# PHO-105: Introductory Quantum Information Theory

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January 14, 2026

Notes for the course *Introductory Quantum Information Theory* instructed by Prof. P.C. Srivastava at IIT Roorkee, Spring, 2026.

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The recommended book for this course is **Quantum Computation and Quantum Information**, *Neilsen and Chuang*. It is not meant to be followed linearly. Instead we will jump over topics and read only what is relevant.

## 1.1 The Six Postulates of Quantum Mechanics

1. The first postulate describes the state of a quantum mechanical system. It can be completely specified by a function $\psi$ known as the **wave function**. The wave function is a function of the coodinates in space and time, usually represented as
$$|\psi\left(\mathbf{r}, t\right)\rangle$$
This function has an important property that $(\psi^*(\mathbf{r}, t)\psi(\mathbf{r}, t)dV)$ is the probability that the particle lies in the volume element $dV$ located at $\mathbf{r}$ at time $t$. The wave function must also satisfy the following normalization condition due to the previous probabilistic interpretation,
$$\int_{-\infty}^{\infty} \psi^*(\mathbf{r}, t)\psi(\mathbf{r}, t)dV = 1$$

2. The second postulate describes a correspondence between every observable quantity $A$ in classical mechanics to its quantum counter-part using the linear, Hermitian operator $\hat{A}$ in quantum mechanics.

3. The third postulate describes the measurements of an observable. The only values that will ever be observed for an observable associated with $\hat{A}$ are its eigenvalues
$$\hat{A}\psi = a\psi$$

4. The fourth postulate describes the expectation of an observable corresponding to $\hat{A}$, which is given by
$$\langle A\rangle = \int_{-\infty}^{\infty} \psi^* \hat{A}\psi dV$$
An immediate consequence of the fourth postulate is that, after the measurement of $\psi$, the wave functions immediately *collapses* into the corresponding eigenstate. In other words, the measurement affects the state of the system.

5. The fifth postulate describes the **time evolution** of a wave function. The time evolution of the wave function is governed by the **Schrödinger Equation**.
$$i\hbar\frac{\partial}{\partial t}|\psi(t)\rangle = \hat{H}|\psi(t)\rangle$$

6. The sixth, and the last postulate, states that the wave function is symmetric for particles with integer spin, called the **bosons**, and it is antisymmetric for particles with half-integer spin, called the **fermions**. The mathematical treatment of this postulate yields the **Pauli Exclusion Principle** which states that no two identical fermions can occupy the same quantum state.