Quantum Mechanics M.T. 2000

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Synopsis

Aims: to provide an introduction to quantum mechanics and in particular to those aspects used in the rest of the Part A course.
Objectives: to acquire understanding of the basic principles of quantum mechanics and to be able to solve problems for one-body systems in one, two, and three dimensions. After careful study of the material in the lectures and textbooks, together with practice in problem-solving for the associated tutorials, the student should achieve a broad competence in the subjects covered, and be able to apply it to the solution of problems such as those in the quantum mechanics questions in Paper A3 of Finals.

Contents
This course consists in total of 22 lectures. I shall give the first 14 lectures this term; the remaining 8 will be given by Dr. Wheater next term. A number of problem sets covering the basic material in the Part A syllabus will be handed out during the course. This term I shall hand out Sets 1-5. Set 1 will contain some questions on material which should be familiar to those who did Physics 2 in Prelims, but it will also contain some questions on topics outside the Physics 2 syllabus (but inside the Part A one). Please note, though, that the lectures will contain new material right from the beginning. These sets 1-5 are intended for students to work through in parallel with the lecture course this term. Next term Dr. Wheater will hand out further sets of problems to accompany the remaining 8 lectures of the course. There will also be a "supplementary" set containing more challenging problems, many of them outside the Part A syllabus.

The first section of the lecture course, consisting of 9 lectures, will cover the fundamental principles of quantum mechanics and illustrate them using one-dimensional plane waves, wave packets, the infinitely deep potential well, and the step potential. The numbers in brackets refer to problems in the sets: e.g. 1.6 means set 1 question 6.

1. Brief historical survey 1900-1926. Main experiments and ideas. The importance of h (or $\hbar$) [1.1 - 1.6].

2. The time-dependent Schrödinger equation. Plane wave solutions and the connection with de Broglie waves. Probability interpretation of the wavefunction. Average value of x. Conservation of probability. [1.7 - 1.10]

3. Stationary state solutions. Energy eigenstates. (i) Energy quantisation for bound states (infinite well). Approach to classical physics at large quantum number. [1.11, 1.12]

4. Stationary state solutions (ii). Boundary conditions, curvature of wavefunction, penetration into classically forbidden regions. Scattering from a finite potential step. [2.1, 2.2]

5. Non-stationary state solutions. Energy non-eigenstates. Probability of energy measurement. Time-dependent $\langle x \rangle$. [2.3 - 2.5]

6. $\langle p \rangle$, classical motion of $\langle x \rangle$. Hermitian operators and observables. [2.6 - 2.8]

7. Eigenfunctions and eigenvalues. Orthogonality and completeness of eigenfunctions. General probability interpretation of quantum mechanics. Momentum probability distribution. [2.9, 3.1 - 3.3]

8. Change of state following a measurement. Collapse of the wavefunction. Conservation laws; constants of the motion. Commuting operators; compatible observables; complete sets of quantum numbers. [3.4 - 3.9]

9. Non-commuting operators. The uncertainty principle. Successive measurements. [3.10, 3.11]

   The second section, of 5 lectures, will cover applications: first some slightly more advanced one-dimensional ones, and then in higher dimensions.

10. The finite depth potential well; tunnelling through finite barriers. [4.1, 4.2]

11. The one-dimensional harmonic oscillator. [4.3, 4.4]

12. The Schrödinger equation in two and three dimensions. Separation in Cartesian coordinates; the infinite well; the three-dimensional harmonic oscillator; degeneracy. [4.5, 4.6]

13. Spherically symmetric potentials. Separation in spherical polar coordinates. Orbital angular momentum in quantum mechanics using differential operators. [5.1, 5.2]

14. The angular momentum eigenfunctions. Constants of the motion. [5.3 - 5.6]

Books

The recommended text for the course is Rae "Quantum Mechanics" (Institute of Physics Publishing). An alternative which you might like to look at is McMurry "Quantum Mechanics" (Addison-Wesley); this includes a disk of programmes to run on a PC which demonstrate various aspects of quantum mechanics. A slightly more advanced text is Mandl "Quantum Mechanics" (Wiley) which is recommended for the Part A Theory Option Quantum Mechanics course. Vol. III of the Feynman Lectures on Physics is a very stimulating read, and chapters 1 and 2 are a classic physical introduction to the essence of quantum mechanics. Dirac's "Principles of Quantum Mechanics" is the only quantum mechanics textbook written by one of the founders of quantum mechanics, and well worth study once you have got a basic grip of the subject.