QM1

Quantum Mechanics: Introduction

There is, of course, a recommended book for the course, Binney and Skinner, The Physics of Quantum Mechanics, available for purchase from Clarendon Reception. (This is not just a 'nice little earner' — more importantly it cuts out the bookseller's overhead, which makes the price very reasonable!) This represents a new and distinctive approach to QM which matches badly with many earlier textbooks. I'm very supportive of what Prof. Binney is doing in this course, and I urge you to study his book. I have therefore selected from a galaxy of other titles a few that adopt a broadly similar (ket-based rather than wavefunction-based) approach. Even so this is very far from an exhaustive list. I strongly recommend that you refer to a range of books.

Robinett R, Quantum Mechanics (OUP) 2nd edition 2006 (Fairly wanvefunction-based but otherwise a modern approach)

Capri A Z, Nonrelativistic Quantum Mechanics (3rd ed.) World Scientific 2002 (Contains some really important mathematical material on the details of Hermitian operators that you don't find elsewhere)

Cohen-Tannoudji C, Diu B, and Laloë F, Quantum Mechanics (2 vols), (Wiley) 1977 (Formal French style at its best.)

Dirac P A M, The Principles of Quantum Mechanics (OUP) 4th edition 1958

Gottfried K, Quantum Mechanics Vol 1: Fundamentals (Addison-Wesley) 1966 (An older text but one that takes a slightly different approach)

Feynmann, Leighton and Sands, The Feynmann Lectures on Physics vol III (Addison-Wesley), 1965 (The most significant earlier book to take the state-based approach and not the wavefunction approach - but without using much mathematics, a benefit or drawback depending on your point of view!)

Hannabuss K, An Introduction to Quantum Theory (OUP), 1997 (The text used for the introductory course in the Maths dept)

Levin F S, An Introduction to Quantum Theory (CUP), 2002 (I presume, the text used at Cambridge?)

1) Conceptual preliminaries:

What is a probability?
What is a probability density?
What is a probability amplitude?

2) What is a classical state? Think of a planet orbiting a star — how many variables define its state of motion uniquely? How does this relate to a QM ket (how many quantum numbers)? Does this help to explain what the amplitude $\langle a|b\rangle$ is? Discuss.

The next question uses the particle in an infinite square well as an example. Try to make your discussion general, and acknowledge that space is three-dimensional, even though this example is one-dimensional.

3) A particle of mass m is confined to a 1-dimensional box of width a:

$$V(x) = \begin{cases} 0 & \text{if } 0 \le x \le a; \\ \infty & \text{if } x < 0 \text{ or } x > a. \end{cases}$$

a) Write down the time-dependent Schrödinger equation in general, both for kets and wavefunctions, and as applied to this problem. In the wavefunction case separate the variables to find two equations, one of which is the time-independent Schrödinger equation. Discuss the assumptions underlying the technique of separation of variables — can all solutions be separated in this way? If not, are there solutions which are not given by this technique?

b) Discuss the boundary conditions applicable in general, and to this problem in particular. Solve to find the eigenvalues and eigenfunctions. Normalize the eigenfunctions. Why is this important? Use them to write down a general solution to the time-dependent Schrödinger equation for the infinite square well. Obtain the equivalent result using the ket equation.

c) Using the physical interpretation of the wavefunction, find an expression for the expectation value of the x co-ordinate. Show that the expectation value of x is $a/2$ in all eigenstates. Is this obvious?

d) Discuss how this solution is changed if the potential energy at the bottom of the box is V_0 instead of zero. Can you find a general argument which tells you the effect of shifting the zero of potential energy on the solutions? In other words, if you know the eigenfunctions and eigenvalues for an arbitrary potential V, can you find the eigenfuctions and eigenvalues for a potential $V + V_0$? (Hint: has anything really changed?)

Blundell Sheet 1 questions 1.4 – 1.9