

## Aims and Objectives Quantum Physics I Session 17

### THE QUANTUM HARMONIC OSCILLATOR AND ZERO-POINT ENERGY

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#### **Aims (What I intend to do)**

- 1) To examine the importance in Physics of the parabolic (harmonic) potential.
- 2) To investigate the time independent Schrödinger equation (TISE) applicable to a quantum harmonic oscillator.
- 3) To use the concepts and techniques we have developed so far to find the lowest energy wavefunction of the quantum harmonic oscillator, and the associated energy eigenvalue – the zero-point energy.

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

- 1) To be able to explain why the parabolic (harmonic) potential is so important to physics.
- 2) To be able to set up the time independent Schrödinger equation for the quantum harmonic oscillator.
- 3) To be able to describe the results of applying quantum mechanics to find the lowest energy state of the quantum harmonic oscillator.
- 4) To be able to explain the physical significance of zero-point energy.

## Quantum Physics 1 PHY2002 Worksheet 17

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- Task 1.** Go over your lecture notes and consult section 2.6 in Rae. You can find a more extended treatment in, “An introduction to quantum physics” by A.P. French and Edwin F. Taylor, Library catalogue number 530.12 FRE.
- Task 2.** Show that the ‘width’ parameter, (we called it  $a$  in class, equation 5) is equal to the maximum displacement of a classical oscillator of energy  $\frac{1}{2}\hbar\omega_0$ . [You may need to brush up on your knowledge of the classical harmonic oscillator].
- Task 3.** An experimenter seeks funds from a foundation to observe visually through a microscope the quantum behavior of a small harmonic oscillator. According to the proposal, the oscillator consists of an object of 10 microns diameter with an estimated mass of  $10^{-15}$  kg. It vibrates on the end of a thin fibre with a maximum amplitude of  $10^{-5}$  m and frequency 1000 Hz. You are referee for the proposal.
- What is the approximate quantum number for the system in the state described?
  - What would be its energy in electron volts if it were in its lowest energy state? Compare your answer with the average thermal energy (1/40 eV) of air molecules at room temperature.
  - What would be its classical amplitude of vibration if it were in its lowest energy state? Compare this amplitude with the wavelength of visible light (about 500nm) by which it is presumably to be resolved.
  - Would you, as referee of this proposal, recommend award of a grant to carry out this research?