

Aims and Objectives Quantum Physics I (PHY2002) Session 1

WAVES AND PARTICLES

Aims (What I intend to do)

- 1) To introduce the subject and the reasons why it is central to physics, science and the wider worldview.
- 2) To refresh the activity of thinking quantum mechanically.
- 3) To introduce the concept of the wavefunction as a wave way of describing a particle, both free and subject to a potential.

Objectives (What you should be able to do after completing the lecture and worksheet)

- 1) To be able to identify and describe some aspects of science and technology that depend on quantum mechanics.
- 2) To be able to describe aspects of wave/particle duality of quanta, and to be able to state and use simple mathematical relationships between wave and particle characteristics of quanta.
- 3) To be able to show how wave/particle formulae can be combined with standard wave equations of classical physics to produce particle wavefunctions.
- 4) To be able to identify the terms in the Schrödinger equation, both the free particle form and particle subject to a potential form.
- 5) To be able to show that only complex wave functions satisfy the Schrödinger equation for a free particle.

PHY 2002, Quantum Physics I: BOOKS

Recommended Text

"Quantum Mechanics" A. I. M. Rae, 530.12 RAE

The recommended text. An excellent book that also contains sufficient material for both this and Quantum Mechanics II. It covers some of the recent developments such as quantum information in a way accessible to undergraduates – **buy it!**

Additional reading

"Introduction to Quantum Mechanics" French and Taylor

A friendly but rather chatty (and lengthy) treatment.

"Quantum Mechanics" P. C. W. Davies and Betts

A bit simplistic and brief, but very readable.

"The Feynman Lectures on Physics" R. P. Feynman, Leighton and Sands (Addison-Wesley) Vol. III

Feynman takes a different approach, dealing with the Matrix formulation of Quantum Mechanics, Dirac Bra and Ket notation and spin before looking at the Schrödinger equation. As always full of insight. See also, **"QED The strange theory of light and matter"**, R. P. Feynman. (Available as a Penguin paperback) Excellent background reading, but unlikely to help you solve a specific problem.

"Quantum Mechanics" Leonard I. Schiff.

"Introduction to the quantum theory", David Park.

Two classic texts.

As ever with books, everyone has their own favourite. It's worth checking a few to find out which you prefer.

The first year core text, Young and Freedman has a lot of useful information, although some of it is at a rather low level – it is good background material.

Electronic resources can be found at
<http://newton.ex.ac.uk/teaching/resources/wlb/phy2002/>

Quantum Physics 1 PHY2002 Worksheet 1

Task 1. Go over your lecture notes. If your recollection of quantum phenomena is not excellent, or you are a combined honours student who has not studied atomic physics before, you should work through the atomic physics and wave-particle duality section of a textbook. For example Chapter 38 and the first part of Chapter 39 from Young and Freedman, or the first chapter and a half of Rae.

Task 2. Through what potential difference must electrons be accelerated so that they will have (a) the same wavelength as an X-ray of wavelength 0.15 nm and (b) the same energy as the X-ray in part (a)?

Task 3. In class we looked at the wave equation needed for a free particle wavefunction. See if you can ‘derive’ the equation we had, i.e.,

$$i\hbar \frac{\partial \Psi_f}{\partial t} = -\frac{\hbar^2}{2m} \frac{\partial^2 \Psi_f}{\partial x^2},$$

by starting with the free particle solution, $\Psi_f = A \exp[i(kx - \omega t)]$ and

using $E = \hbar\omega$, $p = \hbar k$ and $E = \frac{p^2}{2m}$. by trying different combinations of

$\frac{\partial}{\partial t}$ etc.

Task 4. See now if you can ‘derive’ the 1-D Schrödinger equation, i.e.,

$$i\hbar \frac{\partial \Psi_f}{\partial t} = \left[-\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2} + V(x) \right] \Psi_f,$$

this time using $E = \frac{p^2}{2m} + V(x)$ rather than $E = \frac{p^2}{2m}$.

Task 5. Show that the free particle wave equation cannot be solved using the real wave functions, $\Psi_f = \sin(kx - \omega t)$ or $\Psi_f = \cos(kx - \omega t)$, but is solved using the function, $\Psi_f = A \exp[i(kx - \omega t)]$. This is an important distinction between classical waves and particle waves (well, those with rest mass).

Task 6. Preparation for lecture 2. Read up about the interpretation of the wavefunction, e.g. Young and Freedman section 39.5.