PHYS 30101 APPLICATIONS OF QUANTUM PHYSICS

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Overview

Quantum mechanics is central to many aspects of the world, from the flow of paired electrons through the giant superconducting magnets of the Large Hadron Collider, to the ultra-high-energy collisions between quarks at that machine. In between these extremes, quantum mechanics allows to us understand: how electrons behave in atoms and solids, how atoms get together to form molecules and solids, how protons and neutrons form nuclei, and how quarks and gluons stick together inside protons.

In all of these examples, we see not just randomness or "uncertainty" but also wave-like phenomena (interference patterns, tunnelling, entanglement) that mean classical ideas cannot be used be explain this randomness. Forty years after the birth of quantum mechanics, Richard Feynman infamously remarked "I think I can safely say that nobody understands quantum mechanics." Another forty years on and this is still true!

Nonetheless the theory works beautifully wherever it has been applied. Over the years, people have developed various ways of coming to terms with the weirdness of quantum mechanics. You may have heard of, for example, the Copenhagen interpretation or the many-worlds theory. None of these make any difference to the predictions of quantum mechanics, but some people find them comforting. In his essay "What's wrong with this pillow?", David Mermin has, a little unfairly, characterised the view of many physicists as "Shut up and calculate!"

Today, with entangled photons being sent hundreds of kilometers, quantum keys being used to encrypt messages and "teleportation" of quantum states, it might be better to say "Shut up and and use it!" and this is the view I'll take here.

In this course, we'll explore further some of the ideas that you met last year in PHYS 20101 Introduction to Quantum Mechanics, and also in PHYS 20302 From Atoms to Solids. The emphasis will be on their applications, to atomic physics, to nuclear physics, to nanoscale systems, and to simple examples of quantum information. Although I should warn you that, in 22 lectures, we won't have time to go very deeply into any of these applications, this course should give you basic tools you'll need if you do want to explore some of these areas further.

Recommended books

Everyone who lectures a course on quantum mechanics takes a slightly different approach to it. As a result, the shelves of the library are crammed with textbooks on the subject. You should take time to browse them and find ones you like.

My suggestions are:

- A. I. M. Rae, *Quantum mechanics*, 5th edition (Taylor and Francis, 2008)
- S. Gasiorowicz, *Quantum physics*, 3rd edition (Wiley, 2003)
- F. Mandl, *Quantum mechanics* (Wiley, 1992)
- D. A. B. Miller, *Quantum mechanics for scientists and engineers* (Cambridge, 2008)

The main recommended book for this course is the one by Rae. Although it can be rather brief on some of the applications to atomic physics, it is one of the few books that discusses quantum information at an appropriate level.

More detail on the applications to atomic and nuclear physics can be found in the book by Gasiorowicz and on its associated website. This is my favourite reference for these topics. Another good, traditional textbook on the subject is Mandl's. It takes a more formal approach which some people prefer. Finally, a new book aimed at other mathematically trained scientists as well as physicists is the one by Miller. This covers a number of interesting modern applications. Just don't expect it to be an easy read because the title says it's "for engineers"!

I shall give references to the relevant sections of the first three books using the abbreviations: **R**, **G** and **M**.

If you feel that you need to remind yourself about the basics of quantum mechanics, you should read the first four chapters of Rae's book or look back at the recommended book for last year's course: A. C. Phillips, *Introduction to quantum mechanics* (Wiley, 2003). You can find the important principles listed in Rae, Chapter 4 (where they are called, rather grandly, "the postulates") or on the summary sheet for PHYS 20101.

Examples sheets

I know you've heard this before, but the only way to become familiar with physical techniques is to *use* them. I will provide examples sheets to give you some practice on the ideas and methods from each section of the course. There will be three examples classes devoted to this course, which will give you opportunities to get help with these examples and to work on them with other students. To get the maximum benefit from these classes, it is important that you start working on the examples *before* each class. More examples can be found in the recommended textbooks.

Webpage

I have set up a webpage for the course at:
`http://theory.physics.manchester.ac.uk/~mikeb/lecture/phys30101/`

Discussion boards and other material for the course are on Blackboard 9:
`https://my.manchester.ac.uk/`

Mike Birse (September 2013)