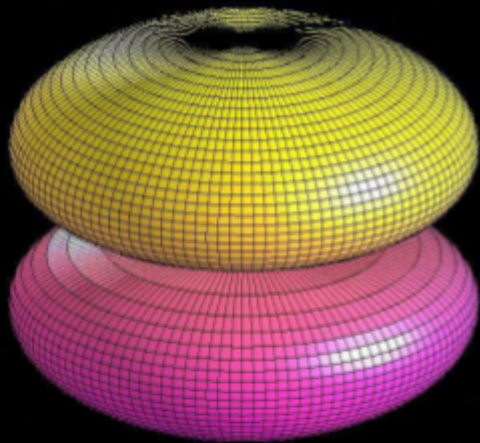


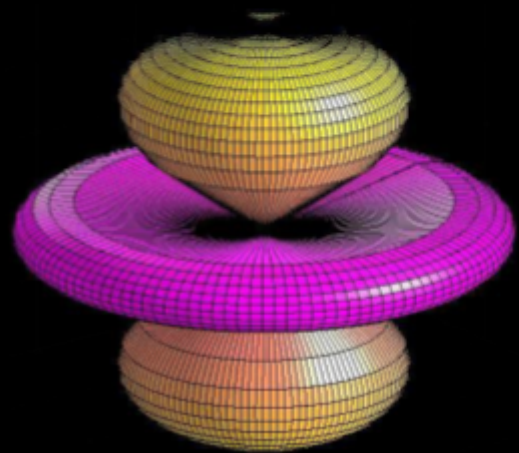


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$$H(t)|\psi(t)\rangle = i\hbar\frac{\partial}{\partial t}|\psi(t)\rangle$$

$$\Delta x \Delta p \geq \frac{\hbar}{2}$$



PHYS4025

Quantum Mechanics

Course Information Guide 2023-24

## 1 Course Details

<b>Lecturer:</b>	Prof Andy Buckley	<b>Schedule:</b>	18 lectures: Tue 10am, Thu 10am
<b>SCQF Credits:</b>	10	<b>ECTS Credits:</b>	5
<b>Assessment:</b>	Examination (100%)	<b>Co-requisites</b>	PHYS4011 PHYS4030 PHYS4031
<b>Level:</b>	Honours		
<b>Typically offered:</b>	Semester 2	<b>Prerequisites:</b>	Physics 2

## 2 Course Aims

This course is compulsory for all third year BSc (Honours) and MSci students and is an elective for the designated degree programme in the School of Physics & Astronomy. It aims to provide students with an opportunity to develop their knowledge and understanding of the key principles and basic applications of single-particle quantum mechanics, and its relevance to modern physics. In particular, it will provide a working knowledge of:

- The origins of quantum mechanics;
- Fundamental concepts of quantum theory;
- Wavefunctions, time-evolution, and the Schrödinger equation;
- Bound and scattering states;
- Quantum angular momentum.

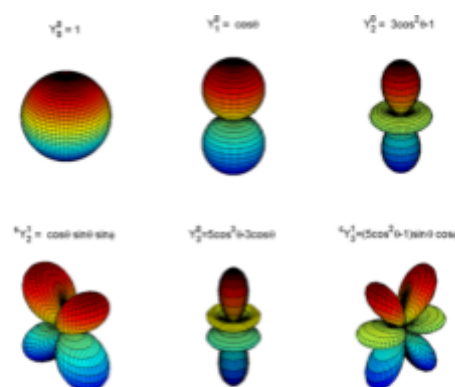


Figure 1: The first six spherical harmonic forms: the solutions to the angular part of the Schrödinger Equation in a spherically symmetric potential.  
Credit: Knowino

## 3 Intended Learning Outcomes

By the end of the course, students will be able to:

- Demonstrate knowledge and a broad understanding of quantum mechanics;
- Describe qualitatively and quantitatively process, relationships and techniques relevant to the topics included in the course outline, and apply these techniques to solve general classes of problems;
- Write down and, where appropriate, either prove or explain the underlying basis of physical laws relevant to the course topics, discussing their applications and appreciating their relation to the topics of other courses taken.

## 4 Course Outline

**Motivations:** Review the motivations of quantum theory, including the classical derivation of the Rayleigh-Jeans spectrum and its resulting Ultraviolet Catastrophe, the quantum derivation of the Black Body spectrum and its confirmation by experiment. Review experiments which exhibit the wave-like properties of particles and the particle-like properties of electromagnetic radiation, including Compton scattering and the photoelectric effect. Introduce the concepts of the de Broglie wavelength and particles as wave-packets.

**Fundamental concepts:** Motivate the need for the concept of probability in quantum mechanics. Explain complex probability amplitudes and wavefunctions, wavepackets, the Heisenberg Uncertainty Principle, eigenfunctions, and wavefunction overlaps.

**Schrödinger Equation and Wavefunctions:** Introduce the operators for position, momentum and energy (Hamiltonian), and use these to develop the Schrödinger equation. Describe the properties of the wavefunction solutions to this equation, such as continuity, linearity, and normalisation. Discuss the physical significance of probability-current density as a flux of particles. Introduce the connection between observables and operators and their expectation values. Derive commutation relations for momentum and position operators. Relate measurement values and statistics to expectation values, probability distributions and the Uncertainty Principle. Derive the Time-Independent Schrödinger Equation (TISE) and discuss its solutions in terms of eigenfunctions and stationary states.

**Applications of the Schrödinger Equation:** Solve the 1-dimensional TISE for the potential step, well, and barrier. Interpret the solutions: the Ramsauer-Townsend resonant scattering effect and the tunneling process. Solve the TISE for potential square wells of finite and infinite depth. Discuss the resulting quantised and continuous energy levels, eigenvalues and quantum numbers. Show that the TISE for the (1D) simple harmonic oscillator results in solutions which are Hermite functions. Show that boundary conditions result in quantization of energy levels. Show that ladder operators transform from one eigenfunction to another. Show examples, e.g. optical spectroscopy of quantum wells, STM microscopy, and alpha particle decay.

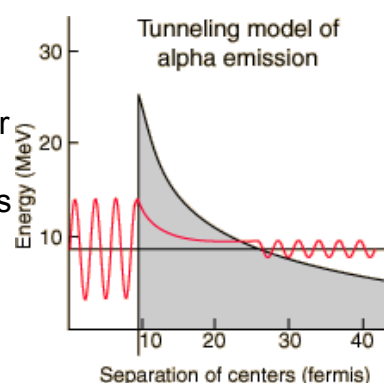


Figure 2. The Gamow tunneling model of alpha-particle emission.

**Angular Momentum:** Review “classical” angular momentum. Motivate the angular momentum operators in quantum mechanics and derive their commutation relations. Solve the angular part of the TISE for a central potential and define spherical harmonics and Legendre functions in terms of eigenfunctions of angular momentum. Provide an elementary treatment of the addition of angular momenta.

## 5 Further Information

Further information can be found on the course Moodle page and via the links below:

- [Course specification](#)
- [Reading list](#)