NATIONAL UNIVERSITY OF ENGINEERING

COLLEGE OF SCIENCES

PHYSICS PROGRAM

CF302 – QUANTUM MECHANICS I

I. GENERAL INFORMATION

CODE	: CF302 – Quantum Mechanics I
SEMESTER	: 6
CREDITS	: 06
HOURS PER WEEK	: 08 (Theory – Laboratory)
PREREQUISITES	: CF221 Theoretical Mechanics I CF381 Introduction to Modern Physics CF391 Mathematical Methods for Physicists II
CONDITION	: Mandatory

II. COURSE DESCRIPTION

Familiarize the student with the fundamental concepts and principles of quantum mechanics as well as the use of the necessary mathematical tools. Learn to use these concepts to study and analyze simple non-relativistic quantum systems.

III. LEARNING UNITS

1. Summary of the Classic Model

The need to represent the natural world / Astronomy as a precursor model / Kepler and Galileo and the experimental measurements / The visions of Newton, Maxwell, Boltzmann and the classical model.

2. Critical discrepancies between the Classic Model and the Experimental Results

Atomic spectra and stability / Ether for electromagnetic waves / Irradiation of accelerated charges / Photoelectric effect / Problem of thermal emissions of hot bodies / Problem with "invisible" atoms and molecules existence / Radioactive substances / Energy conservation / Problem of ideal measurements (accurate, without disturbing the system and macroscopic).

3. Probabilities and Measurements

Introduction / Measurement as an experiment / Function that expresses the measurement of observable physical events / Mean value and uncertainty of the measurement experiment / A specific measurement gives a numerical result with some probability / Further disturbs the physical system in consideration / Examples. Each measurement "interrupts" the dynamic process proper of the considered SF / The confusion between the measurement error and the uncertainty of the measurement.

4. **The Quantum Model from Experimental Measurements**

   A physical system / The wave function and the Schrödinger equation / Linearity effect and probability amplitudes / The hermetic (linear) operators as physical information extractors / Their eigenvalues and the probability of obtaining a certain numerical value / Probability of jumping to a state / Conditions for wave function at infinity: free system and bound system (confined.)

5. **Operators**

   Operators of position, momentum, potential energy and total mechanical energy / Some switches [Pj, Rk], [P2, R], [V, R], [H, R], [H, P] / Proper functions common to commuting operators.

6. **Mean Value of Operators**

   Temporary derivative of operators and their averages / Ehrenfest's Theorem / Newton's Second Law as a guarantee in the (average) results of quantum processes / (The Second Law, the Hamilton-Jacobi equation and the Schrödinger equation).

7. **The Free Particle Case (Constant and Uniform Potential) as a Wave Package**

8. **Time Independent Potential**

   Time-independent potential and the separation of the temporal component in the Schrödinger equation / The stationary equation and the total energy.

9. **The One-dimensional Case**

   The sectionally constant potential case: Tie conditions / Step potentials, potential barriers and potential wells / Tunnel effect. Energy quantification.

10. **Harmonic Oscillator**

    The analytical solution and the algebraic solution / Energy spectrum / Three-dimensional harmonic oscillator / Angular momentum operator / Radial momentum operator / Equation in spherical coordinates / Angular equation and L^2 and L_z quantization. Radial equation and energy quantification / Symmetry and degeneration of energy and angular momentum / Simultaneous measurements / Uncertainty principle / Minimum energy of an oscillator.

11. **Schrödinger Equation for Many Punctual Bodies**

    Two bodies case / Review of the classic model for two bodies / Variables change to separate the CM movement and the relative movement / Spherical symmetry and the use of spherical coordinates / Radial momentum operator and angular momentum operator / $[L_j, R_k]$, $[L_j, P_k]$, [H, L], $[H, L^2]$ operators / Radial equation and angular equation / Angular equation and spherical harmonics. Radial equation / Physical conditions as boundary conditions and quantization of angular momentum and energy.

12. Hydrogen atom

Free states and linked states / Energy levels / Balmer, Paschen and Lyman spectral series / Probability density and probability current density as charge and current densities / Orbital magnetic moment model / Parallelism of the magnetic moment and the third component of angular momentum.

13. Time Independent Disturbances

Non-degenerate case / First-order and second-order perturbations / Harmonic oscillator and type R, P, R^n, P^n disturbances. Exact solutions for type R^2 or P^2 disturbances cases / Degenerate case / Determination of the disturbed wave function.

14. Zeeman Effect and Stark Effect

Construction of the classical Hamiltonian for a charge in an electromagnetic field (based on the Maxwell equations and the Lorentz force) / Schrödinger equation for the atom in an electromagnetic field / Disturbance caused by an external magnetic field: the Zeeman effect (linear) and partial-lifting of energetic levels degeneration / Disturbance caused by an external electric field: first-order Stark effect / Problem of the main axes of inertia as an example of symmetry and degeneration.

IV. BIBLIOGRAPHY

- B.H. Bransden & C.J. Joachain. Quantum Mechanics. Benjamin Cummings, 2 edition, 2000.
- W. Greiener, Quantum Mechanics, Springer, 2001.
- David J. Griffiths, Introduction to Quantum Mechanics, Pearson Education, Inc, 2005.
- Cohen-Tannoudji, C., Diu, B. y Laloë, F. Quantum Mechanics, Vols. I y II, John Wiley Inc., N.Y., 1977.
- Davidov, A. S., Quantum Mechanics (2 ed.), Pergamon Press, 1976.
- P. Dirac, Principios de Mecánica Cuántica, Ediciones Ariel, Barcelona, 1967.

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