The University Of Sheffield.

DEPARTMENT OF PHYSICS AND ASTRONOMY

PHY251	**From Thermodynamics to Atomic and Nuclear Physics**
Spring	*25 Credits*
Staff contact	*Quantum Mechanics II (12 lectures) Dr Matthew Malek - m.malek@sheffield.ac.uk* *Thermodynamics and Statistical Mechanics (22 lectures) Prof Jamie Hobbs - jamie.hobbs@shef.ac.uk* *Solids II (10 lectures) Prof Richard Jones -r.a.l.jones@sheffield.ac.uk* *Atomic Physics (10 lectures) Dr Dmitry Krizhanovskii - d.krizhanovskii@shef.ac.uk* *Nuclear Physics (10 lectures) Dr Vitaly Kudryavtsev - v.kudryavtsev@shef.ac.uk*

Outline Description	This module provides the second half of the core level 2 physics. Subjects covered are: quantum mechanics, statistical mechanics, solids, thermodynamics, atomic and nuclear physics.
Core for Programmes	PHYU01, PHYU02, PHYU06, PHYU11, PHYU25, PHYU14, PHYU18, PHYU19, PHYU05, PHYU10, PHYU24, PHYU23, PHYU04, PHYU16, PHYU30, CHMU08
Prerequisites	PHY101, PHY102, PHY112 or similar
Co requisites	PHY250
Approx Time allocation (hours)	Lectures - 66, Tutorials - 7, Independent study - 164, problem classes - 7, exams - 6.
Assessment (%)	Examination 80% (2 x 3 hrs), seven assessed homeworks - 20%
Aims	This unit aims to provide students with an understanding of half of the core level two physics material. PHY250 provides the first half. The module covers six main topics: · Quantum mechanics – Quantum harmonic oscillator, Schrodinger equation in 2D and 3D, time dependent measurements, quantum propagation (incl. reflection & transmission at potential barriers, and quantum tunnelling), ladder operators, perturbation theory, Dirac notation & introduction to matrix formulation of quantum mechanics, quantum mechanics & reality · Statistical mechanics - Probability and statistics, macro- and microstates, equilibrium and entropy, statistical formulation of the Second Law, Boltzmann distribution and the partition function, simple applications of statistical mechanics, thermal properties of solids · Thermodynamics - Heat Capacities, Kinetic theory, Heat Engines, Second Law, Entropy, Thermodynamic Potentials, Applications of thermodynamics, Phase changes · Solids – Solids Crystal dynamics, heat capacity, phonons, Sound Waves, Thermal Conduction, Electrons in solids, free electron model, density of states, Fermi energy and temperature, Fermi-Dirac statistics, heat capacity of an electron gas, failures of the free electron model, Hall effect, metals, insulators and solids. · Atomic physics – Bohr theory, energy levels and spectra, atomic excitations, solution of the Schrodinger equation for the hydrogen atom, quantum numbers, electron probability density, radiative transitions and selection rules, Zeeman effect.

	- Nuclear physics - structure of the nucleus, nuclear mass and binding energy, the liquid-drop and shell models of the nucleus, radioactive decay, nuclear reactions, fission and fusion, radioactive dating.
Outcomes	By the end of the module the student will have acquired: · An understanding of the solutions for a quantum harmonic oscillator; the application of the time independent Schrodinger equation to simple two and three dimensional systems; the nature of solutions to the time-dependent Schrodinger equation and how time is included in the wavefunctions of systems with time independent potentials; the treatment of propagating particles to include calculation of reflection and transmission at potential steps, and tunnelling depths; the use of ‘ladder operators’ in simple quantum systems; an understanding and ability to apply 1st order time independent perturbation theory; Dirac notation and basic matrix formulation of quantum mechanics. . To understand and apply the fundamental laws of thermodynamics, especially the first and second laws and to understand and apply the concepts of entropy. To understand the properties of thermodynamic systems including heat engines. To understand the significance of thermodynamic potentials and apply these to a number of problems including phase changes. · An understanding of the fundamental concepts of statistical mechanics and the ability to apply these to a range of systems. To be able to calculate the partition function for simple systems and use this to calculate average energies and heat capacities. To understand the statistical approach to entropy. · An understanding of the fundamental properties of electrons in solids, including the concepts of density of electron states, Fermi energy, Fermi-Dirac statistics, the heat capacity of electrons, why the free electron module breaks down and the consequences, the reasons for the classification of solids as either conductors, insulators or semiconductors. · An understanding of the Bohr theory of hydrogen atom, an understanding of the operators of orbital angular momentum (OAM) in Cartesian and spherical coordinates and their eigenvalues and eigenwavefunctions, the concept of the quantum numbers associated with OAM and restrictions on their values, an understanding of the solutions of the Schroedinger equation for hydrogen atom and the distribution of electron density in different quantum states, the nature and reasons for selection rules governing optical transitions, understanding of the hydrogen atom spectra in magnetic field (Zeeman effect), concept of electron spin and understanding of the role of spin-orbit interaction on electron spectra in hydrogen atom. · An understanding of the constituents of the nucleus and nuclear forces, the basic nuclear models, properties of nuclear decay and nuclear reactions.
Recommended Books	Thermodynamics and Statistical Mechanics: Blundell and Blundell, "Concepts in Thermal Physics" 2nd edition, Oxford (2010). Schroeder “An introduction to Thermal Physics” Pearson (2014) Quantum mechanics: A.C. Phillips, “Introduction to Quantum Mechanics”, Wiley

	Nuclear physics: Young and Freedman "University Physics with Modern Physics", published by Pearson Addison-Wesley. JR Hook and HE Hall Solid State Physics (Wiley) C Kittel Introduction to Solid State Physics (Wiley)
Syllabus	Quantum Mechanics II 1. Quantum harmonic oscillator 2. Schrodinger equation in 2D and 3D 3. Time dependent measurements 4. Quantum propagation (incl. reflection & transmission at potential barriers, and tunnelling) 5. Ladder operators 6. Perturbation theory 7. Dirac notation & introduction to matrix formulation of quantum mechanics 8. Quantum mechanics and reality Thermodynamics and Statistical Mechanics 1. Kinetic theory 2. Heat engines 3. Second Law 4. Entropy 5. Equilibrium 6. Thermodynamic potentials 7. Macro- and microstates 8. Statistical formulisation of the Second law 9. Boltzmann distribution and the Partition function 10. Simply applications of statistical mechanics 11. Phase transitions. Solids II 1. Heat capacity 2. Phonons 3. Sound waves 4. Thermal Conduction 5. Electrons in solids 6. Free electron model 7. Thermal properties of solids 8. Density of states 9. Fermi energy and temperature 10. Fermi-Dirac statistics 11. Heat capacity of an electron gas 12. Failures of the free electron model 13. Hall effect Atomic Physics 1. Bohr theory 2. Energy levels and spectra 3. Atomic excitations 4. Solution of the Schrodinger equation for the hydrogen atom 5. Quantum numbers 6. Electron probability density 7. Radiative transitions and selection rules 8. Zeeman effect

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	Nuclear Physics 1. Structure of the nucleus 2. Nuclear mass and binding energy 3. The nuclear liquid drop and shell models 4. Radioactive decays 5. Nuclear reactions 6. Fission and fusion 7. Radioactive dating
Academic Notes	The combined examinations must be passed in addition to achieving an overall pass mark.