**D 122526** **(Pages : 2)** **Name.....**

**Reg. No.....**

**SECOND SEMESTER M.Sc. DEGREE (REGULAR/SUPPLEMENTARY) EXAMINATION, APRIL 2025**

(CBCSS)

Physics

PHY 2C 05—QUANTUM MECHANICS—I

(2019 Admission onwards)

Time : Three Hours Maximum : 30 Weightage

**Section A**

*8 Short questions answerable within 7.5 minutes.*
*Answer* **all** *questions, each question carries weightage 1.*

1. What are ladder operators ?
2. What are the necessary and sufficient condition for an operator to be a unitary operator.
3. Distinguish between symmetric wave functions and antisymmetric wave functions.
4. What are Pauli matrices ? Discuss their properties.
5. Calculate the commutator $\left[\hat{X}, \hat{L}x\right]$.
6. Define Hilbert Space.
7. Differentiate between Schrodinger picture and Heisenberg picture.
8. What do you mean by symmetry transformations.

(8 × 1 = 8 weightage)

**Section B**

*4 essay questions answerable within 30 minutes.*
*Answer any* **two** *questions, each question carries weightage 5.*

9. Discuss the Harmonic oscillator problem in Heisenberg picture.
10. Taking an illustrative example of ground state of the Helium atom, describe the important role played by the symmetry of the wave function in the dynamics of the system.

**Turn over**

11. What are Hermitian operators ? Show that the eigen values of the Hermittan operators are real and the eigen vectors corresponding to different eigen values are orthogonal.

12. Discuss the formal theory of angular momentum addition. Obtain the expression for Clebsch-Gordan co-efficient.

(2 × 5 = 10 weightage)

## Section C

*7 problems answerable within* 15 *minutes.*
*Answer any* **four** *questions, each question carries weightage* 3.

13. What is time evolution operator ? Obtain the Schrodinger equation for the time evolution operator.

14. Show that the wavefunction of a system of identical particles is either totally symmetric or totally antisymmetric.

15. Determine the matrix elements of ladder operators.

16. Show that the conservation of the linear momentum of a physical system is a consequence of the translational invariance of the Hamiltonian of the system.

17. Obtain the energy eigen values of the isotropic harmonic oscillator using the radial equation.

18. How do you represent the momentum operator in position basis and vice-versa.

19. Calculate the commutator $\left[\mathrm{J}^2, \mathrm{J}_x\right]$.

(4 × 3 = 12 weightage)

**D 102183** **(Pages : 2)** **Name.....**

**Reg. No.....**

**SECOND SEMESTER M.Sc. DEGREE (REGULAR/SUPPLEMENTARY) EXAMINATION, APRIL 2024**

(CBCSS)

Physics

PHY 2C 05—QUANTUM MECHANICS—I

(2019 Admission onwards)

Time : Three Hours Maximum : 30 Weightage

**Section A**

*8 Short questions answerable within 7.5 minutes.*
*Answer* **all** *questions, each question carries 1 weightage.*

1. Define Unitary operators. What is the importance of unitary operators ?
2. What are projection operators ?
3. How can you differentiate between a symmetric wave functions and antisymmetric wave functions ?
4. Calculate the commutator $\left[J_z^2, J_y\right]$.
5. Discuss the Pauli Exclusion Principle.
6. Explain the properties of Hilbert Space.
7. What is the principle of indistinguishability of identical particles.
8. Explain the important features of Schrödinger picture and Heisenberg picture.

(8 × 1 = 8 weightage)

**Turn over**

## Section B

*4 essay questions answerable within 30 minutes.*
*Answer any* **two** *questions, each question carries 5 weightage.*

9. Derive the generalized uncertainty relation. Deduce the three basic uncertainty relations for canonically conjugate operators

10. Explain the Sequential Stern-Gerlach experiment and describe experimental conclusions which lead to the fundamentals of quantum mechanics.

11. What are Clebsch-Gordan co-efficients ? Deduce recursion relations for Clebsch-Gordan co-efficients.

12. Describe Schrödinger equation for central potentials and hence describe Hydrogen atom.

(2 × 5 = 10 weightage)

## Section C

*7 problems answerable within 15 minutes.*
*Answer any* **four** *questions, each question carries 3 weightage.*

13. What is time evolution operator ? Obtain the Schrödinger equation for the time evolution operator.

14. Explain the Interaction picture. Obtain the equation of motion.

15. How do you represent position operator in momentum basis and the momentum operator in position basis.

16. Evaluate the $x$-$p$ uncertainty product $\left\langle (\Delta x)^2 \right\rangle \left\langle (\Delta p)^2 \right\rangle$ for a one-dimensional particle confined between two rigid walls,

$$V = \begin{cases} 0 \text{ for } 0 < x < a \\ \infty \text{ otherwise} \end{cases}.$$

17. Show that the law of conservation of angular momentum is a consequence of the rotational invariance of the system.

18. For Pauli's matrices, prove that $\left[\sigma_x, \sigma_y\right] = 2i\sigma_z$.

19. State and prove the Jacobi identity.

(4 × 3 = 12 weightage)

**C 42801** **(Pages : 2)** **Name.....**

**Reg. No.....**

**SECOND SEMESTER M.Sc. DEGREE (REGULAR/SUPPLEMENTARY) EXAMINATION, APRIL 2023**

(CBCSS)

Physics

PHY 2C 05—QUANTUM MECHANICS—I

(2019 Admission onwards)

Time : Three Hours Maximum : 30 Weightage

**Section A**

*8 Short questions answerable within 7.5 minutes.*
*Answer* **all** *questions, each question carries 1 weightage.*

1. What is the condition for two eigen vectors to be orthogonal ?
2. Explain wave packet.
3. What are ladder operators ? Why are they called so ?
4. Explain the matrix representation of a wave function ?
5. Conservation of angular momentum is a consequence of the rotational invariance of the system. Substantiate
6. What is time reversal symmetry ?
7. What is the advantage of using spherical polar co-ordinates in the case of central potentials ?
8. What is slater determinant ? How does it incorporate Pauli Exclusion principle ?

(8 × 1 = 8 weightage)

**Section B**

*4 essay questions answerable within 30 minutes.*
*Answer any* **two** *questions, each question carries 5 weightage.*

9. Discuss the matrix representation of kets and bras operators. Derive the general uncertainty relation.
10. Derive equation of motion for states and operators in Schrodinger and interaction pictures.

**Turn over**

11. Obtain Eigenvalue problem for angular momentum operators $J^2$ and $J_z$. Enumerate their matrix representations.

12. Describe the concept of symmetry and conservation laws with specific reference to displacement in space and time.

(2 × 5 = 10 weightage)

## Section C

*7 problems answerable within 15 minutes.*
*Answer any* **four** *questions, each question carries 3 weightage.*

13. Show that $\left[L_k, r^2\right] = 0$; where $r$ is the radius vector $\boldsymbol{p}$ is the linear momentum and ***k, l, m*** are the cyclic permutations of 1, 2, 3.

14. Show that the commutator $\left[x, \left[x, H\right]\right] = -\frac{h^2}{m}$, where H is the Hamiltonian operator.

15. With creation and annihilation operators solve linear harmonic oscillator problem.

16. State and prove the continuity equation.

17. An electron has a speed of 500 m/s with an accuracy of 0.004 %. Calculate the certainty with which we can locate the position of the electron.

18. Discuss the fundamental commutation relations of angular momentum.

19. Show that Pauli spin matrices satisfy $\sigma_i\sigma_j + \sigma_j\sigma_i = 2I\delta_{ij}$ (I is a 2 × 2 matrix).

(4 × 3 = 12 Weightage)

**C 23367** **(Pages : 2)** **Name.....**

**Reg. No.....**

**SECOND SEMESTER M.Sc. DEGREE (REGULAR/SUPPLEMENTARY) EXAMINATION, APRIL 2022**

(CBCSS)

Physics

PHY 2C 05—QUANTUM MECHANICS–I

(2019 Admission onwards)

Time : Three Hours Maximum : 30 Weightage

**General Instructions**

1. *In cases where choices are provided, students can attend* **all** *questions in each section.*
2. *The minimum number of questions to be attended from the Section / Part shall remain the same.*
3. *The instruction if any, to attend a minimum number of questions from each sub section / sub part / sub division may be ignored.*
4. *There will be an overall ceiling for each Section / Part that is equivalent to the maximum weightage of the Section / Part.*

**Section A**

(8 *short questions answerable within* 7.5 *minutes*)
(*Answer* **all** *questions, each carry weightage* 1).

1. Explain Dirac bra and ket vectors.
2. Explain linear vector space.
3. Give the basic features of interaction picture.
4. State and explain Ehrenfest's theorem.
5. Briefly explain addition of angular momenta.
6. Explain the properties of Pauli spin matrices.
7. Distinguish between symmetric wavefunction and antisymmetric wavefunction.
8. What are the applications of quantum harmonic oscillator ?

(8 × 1 = 8 weightage)

**Turn over**

## Section B

(4 *essay questions answerable within* 30 *minutes*)
*(Answer any* **two** *questions, each carry weightage* 5).

9. Explain what is meant by a Hermitian operator. Show that :
   (a) The eigen values of a Hermitian operator are real and
   (b) Eigen functions of a Hermitian operator belongs to different eigen values are orthogonal.
10. Discuss the problem of addition if angular momentum in quantum mechanics. Calculate the Clebsch-Gordan co-efficients for $J_1 = \frac{1}{2}$ and $J_2 = \frac{1}{2}$.
11. Describe Schrödinger equation for central potentials and hence describe Hydrogen atom.
12. Solve the problem of simple harmonic oscillator using operator method.

(2 × 5 = 10 Weightage)

## Section C

(7 *problems answerable within* 15 *minutes*)
*(Answer any* **four** *questions, each carry weightage* 3).

13. If $[A, L_x] = [A, L_y] = [A, L_x] = 0$. What is the value of $[A^2, L^2]$ ?
14. Show that the expectation value of the momentum P for a bound state of a one particle system is zero for a stationary state.
15. Show that the zero-point energy of a linear harmonic oscillator is a manifestation of the uncertainty principle.
16. Prove that the spin matrices $S_x$ matrix and $S_y$ have $\pm\frac{\hbar}{2}$.
17. The position of an electron is measured with an accuracy of $10^{-6}$ *m*. Find the uncertainty in the electron's position after 1 s. Comment on the result.
18. Show that the expectation value of an observable, whose operator does not depend on time explicitly, is a constant with zero uncertainty.
19. For Pauli's matrices, prove that (i) $[\sigma_x, \sigma_y] = 2i\sigma_z$. (ii) $\sigma_x\sigma_y\sigma_z = i$.

(4 × 3 = 12 weightage)

8522

C 4757 (Pages : 2)

Name.....

Reg. No.....



**SECOND SEMESTER M.Sc. DEGREE (REGULAR/SUPPLEMENTARY) EXAMINATION, APRIL 2021**

(CBCSS)

Physics

PHY 2C 05—QUANTUM MECHANICS—I

(2019 Admissions)

Time : Three Hours Maximum : 30 Weightage

**General Instructions**

1. *In cases where choices are provided, students can attend* **all** *questions in each section.*
2. *The minimum number of questions to be attended from the Section / Part shall remain the same.*
3. *There will be an overall ceiling for each Section / Part that is equivalent to the maximum weightage of the Section / Part.*

**Section A**

*8 short questions answerable within 7.5 minutes.*
*Answer* **all** *questions.*
*Each question carries weightage* 1.

1. Prove that an operator in a linear vector space can be represented by a square matrix.
2. What is the quantum mechanical operator representing energy ?
3. What are Hermitian operators ? Give their important properties.
4. Briefly explain the features of interaction picture.
5. Are the rigid rotator energy levels degenerate ? Explain.
6. What are the admissibility conditions on a wavefunction ?
7. Explain the principle of indistinguishability in quantum mechanics.
8. Discuss the conservation law associated with space inversion symmetry.

(8 × 1 = 8 weightage)

**Section B**

*4 essay questions answerable within 30 minutes.*
*Answer any* **two** *questions.*
*Each question carries weightage* 5.

9. Describe the Sequential Stern-Gerlach experiment and the conclusions which lead to the basics of quantum mechanics.

**Turn over**

10. Establish the Schrodinger equation for one dimensional harmonic oscillator and solve it to obtain the energy eigen values and eigen functions. Also discuss the significances of zero-point energy.

11. Establish the addition of orbital angular momentum and spin angular momentum. Arrive at Clebsch-Gordan coefficients.

12. Discuss the importance of symmetry of the wavefunctions, taking the example of the ground state of Helium atom.

(2 × 5 = 10 weightage)

## Section C

*7 problems answerable within 15 minutes.*
*Answer any* **four** *questions.*
*Each question carries weightage 3.*

13. Show that $(\sigma . A)(\sigma . B) = A . B + i\sigma . (A \times B)$ where A and B are arbitrary vectors.

14. An electron has a speed of 500 m/s with an accuracy of 0.004%. Calculate the certainty with which we can locate the position of the electron.

15. For an electron in a one-dimensional infinite potential well of width 1Å, calculate (i) the separation between two energy levels (ii) the frequency and wavelength of the photon corresponding to a transition between these two levels (iii) in what region of the electromagnetic spectrum is this frequency wavelength ?

16. Evaluate the commutator (i) $\left[x, p_x^2\right]$ ; and (ii) $\left[xyz, p_x^2\right]$.

17. A beam of electrons is incident from left, normally, on a semi-infinite step potential 5.0 eV height. The incident electrons have kinetic energy E (when to the left of the step potential). What is the relative probability that any given electron will be reflected back by the step potential When E = 10.0 eV.

18. For the operators A, B and C show that [[A, B], C] + [[B, C], A] + [[C, A], B] = 0.

19. Prove that the spin matrices $S_x$ matrix and $S_y$ have $\pm\frac{\hbar}{2}$.

(4 × 3 = 12 weightage)

C 83071 (Pages : 2) Name..... Reg. No.....



**SECOND SEMESTER M.A./M.Sc./M.Com. DEGREE EXAMINATION, JUNE 2020**

(CBCSS)

Physics

PHY 2C 05—QUANTUM MECHANICS–I

(2019 Admissions)

Time : Three Hours Maximum : 30 Weightage

## Section A

*Answer* **all** *questions.*
*Each question carries* 1 *weightage.*

1. Given that P is a projection operator, show that P' = 1 – P also is a projection operator.
2. Show that the set of eigen values of a matrix do not change under similarity transformation.
3. State and explain Ehrenfest's theorem.
4. What is meant by Heisenberg picture ?
5. Show that angular momentum components are generators of rotations.
6. Write a brief note on Clebsch-Gordan co-efficients.
7. What is the advantage of using spherical polar co-ordinates in the case of central potentials ?
8. Write a short note on Pauli's exclusion principle.

(8 × 1 = 8 weightage)

## Section B

*Answer any* **two** *questions.*
*Each question carries* 5 *weightage.*

9. Discuss Stern-Gerlach experiments and its implications.
10. Solve the Simple Harmonic Oscillator problem in one dimension and find the formula for eigen values (no need to obtain the eigen functions explicitly.)
11. Find the eigen values for angular momentum operators $J^2$ and $J_z$.
12. Describe the concepts of symmetry and conservation laws with specific reference to displacement in space and time.

(2 × 5 = 10 weightage)

**Turn over**

## Section C

*Answer any* **four** *questions.*
*Each question carries* 3 *weightage.*

13. Assuming the basic commutation relations between $q$ and $p$ prove the general uncertainty relation.

14. Given that $|0\rangle = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$ and $|1\rangle = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$ write down the matrix representations for

    (a) $|0\rangle\langle 0|$,

    (b) $\langle 0|1\rangle$,

    (c) and show that the two kets form a basis.

15. Show that a Gaussian wave packet continues to be a Gaussian whether we choose the basis as position space or momentum basis.

16. State and prove the continuity equation.

17. Prove the commutation relation between angular momentum components given by ;

    $$\left[L_x, L_y\right] = i\hbar L_z$$

18. Discuss addition of angular momenta of two spin $-\frac{1}{2}$ particles.

19. Write a note on conservation of parity.

(4 × 3 = 12 weightage)

C 82892 (Pages : 2) Name.....

Reg. No.....



# SECOND SEMESTER M.A./M.Sc./M.Com. DEGREE EXAMINATION
# JUNE 2020

(CUCSS)

Physics

PHY 2C 05—QUANTUM MECHANICS—I

(2017 Admissions)

Time : Three Hours Maximum : 36 Weightage

## Section A

*Total* 12 *questions each answerable within* 5 *minutes.*
*Answer* **all** *questions, each carries weightage* 1.

1. What is square integrable wave function ? Explain its relevance in quantum mechanics.
2. What is unitary operator ? Comment on the eigen values and eigen vectors of unitary operator.
3. Give the superposition principle to represent the state of a system.
4. Define Poisson Bracket. What are its properties ?
5. What are the properties of spherical harmonics ?
6. Give the three Pauli spin matrices.
7. Find the time evolution of state vector in interaction picture.
8. What is slater determinant ? What does it physically represent ?
9. What is isotropic Harmonic oscillator ? Give the degeneracy for its $n^{th}$ excited state.
10. Show that the Hamiltonian is the generator of infinitesimal time translations.
11. What is optical theorem ? What does it imply ?
12. What is scattering amplitude and differential cross-section ? How are they related ?

(12 × 1 = 12 weightage)

## Section B

4 *Essay questions, each answerable within* 30 *minutes.*
*Answer any* **two** *questions, each carries weightage* 6.

13. Discuss position and momentum representations. Establish Parseval's theorem.
14. State and prove Ehrenfest Theorem. How is it related to Hamilton Jacobi equations ?

**Turn over**

15. Discuss eigen functions and eigen values of $L_z$ and $L^2$.

16. Discuss First order Born approximation method for scattering. Illustrate it for coulomb potential.

(2 × 6 = 12 weightage)

## Section C

*6 Problem questions, each answerable within 15 minutes.*
*Answer any* **four** *questions, each carries weightage 3.*

17. Derive uncertainty product of two operators and hence derive Heisenberg's uncertainty relations.

18. Consider a particle of mass $m$ confined to move inside an infinitely deep potential Well defined by :

$$\begin{aligned} V(x) &= +\infty \quad x < 0 \\ &= 0 \quad 0 \le x \le a \\ &= +\infty \quad x > a. \end{aligned}$$

Show that energy is quantised. Also find the generalized solutions of time independent Schrödinger equations.

19. Compute the Clebsch Gordan coefficients for two spin ½ particles.

20. Find the wave functions of systems of identical, non-interacting particles for a system of two spin ½ particles.

21. Write the time dependent Schrödinger equation for Hydrogen atom. Discuss the quantization of energy.

22. Calculate the total cross-section in the low-energy limit for scattering of a particle from a hard sphere potential.

(4 × 3 = 12 weightage)

C 82888 (Pages : 2) Name.....

Reg. No.....

**SECOND SEMESTER M.A./M.Sc./M.Com. DEGREE EXAMINATION, JUNE 2020**

(CUCSS)

Physics

PHY 2C 05 QUANTUM MECHANICS—I

(2012 Admissions)

Time : Three Hours Maximum : 36 Weightage

## Section A

*12 Short questions answerable within 5 minutes.*
*Answer* **all** *questions, each carries 1 weightage.*

1. What are the admissibility conditions on a wavefunction ?
2. The zero-point energy is a manifestation of which principle ?
3. What is the condition for two eigen vectors to be orthogonal ?
4. Explain the matrix representation of a wave function ?
5. State and explain the Schrödinger equation in matrix form.
6. Briefly explain addition of angular momenta.
7. Explain the properties of Pauli spin matrices.
8. What is phase shift ? Explain the nature of phase shift in the case of repulsive and attractive square well potentials ?
9. Conservation of angular momentum is a consequence of the rotational invariance of the system. Substantiate
10. What is scattering amplitude ? How is it related to scattering cross section ?
11. Define differential cross section and total cross section. What is the unit in which they are measured ?
12. Explain symmetric and antisymmetric wavefunctions.

(12 × 1 = 12 weightage)

**Turn over**

## Section B

*2 essay questions answerable within 30 minutes.*
*Answer any* **two** *questions, each carries 6 weightage.*

13. Explain what is meant by a Hermitian operator. Show that :
    a) The eigen values of a Hermitian operator are real ; and
    b) Eigen functions of a Hermitian operator belongs to different eigen values are orthogonal.
14. What are clebsch Gordan co-efficients ? Mention their properties and selection rules ?
15. Write short notes on :
    a) Symmetric and anti-symmetric wave functions.
    b) Pauli exclusion principle and Spin wave functions for two electrons.
16. What is phase shift ? Explain the nature of phase shift in the case of attractive square well potentials.

(2 × 6 = 12 weightage)

## Section C

*3 problems answerable within 15 minutes*
*Answer any* **three** *questions, each carries 4 weightage.*

17. Discuss the Heisenberg pictures.
18. Show that the expectation value of the momentum P for a bound state of a one particle system is zero for a stationary state.
19. A bullet of mass 0.03 kg is moving with a velocity 500 m/s . The speed is measured up to an accuracy of 0.02%. Calculate the uncertainty in x. Also comments on the result.
20. If $[A, L_x] = [A, L_y] = [A, L_x] = 0$ what is the value of $[A^2, L^2]$ ?
21. Show that Pauli spin matrices satisfy $\sigma_i\sigma_j + \sigma_j\sigma_i = 2I\delta_{ij}$ (I is a $2 \times 2$ matrix).
22. Discuss validity conditions for Bom approximation.

(3 × 4 = 12 weightage)

C 63087 (Pages : 2) Name.....

Reg. No.....



# SECOND SEMESTER M.Sc. DEGREE EXAMINATION, JUNE 2019

(CUCSS)

Physics

PHY 2C 05—QUANTUM MECHANICS – I

(2017 Admissions)

Time : Three Hours Maximum : 36 Weightage

## Section A

*(Total 12 questions each answerable within 5 minutes)*

*Answer* **all** *questions.*

*Each question carries a weightage of* 1.

1. What is Schwarz inequality ? State the condition for it to become an equality relation.
2. Describe how the operator is represented by a matrix.
3. What is a wave packet ? Give the physical interpretation of wave packet.
4. Define expectation value for discrete and continuous systems. What does it represent ?
5. Derive the Heisenberg equation of motion.
6. Find [J+, J–].
7. What are Clebsch-Gordan coefficients ? What are its properties ?
8. Compare the identical particles in classical and quantum mechanics.
9. Write down the radial equation for a free particle in spherical co-ordinates. Give the general solution for the same.
10. How a state and an operator are identified to have odd or even parity ?
11. What is the role of Green's function in scattering problem ?
12. Under what conditions is the Born approximation for scattering problem is valid? Justify your answer.

(12 × 1 = 12 weightage)

## Section B

*(4 Essay questions, each answerable within 30 minutes)*

*Answer any* **two** *questions.*

*Each question carries a weightage of* 6.

13. Find the relationship between the Poisson bracket and commutator bracket. State and prove Ehrenfest theorem.
14. Discuss the formal theory of addition of angular momentum. Discuss the relevant commutation relations.

**Turn over**

15. Describe the Schrödinger equation for motion in central potential and hence describe Hydrogen atom.

16. Discuss partial wave analysis of scattering. Obtain the scattering cross-section corresponding to rigid sphere scattering.

(2 × 6 = 12 weightage)

## Section C

*(6 Problem questions, each answerable within 15 minutes)*
*Answer any* **four** *questions.*
*Each question carries a weightage of* 3.

17. Apply commutator algebra to find the uncertainty relation between any two operators.

18. Calculate the commutator operator $[r_i, p_j]$ in the position representation.

19. Find the expectation value of momentum for a Gaussian wave packet.

20. Give the Unitary operators for Rotations. Establish the relevant conservation law.

21. Find the matrix elements of the operator $J_x$ for $j = 1$.

22. Find the total scattering cross-section for scattering by Yukawa potential.

(4 × 3 = 12 weightage)

C 63083 (Pages : 2) Name.....

Reg. No.....



**SECOND SEMESTER M.Sc. DEGREE EXAMINATION, JUNE 2019**

(CUCSS)

Physics

PHY 2C 05—QUANTUM MECHANICS – I

(2012 Admissions)

Time : Three Hours Maximum : 36 Weightage

## Part A

*Answer* **all** *questions.*

*Each question carries* a *weightage of* 1.

1. When do you say two functions are orthonormal ?
2. What is a linear operator ? Give example.
3. Outline Dirac bra and ket notation.
4. Why are only Hermitian operators associated with Physical quantities ?
5. What are ladder operators ? Why are they called so ?
6. Define a general angular momentum operator.
7. What do you understand by spin of an electron ?
8. What is Slater determinant ?
9. What are Pauli matrices ?
10. Distinguish between Fermions and Bosons.
11. What are Partial waves ?
12. Distinguish between laboratory Co-ordinate system and centre of mass Co-ordinate system.

(12 × 1 = 12 weightage)

## Part B

*Answer any* **two** *questions.*

*Each question carries* a *weightage of* 6.

1. Discuss the problem of scattering by a central potential using the partial wave analysis.
2. Describe the matrix representation method of representing vectors and operators. Show that an operator is represented by a diagonal matrix.
3. State the commutation relations obeyed by the components of angular momentum and express them in vector notation. What is the value of the uncertainty product ($\Delta L_x$) ($\Delta L_y$) in a representation in which $L^1$ and $L_z$ have simultaneous Eigen functions.

**Turn over**

4. What do you mean by identical particles ? Define symmetric and antisymmetric wave functions. Construct symmetric & anti symmetric wave functions for a system of identical particles.

(2 × 6 = 12 weightage)

## Part C

*Answer any* **four** *questions.*

*Each question carries a weightage of* 3.

1. Show that the Eigen functions of a Hermitian operator belonging to different Eigen values are orthogonal.
2. Deduce the equation of motion in the momentum representation.
3. Show that the time reversal operator operating on any number changes it into its complex conjugate.
4. Obtain the matrix representation of the wave function.
5. Reduce the following operators using Pauli's spin matrix representation :

   (a) $S^2x, Sy, S^2z$ ; (b) $S^2x, S^2y, S^2z$ ; (c) $Sx\ Sy\ S^2z$.
6. The PE of scattering for an electron by an atom can be represented approximately as a screened coulomb field by $V(r) = \frac{ze^2}{r} . e^{-r/a}$ where $a$ is the shielding radius. Find the scattering amplitude ?

(4 × 3 = 12 weightage)

C 63094 (Pages : 2) Name.....

Reg. No.....



**SECOND SEMESTER M.Sc. DEGREE EXAMINATION, JUNE 2014**

(CUCSS)

Physics

PHY 2C 05—QUANTUM MECHANICS

(2012 Admissions)

Time : Three Hours Maximum : 36 Weightage

## Section A

*Answer* **all** *questions.*
*Each question carries weightage of* 1.

1. Define a linear vector space. What are its properties ?
2. Explain momentum representation. What is the operator for position in the momentum representation ?
3. Briefly explain the three pictures of time development in quantum mechanics.
4. What are Clebsch-Gordan coefficients ? Mention their uses.
5. Write a brief note on Pauli spin matrices.
6. Give the commutation relations that define angular momentum operator in quantum mechanics.
7. Discuss the symmetries associated with the different conservation laws in physics.
8. What is time reversal operation ? Mention its significance in physics.
9. Distinguish between symmetric and antisymmetric wave functions.
10. Explain the differences between the Born approximation and partial wave method in scattering.
11. Explain the physical significance of scattering length.
12. What is meant by the Ramsauer-Townsend effect ?

(12 × 1 = 12 weightage)

## Section B

*Answer any* **two** *questions.*
*Each question carries a weightage of* 6.

13. What are the fundamental postulates of quantum mechanics ? Explain their significance.
14. Using the Schrödinger picture, obtain the energy eigenvalues and eigenfunctions of a linear harmonic oscillator.

Turn over

15. Outline the method of partial wave analysis for low energy scattering. Obtain the expression for the total cross section.

16. Establish the importance of the symmetry of the wave functions, taking the example of the ground state of helium atom.

(2 × 6 = 12 weightage)

## Section C

*Answer any* **four** *questions.*
*Each question carries* 3 *weightage.*

17. If A and B are Hermitian operators, show that (AB + BA) is Hermitian and (AB – BA) is not Hermitian.

18. In beta decay of a nucleus, an electron is emitted. If the nucleus is assumed to consist of protons and electrons, calculate the minimum energy of the electron confined within a nucleus of radius 1.5 fm., using Heisenberg's uncertainty relation. Calculate also the minimum energy of the proton confined within the nucleus.

19. Evaluate Clebsch-Gordan coefficients for angular momentum coupling of two spin half particles.

20. (a) Show that if a particle has the wave function $\psi = \exp(ikz)$, the $z$-component of its angular momentum is zero.

    (b) Show that the expectation values of $L_X$ and $L_Y$ are zero for a system which is in an eigen state of $L_Z$.

21. Using the Slater determinant, prove the Pauli exclusion principle.

22. Obtain an expression for scattering cross-section for a beam of particles scattered by a rigid sphere.

(4 × 3 = 12 weightage)

C 83628 (Pages : 2) Name.....

Reg. No.....



# SECOND SEMESTER M.Sc. DEGREE EXAMINATION, JUNE 2015

(CUCSS)

Physics

PHY 2C 05—QUANTUM MECHANICS—I (4C)

(2012 Admissions)

Time : Three Hours Maximum : 36 Weightage

## Part A

*Answer* **all** *questions. Each question carries* 1 *weightage.*

1. What is Hilbert space ?
2. When do you say two functions are orthonormal ?
3. Outline Dirac bra and ket notation ?
4. Explain the different postulate in Quantum mechanics.
5. What are ladder operators ? Why are they called so ?
6. The definition of angular momentum given by $L = r \times p$ is not a general one. Why ?
7. What do you understand by spin of an electron ?
8. What is Slater determinant ?
9. Distinguish between Fermions and Bosons.
10. What are Partial waves ?
11. Distinguish between laboratory Coordinate system and centre of mass Coordinate system.
12. What is Phase shift ?

(12 × 1 = 12 weightage)

## Part B

*Answer any* **two** *questions. Each question carries* 6 *weightage.*

1. Discuss the problem of addition if angular momentum in quantum mechanics. Calculate the Chebsch - Gordon Coefficients for $J_1 = 1/2$ and $J_2 = 1/2$.
2. Explain the Born approximation theory for scattering and apply the same in the case of a screened Coulomb potential and arrive at the scattering cross section.
3. Explain the features of the Schrödinger picture and Heisenberg picture. Illustrate the difference between the Schrödinger and the Heisenberg pictures by applying the two methods to the solution of the problem of a linear harmonic oscillator.
4. What do you mean by identical particles ? Define symmetric and antisymmetric wave functions. Construct symmetric and antisymmetric wave functions for a system of identical particles.

(2 × 6 = 12 weightage)

**Turn over**

## Part C

*Answer any* **four** *questions. Each question carries* 3 *weightage.*

1. Define the commutator of two operators. Evaluate the commutators of $\left[x,\frac{d}{dx}\right]$ and $\left[\frac{d}{dx},F(x)\right]$.
2. Define a Hermitican operator. Show that the Eigenvalues of a Hermitian operator are real.
3. For a spinless particle moving a potential V($r$) show that the time reversal operator T commutes with the Hamiltonian.
4. Evaluate the following commutators

   a) [L$x$, [L$y$,L$z$]) ; b) [$L^2y$,L$x$] ; c) [$L^2x$ $L^2y$].
5. .What is Probability current density vector ? Determine this quantity for a plane wave.
6. Determine the change in the Partial Phase Shift (Si) when the field V($r$) is varied.

(4 × 3 = 12 weightage)

C 4673 (Pages : 2) Name.....

Reg. No.....

# SECOND SEMESTER M.Sc. DEGREE EXAMINATION, JUNE 2016

(CUCSS)

Physics

PHY 2C 05—QUANTUM MECHANICS—I

(2012 Admissions)

Time : Three Hours Maximum : 36 Weightage

## Part A

*Answer* **all** *questions.*
*Each question carries* 1 *weightage.*

1. What is Hilbert space ?
2. What is a linear operator ? Give example.
3. Why are only Hermitian operators associated with Physical quantities ?
4. Explain the different postulated in Quantum mechanics.
5. What are ladder operators ? Why are they called so ?
6. Define a general angular momentum operator.
7. The definition of angular momentum given by $L = r \times p$ is not a general *one*. Why ?
8. What is Slater determinant ?
9. What are Pauli matrices ?
10. Distinguish between Fermions and Bosons.
11. What are Partial waves ?
12. Distinguish between laboratory Coordinate system and centre of mass Co-ordinate system.

(12 × 1 = 12 weightage)

## Part B

*Answer any* **two** *questions.*
*Each question carries* 6 *weightage.*

1. Discuss the problem of addition if angular momentum in quantum mechanics. Calculate the Chebsch - Gordon Coefficients for $J_1 = 1/2$ and $J_2 = 1/2$.
2. Explain the Born approximation theory for scattering and apply the same in the case of a screened Coulomb potential and arrive at the scattering cross section.
3. Explain the features of the Schrödinger picture and Heisenberg picture. Illustrate the difference between the Schrödinger and the Heisenberg pictures by applying the two methods to the solution of the problem of a linear harmonic oscillator.

**Turn over**

4. What do you mean by identical particles? Define symmetric and antisymmetric wave functions. Construct symmetric and antisymmetric wave functions for a system of identical particles.

(2 × 6 = 12 weightage)

## Part C

*Answer any* **four** *questions.*
*Each question carries* 3 *weightage.*

1. Define the commutator of two operators. Evaluate the commutators of $\left[x, \frac{d}{dx}\right]$ and $\left[\frac{d}{dx}, F(x)\right]$.

2. Show that the Eigen functions of a Hermitian operator belonging to different Eigen values are orthogonal.

3. For a spinless particle moving a potential V($r$) show that the time reversal operator T commutes with the Hamiltonian.

4. Evaluate the following commutators :—

   (a) [L$x$, [L$y$, L$z$]).

   (b) [$L^2y$, L$x$].

   (c) [$L^2x$, $L^2y$].

5. What is Probability current density vector ? Determine this quantity for a plane wave.

6. Determine the change in the Partial Phase Shift (Si) when the field V($r$) is varied.

(4 × 3 = 12 weightage)

C 24004 (Pages : 2) Name.....

Reg. No.....

# SECOND SEMESTER M.Sc. DEGREE EXAMINATION, JUNE 2017

(CUCSS–PG)

Physics

PHY 2C 05—QUANTUM MECHANICS—I (4C)

(2012 Admissions)

Time : Three Hours Maximum : 36 Weightage

## Section A

*Answer* **all** *questions.*
*Each question has weightage of* 1.

1. Define Hilbert space. How a state function is represented in Hilbert space ?
2. How does the eigen value differ from the expectation value ?
3. Discuss the significance of time-energy uncertainty relationship.
4. State and explain Ehrenfest's theorem.
5. Explain momentum representation. What is the operator for position in the momentum representation ?
6. Write a brief note on Pauli spin matrices.
7. Discuss the symmetries associated with the different conservation laws in physics.
8. Discuss the relation between spin of a particle and the statistics obeyed by it.
9. Explain the principle of indistinguishability in quantum mechanics.
10. What are the conditions of validity of the Born approximation in scattering ?
11. Explain the physical significance of scattering length.
12. Explain resonance scattering.

(12 × 1 = 12 weightage)

## Section B

*Answer any* ***two*** *questions.*
*Each question has weightage of* 6.

13. Discuss the matrix representation of bra and ket operators. Derive the general uncertainty relation.
14. Discuss the different pictures of quantum mechanics. Solve the linear harmonic oscillator problem in the Heisenberg picture.

**Turn over**

15. (a) Obtain the eigen values of the angular momentum operators $J^2$ and $L_z$.
    (b) Enumerate their matrix representations.

16. Outline the method of partial wave analysis for low energy scattering. Obtain the expression for the total cross section.

(2 × 6 = 12 weightage)

## Section C

*Answer any* **four** *questions.*
*Each question has weightage of* 3.

17. Show that for Hermitian operators : (a) the eigen values are real ; (b) eigen vectors belonging to different eigen values are orthogonal.

18. A beam of particles with speed [?] has a wave function $\psi(x) = u(x)\exp(ikx)$, where $u(x)$ is a real function. Calculate the probability density.

19. Discuss the quantum mechanical treatment for collision between identical particles.

20. (a) Show that if a particle has the wave function $\psi = \exp(ikz)$, the z-component of its angular momentum is zero.
    (b) Show that the expectation values of $L_x$ and $L_y$ are zero for a system which is in an eigen state of $L_z$.

21. Show that time reversal operation corresponds to complex conjugation.

22. Obtain the transformation of scattering cross-section from the centre of mass frame to the laboratory frame of reference.

(4 × 3 = 12 weightage)

**D 43531** (Pages : 2) Name.....

Reg. No.....

# SECOND SEMESTER M.Sc. DEGREE EXAMINATION, JUNE 2018

(CUCSS–PG)

Physics

PHY 2C 05 – QUANTUM MECHANICS – I

(2017 Admissions)

Time : Three Hours Maximum : 36 Weightage

## Section A

*(Total 12 questions, each answerable within 5 minutes)*

*Answer* **all** *questions.*

*Each question carries a weightage of* 1.

1. What is a Hermitian operator? Show that the expectation value of Hermitian operator is real and that of an anti Hermitian operator is imaginary.
2. What is a Hilbert space? Describe its properties.
3. Find the time dependence of the expectation value of a linear operator. What is the condition for an observable to be constant of motion?
4. What is a wave packet? Distinguish between group and phase velocities of a wave packet.
5. Describe interaction picture in quantum mechanics.
6. State any *four* properties of Pauli spin matrices.
7. Find the eigen value equation for the operator J+.
8. Write down the Schrödinger equation for Hydrogen atom. Find the equation of motion for the center of mass of the atom.
9. State the condition for the Hamiltonian to be invariant under spatial translations. Illustrate.
10. Explain exchange degeneracy.
11. What is differential scattering cross section? What is its dimension?
12. Describe the validity of first order Born approximation for scattering problem.

(12 × 1 = 12 weightage)

## Section B

*(4 Essay questions, each answerable within 30 minutes)*

*Answer any* **two** *questions.*

*Each question carries a weightage of* 6.

13. Apply commutator algebra to derive the general relation giving the uncertainty product of two operators and hence derive the Heisenberg's uncertainty relations.

**Turn over**

14. Find the Schrödinger equation for Harmonic oscillator problem. Discuss the energy eigen values and energy eigen states.

15. Discuss the formal theory of addition of angular momenta.

16. Discuss the method of partial waves for elastic scattering. Illustrate with spherically symmetric potential.

(2 × 6 = 12 weightage)

## Section C

*(6 problem questions, each answerable within 15 minutes)*

*Answer any* **four** *questions.*

*Each question carries a weightage of* 3.

17. Determine the form of the momentum operator in the position representation. Also represent the position operator in momentum representation. Calculate the commutator [X, P] in the momentum representation.

18. (a) Calculate the Poisson bracket between the $x$ and $y$ components of the classical orbital angular momentum.

    (b) Calculate the commutator between the $x$ and $y$ components of the orbital angular momentum operator.

19. Find the matrix elements of the operator $J_y$ for $j = 1$.

20. Find the Hamiltonian of a particle of mass $\mu$ and charge $q$ moving in a central potential $V(r)$ under the influence of uniform magnetic field B.

21. Discuss the singlet and triplet state wave functions of Helium atom and hence show that the singlet state has higher energy than the triplet state.

22. Calculate the differential cross section for scattering by coulomb potential for the first Born approximation.

(4 × 3 = 12 weightage)

D 43527 (Pages : 2) Name.....

Reg. No.....

# SECOND SEMESTER M.Sc. DEGREE EXAMINATION, JUNE 2018

(CUCSS–PG)

Physics

PHY 2C 05—QUANTUM MECHANICS—I (4C)

(2012 Admissions)

Time : Three Hours Maximum : 36 Weightage

## Section A

*Answer* **all** *questions.*
*Each question carries* 1 *weightage.*

1. Explain what is meant by Hilbert space ?
2. When are two operators said to be same ?
3. What is meant by co-ordinate representation ?
4. What are ladder operators ? Why are they called so ?
5. What do you understand by spin of an electron ?
6. What are Clebsch-Gordon co-efficients ? Give their significance.
7. What is slater determinant ? How does it incorporate Pauli principle ?
8. Bring out the meaning of time reversal invariance. Show that the time reversed state of $\psi(r, t)$, is not $\psi(r, -t)$ but $\psi^*(r, -t)$.
9. What is phase shift ? Explain the nature of phase shift in the case of repulsive and attractive potentials.
10. Give the geometrical interpretation of scattering length.
11. What is the relevance of Green's function in the scattering problem in a central potential.
12. What are partial waves ?

(12 × 1 = 12 weightage)

## Section B

*Answer any* **two** *questions.*
*Each question carries* 6 *weightage.*

13. Establish the Schrödinger equation for a one-dimensional harmonic oscillator and solve it to obtain the energy eigen values and eigen functions. Also discuss the significance of zero point energy.
14. Obtain the eigen values and eigen functions of orbital angular momentum operators.

**Turn over**

15. (a) Explain the concept of symmetry and antisymmetry of wave functions for a system of identical particles.

    (b) Obtain the ground state wave function and energy of the Helium atom by considering the symmetry of wave functions.

16. What is Born approximation ? Explain. Also bring out the validity conditions for Born approximation.

(2 × 6 = 12 weightage)

## Section C

*Answer any* **four** *questions.*
*Each question carries* 3 *weightage.*

17. If $\hat{A}$ and $\hat{B}$ are two commuting operators, prove that they have a set of common eigen functions.

18. Show that angular momentum is conserved for a particle in a central potential.

19. Estimate the size of the hydrogen atom and its ground state energy using uncertainty principle.

20. For any vector A, show that $[\sigma, A \cdot \sigma] = 2iA \times \sigma$.

21. Find out the angular momentum matrices $J^2$, $J_+$, $J_-$, $J_x$, $J_y$ and $J_z$ corresponding to $j = 1$ in a representation in which $J^2$ and $J_z$ are diagonal.

22. In a scattering experiment, the potential is spherically symmetric and the particles are scattered at such energy that only *s* and *p* waves need to be considered. (i) Show that the differential scattering cross-section can be expressed in the form $\sigma(\theta) = a + b\cos\theta + c\cos^2\theta$ ; (ii) What are the values of $a$, $b$ and $c$ in terms of phase shifts ?

(4 × 3 = 12 weightage)