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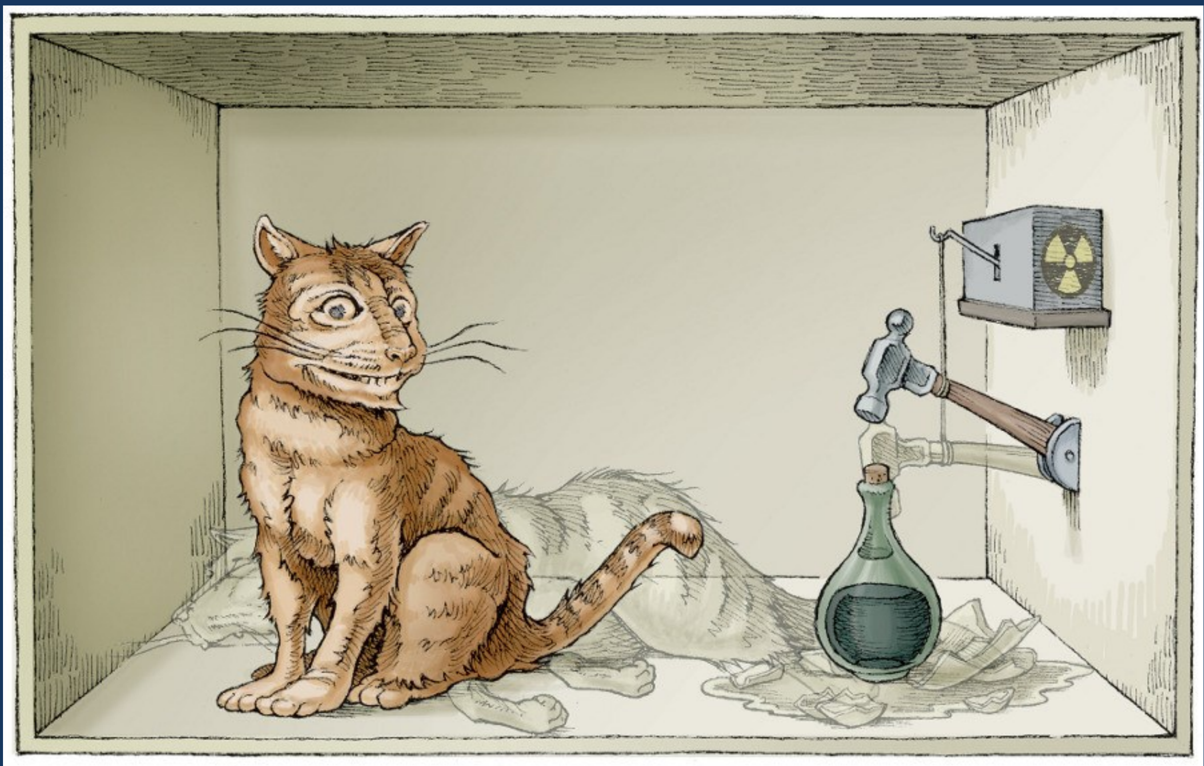
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PHYS4051 Quantum Theory (Dec Exam)

Course Information Guide

1 Course Details

PHYS4051 Quantum Theory (Dec Exam) is a level 4 Physics Honours course. It is compulsory for Theoretical Physics students and elective for many other physics degree options. It is composed of 18 lectures and 2 full class tutorials, normally given in Semester 1.

Lecturer: Dr Sarah Croke
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Recommended Text:
Alistair I. M. Rae, Quantum Mechanics, (Taylor & Francis)

Course notes and Question Sheets are made available on Moodle.

2 Assessment

The course will be assessed via an examination in the December diet. It provides 10 H-level credits.

3 Required Knowledge

Students are expected to have completed the Level 3 course PHYS4025 Quantum Mechanics. They should be familiar with the motivations of quantum mechanics and its historical development as a solution to problems in early 20th century physics such as the ultraviolet catastrophe and Young's double-slit experiment. They should be familiar with the concept of a wavefunction and wavefunction collapse, and the expression of observables as operators. They should by able to apply the Schrödinger Equation to simple potentials. We will assume a familiarity with mathematical concepts such as vector spaces and Fourier series. This course will have some overlap with P403H Atomic Systems.

4 Intended Learning Outcomes

By the end of the course, students will be able to demonstrate a knowledge and broad understanding of Quantum Theory. They should be familiar with the postulates of quantum mechanics, and be able to describe quantum states and measurements using the formal language of Hilbert space and operators. They should be able derive the Heisenberg uncertainty principle and the Pauli exclusion principle. Students should be able to demonstrate how quantum states change with time. They should be able to demonstrate knowledge of entangled states and quantum encryption. They should be able to apply perturbation theory to both time-independent and time-dependent (Schrödinger) systems, derive the corrections to the energy levels of perturbed systems and derive Fermi's golden rule. Students should also be able to discuss the consequences and applications of these ideas to topics such as lasers, masers, spontaneous and stimulated emission, electron spin resonance and nuclear magnetic resonance, and particle scattering. They should also appreciate how quantum mechanics affects and relates to the topics of their other Honours level physics courses.

5 Course Outline

5.1 Fundamental concepts

We will review the principles and postulates of quantum mechanics using the formal language of operators, eigenvalues, eigenfunctions and commutators. We will introduce the state vector and Hilbert Space and relate physical observables to Hermitian operators. We will discuss the state vector in momentum and position space using the concepts of vector spaces, such as completeness and orthonormality, and demonstrate their relation to one another by Fourier transform. We will explore the probability interpretation of measurement and its associated conceptual issues. A general derivation of Heisenberg's uncertainty principle will be given. We will make extensive use of Dirac's "bra-ket" notation and the matrix representations of operators throughout.

5.2 Angular momentum

We will then review the orbital angular momentum operator in quantum mechanics and investigate its properties. We will introduce spin angular momentum and relate it to the Pauli matrices. This will lead to a demonstration of the Pauli exclusion principle.

5.3 Quantum measurements

We will discuss the locality of quantum measurements, the Einstein-Podolsky-Rosen Paradox and Bell's inequality. This will lead to a brief overview of quantum cryptography and entangled states.

5.4 Time-independent perturbation theory:

An introduction to perturbation theory will be given, as an approximate method for solving the time-independent Schrödinger equation. We will apply this up to second order in the perturbative expansion for the case of non-degenerate energy eigenstates. The Stark effect will be used as an example. Perturbation theory for degenerate states will be discussed to first order and we will demonstrate how the perturbation lifts the degeneracy. We will use the variational principle to determine upper bounds on ground state energies.

5.5 Time dependence

We will investigate the time-dependent Schrödinger equation and show how systems evolve with time according to the Hamiltonian operator, including a discussion of stationary and non-stationary states. We will apply this to the precession of a spinning charged particle in a magnetic field, neutrino oscillations and the spreading of wave packets. We will describe the sudden approximation and apply it to beta decay.

5.6 Time-dependent perturbation theory

We will derive expressions to first order in the perturbative expansion for time-dependent perturbation theory, leading to a Fermi's golden rule. We will apply this to a particle in an electromagnetic field and show how this leads to selection rules. We will discuss lasers and masers and quantitatively investigate spontaneous and stimulated emission. We will then apply these ideas to electron spin resonance and nuclear magnetic resonance. Finally we will discuss line shapes, decay widths and particle scattering.