2+3 =10

3. a) What do you mean by Hermitian operator? Prove that two eigen function of a Hermitian operator belonging to different eigen values are orthogonal. 1+4=5

b) (i) Examine if $\frac{d^2}{dx^2}$ is a Hermitian operator. 2+3=5

(ii)Calculate the average value of the momentum of a particle confined in a length 'a'.

4. What do you mean by identical particles? Distinguish between classical and quantum identical particles. Define particle exchange operator and calculate the eigen values of the particle exchange operator. 2+2+2+1 +3=10

5. (a) Evaluate the following commutators. 3+2=5

I. $[\hat{L}_+, \hat{L}_-]$

II. $[\hat{L}_z, \hat{L}_\pm]$

(b) Find the equation of motion in Heisenberg representation.

6. (a) Show that spherical harmonics are eigen functions of $\hat{L}^2$ and $\hat{L}_z$. Write the eigen values of both the operators. 3+2=5

(b) (i) Give the relation between the spin angular momentum and spin magnetic moment. What are pauli's spin matrices? 2+3=5

(ii) Prove that $[\sigma_x, \sigma_y] = 2i\sigma_z$

7. (i) What do you mean by symmetric and antisymmetric wave function? Explain exchange energy. Discuss how spin statistics are connected with symmetric and antisymmetric wave functions. 1+1+2+1 +1=6

(ii) How can you contruct symmetric and antisymmetric wave function from unsymmetric wavefunction ? 2+2=4

8. (i) Define radial probability density of finding the electron of the hydrogen atom at a distance 'r' and write the expression of it. Calculate the position of maximum probability of finding the electron in its ground state. 3+3=6

(ii) A proton is confined to a nucleus of radius 5×10^{-15} m. Calculate the uncertainty in its momentum and minimum kinetic energy of the proton (mass of the proton is 1.67×10^{-27} kg). 2+2=4

==***==

M. Sc. Physics
FIRST SEMESTER
QUANTUM MECHANICS -I
MPH - 103

[PART-A : Objective]

Choose the correct answer from the following: **1×20=20**

1. The acceptable wave function is
   a. $\psi = \sin x$
   b. $\psi = \tan x$
   c. $\psi = \text{cosec}\, x$
   d. $\psi = x$

2. The ratio $N_n=2 : N_n=1$ [N_n is the number of nodes in a state with quantum number n for a particle in a 1-D box] is
   a. α
   b. 1
   c. 2
   d. zero

3. The energy of a particle in a 2-D box of size 'A' is $9h^2/4ma^2$. The degree of degeneracy is
   a. 1
   b. 2
   c. 3
   d. 4

4. Which of the following is NOT a physical requirement for an acceptable wave function.
   a. Symmetric
   b. Single valued
   c. Square integrable
   d. Continuous in the given region

5. The speed of the de brogile wave of a particle of mass 'm' and momentum mv is
   a. $\frac{c^2}{v}$
   b. $\frac{c}{v^2}$
   c. $\frac{c}{v}$
   d. v

   [C= velocity light]

6. The energy required to excite a particle of mass 'm' confined in a length 'l' to the first excited state is
   a. $h^2/2ml^2$
   b. $3h^2/8ml^2$
   c. $h^2/4ml^2$
   d. $l^2/2mh^2$

7. An orbital is a/an
   a. operator
   b. one electron wave function
   c. circular tract
   d. observable property

8. Conjugate of an operator $\hat{A} = \hbar \frac{d}{dx}$ is $\hbar \frac{d}{dx}$. Then conjugate of the operator $\hat{O} = i\hbar\frac{d}{dx}$
   a. $i\hbar\frac{d}{dx}$
   b. $-i\hbar\frac{d}{dx}$
   c. $\hbar\frac{d}{dx}$
   d. $-\hbar\frac{d}{dx}$

9. Two functions are orthogonal if their inner product is
   a. $\frac{\hbar}{2}$
   b. Zero
   c. -1
   d. 1

10. The eigenvalue of $\hat{P}_{21}$ is
    a. Zero
    b. ± 1
    c. +1
    d. -1

11. The operator of kinetic energy in one dimension is
    a. $i\hbar\frac{\partial}{\partial x}$
    b. $-i\hbar\,\partial/\partial x$
    c. $-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}$
    d. $\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}$

12. The commutation relation between position and momentum operator is
    a. $[q_j, p_k] = 0$
    b. $[q_j, p_k] = 1$
    c. $[q_j, p_k] = i\hbar\delta_{jk}$
    d. $[q_j, p_k] = -i\hbar\delta_{jk}$

13. If $\hat{P_y} = -i\hbar\frac{\partial}{\partial y}$ then $\hat{P_y^3}$ is
    a. $-i\hbar^3\frac{\partial^3}{\partial y^3}$
    b. $-i\hbar\,\delta^3/\partial y^3$
    c. $i\hbar^3\frac{\partial^3}{\partial y^3}$
    d. $i\hbar\frac{\partial^3}{\partial y^3}$

14. The exchange energy between two electrons is related when they have
    a. Same spin
    b. Opposite spin
    c. Same spin in degenerate orbital
    d. Opposite spin in non degenerate orbital.

15. 2 s orbital of hydrogen atom has a node at $2a_0$, because ψ_{2s} is proportional to
    a. $(2+\frac{r}{a_0})$
    b. $(2-\frac{r}{2a_0})$
    c. $(1+\frac{r}{2a_0})$
    d. $(2-r/a_0)$

16. Two operators $\hat{A}$ and $\hat{B}$ satisfy the equations $\hat{A}(c\psi) = c(\hat{A}\psi)$ and $\hat{B}\psi = \psi^*$ (c is a constant).
    Select the correct statement from the following:
    a. $\hat{A}$ and $\hat{B}$ are Hermitian
    b. $\hat{A}$ and $\hat{B}$ are commute
    c. $\hat{B}$ is linear but $\hat{A}$ is not
    d. $\hat{A}$ is linear but $\hat{B}$ is not

17. The lowest energy is zero for a
    a. Hydrogen atom
    b. Particle in 1-D box
    c. Simple harmonic oscillator
    d. Particle in a ring

18. Which of the following obey Fermi-Dirac statistics?
    a. Pion (π^+)
    b. Kaon (k^+)
    c. η meson
    d. Muon (μ^-)

19. The expectation value of the observable 0 is given by
    a. $< O >= \int_{-1}^{1} \psi^* \psi d\tau$
    b. $< O >= \int_{-\infty}^{\infty} \psi^* \hat{O} \psi d\tau$
    c. $< O >= \int_{-\infty}^{\infty} \psi \hat{O} \psi d\tau$
    d. $< O >= \int_{-\infty}^{\infty} \psi \hat{O} \psi d\tau$

    [$\hat{O}$= operator of the observable o]

20. If the operator $\hat{A}$ commutes with the operator $\hat{B}$ then
    a. $\hat{A}$ and $\hat{B}$ are equal
    b. $\hat{A}$ and $\hat{B}$ are skew- hermitian
    c. $\hat{A}$ and $\hat{B}$ have common set of eigen values
    d. $\hat{A}$ and $\hat{B}$ have the common set of eigenfunctions.

==***==

UNIVERSITY OF SCIENCE & TECHNOLOGY, MEGHALAYA

[PART (A) : OBJECTIVE]

Duration : 20 Minutes

Serial no. of the main Answer sheet

Course : .....

Semester : ..... **Roll No :** .....

Enrollment No : ..... **Course code :** .....

Course Title : .....

Session : 2017-18 **Date :** .....

****

Instructions / Guidelines

- The paper contains twenty (20) / ten (10) questions.
- Students shall tick (✓) the correct answer.
- No marks shall be given for overwrite / erasing.
- Students have to submit the Objective Part (Part-A) to the invigilator just after completion of the allotted time from the starting of examination.

Full Marks	Marks Obtained
20	

Scrutinizer's Signature *Examiner's Signature* *Invigilator's Signature*