The daily routine

- Breakfast is served each day from 8am
- Lunch is served each day from 12:45pm, with the exception of Sunday when a packed lunch is provided
- Dinner is served each day at 7pm

Schedule of lectures, tutorials and seminars

	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm
Mon 30th							Arrival					CL intro
Tue 31st	SCQ			STM		CQF			T-SCQ			S-1
Wed 1st	STM			ELS		SCQ			T-STM			P-1
Thu 2nd	CQF		Break	STM	Lunch	SCQ	Free Time		T-CQF			S-2
Fri 3rd	ELS			CQF		SCQ			T-ELS		Dinner	P-2
Sat 4th	STM			SCQ		ELS	Free Time					
Sun 5th	Free Day											
Mon 6th	QIP			SCM		DFT			T-QIP+DFT			S-3
Tue 7th	SCM			QIP		DFT			T-SCM+DFT			S-4
Wed 8th	MES		Break	SCM	Lunch	TOP	Free Time		T-MES+TOP			S-5
Thu 9th	BIE			TOP		TOP			T-MIX			S-6
Fri 10th	MES			BIE		Departure						

Key to lectures and tutorials

Lecture	Tutorial	Topic
CQF	T-CQF	Correlated Quantum Fluids
ELS	T-ELS	Electrons in Solids
SCQ	T-SCQ	Strongly Correlated Systems
STM	T-STM	Statistical Mechanics
QIP	T-QIP	Quantum Information Processing
SCM	T-SCM	Soft Condensed Matter
DFT	T-DFT	Density Functional Theory
MES	T-MES	Mesoscopic Physics
TOP	T-TOP	Topological Phases of Matter
BIE		Physics of Biological Evolution
	T-MIX	Wildcard tutorial

We consider the courses in the first week to be core material, and cover material that one would expect any aspiring theoretical condensed matter physicist to be aware of, even if it is not your specialized topic. The courses in the second week are more specialized, applying the core material from the first week to different subfields of condensed matter theoretical physics. This gives you a breadth of knowledge that you often don't appreciate working on a PhD thesis, as well as illustrating that the same concepts appear again and again in seemingly completely different areas.

While lectures guide you through a subject, you don't really understand anything until you've tried to do questions on it yourself. In the tutorials, the lecturers and tutors will help you with this, as well as discussing with you any topic of physics you wish. While most of the tutorial sessions have been given a topic as a guide, please feel free to work on whichever question sheets interest you the most. Ultimately, there are far more problems than you will possibly have time to answer in two weeks!

Finally, if there is a topic you are interested in that isn't covered, then ask around – if one of the staff knows about this topic and is willing, and enough students are interested, then we can schedule extra optional lectures on rainy days!

Poster Sessions

The evening sessions marked P-1 and P-2 on the schedule are poster sessions. As there are too many posters to see in one evening, you will be randomly divided into two groups. At the beginning of the poster session, you will be asked to make a 1-minute introduction to your poster in the lecture theatre, before we go to see posters and have some drinks. There will be a prize for the best poster.

Key to Seminars

In the evenings when there are no poster sessions, we have research seminars, indicated by S-n (n=1-6) on the schedule.

S-1	Graeme Ackland	Metallic Hydrogen: The Holy Grail of High Pressure Physics
S-2	Mike Payne	The story of CASTEP
S-3	Julie Staunton	Spin-orbit coupling effects on electrons, magnetic anisotropy and crystal field effects
S-4	Raul Santos	Symmetry fractionalization in quasi-one dimensional systems
S-5	Alexandre Zagoskin	Schrödinger's elephants and quantum slide rules
S-6	Mike Gunn	TBA

Core Lecture Courses

CQF: Cold Matter and Quantum Fluids

Course and lecture notes written by Derek Lee (Imperial)
Lectures presented by members of the cast

Quantum fluids are those many-particle systems in whose behaviour the effects of both the quantum mechanics and quantum statistics are important, which occurs at cold temperatures. The most important two examples are superfluids, such as liquid Helium, and superconductors. This lecture course will begin with the phenomenon of Bose condensation in an ideal Bose gas with interactions; explore why this is not a true superfluid, and go on to look at the role of interactions. It then proceeds to explore what is different when the particles are charged, and finally look at the BCS theory of superconductivity where one begins with fermions rather than bosons.

ELS: Electrons in Solids

Martin Lueders (Daresbury)

A quantitative understanding of bonding in condensed matter systems demands a solution of the many electron problem. This course will show how the many electron problem can be mapped onto single electron problems in an approximate way (Hartree and Hartree Fock approximations) and a formally exact way (density functional theory and the Kohn Sham equations). Further, some of the methodology used to solve the Kohn Sham equations in complex systems will be described. In the last part of the lectures, some examples will be discussed, which show how electronic structure theory was able to explain some selected phenomena.

Martin is a principal scientist at Daresbury Laboratories. His main research interests are in the field of material-specific electronic structure theory of correlated systems, including normal, superconducting and magnetic states. The aim is to develop and apply methods within the density functional theory (DFT) framework and beyond, which allow to study materials of current interest from first principles.

SCQ: Strongly Correlated Quantum Systems

Chris Hooley (St Andrews)

This course deals mainly with the influence of interactions on the electrons in materials. We begin with a review of second quantisation and the Fermi gas theory of metals, and then progress to Landau's Fermi liquid theory and the notion of quasiparticles. The effect of impurities on the Fermi liquid (including the Kondo effect) is discussed, and we then move on to consider how the Fermi liquid gives way to other phases as the interactions are increased, concentrating on the Stoner instability and the Mott insulator. We analyse the magnetism in the Mott insulating phase, developing the concept of spin waves. Finally, we make a survey of some experimental data on strongly correlated crystalline solids, giving basic interpretations in terms of the concepts developed in the course.

Chris is a senior lecturer at the University of St Andrews. He works on various topics in the theory of strong correlations, including non-Fermi-liquids, highly frustrated magnets, non-equilibrium atomic fluids, and vortex-mediated phase transitions.

STM: Statistical Mechanics

Richard Blythe (University of Edinburgh)

Statistical Mechanics aims to provide a macroscopic description of a physical system starting from knowledge of its microscopic properties. The methodology and techniques are widely used throughout condensed matter physics and are also today being applied to understand the dynamics of model ecologies, economies and societies. In these lectures, we will revisit the equilibrium properties of matter - such as phase transitions and universality - from the perspective of dynamics (as opposed to statics, as is typically done in undergraduate courses). Then we will examine successively further-from-equilibrium systems, ending with a discussion of fluctuations in driven systems, a subject currently generating considerable excitement in this field.

Richard is a Reader at the University of Edinburgh. Since his PhD days, he has been researching models and theories for nonequilibrium dynamical systems. Applications of these models include transport in biological systems, traffic flow, population dynamics and language change.

Applications Lecture Courses

BIE: The physics of biological evolution

Bartlomiej Waclaw (School of Physics, University of Edinburgh)

The aim of this course is to discuss applications of statistical and quantum physics to the theory of Darwinian evolution. Lecture 1 will introduce basic concepts (selection, mutation, genetic drift) and simple models (Moran process) and explain how the methods of statistical physics can be applied to solve these models and derive important and quite general results. In lecture 2 we will discuss a more advanced model - the quasispecies model - and show how it can be solved in some special cases by mapping to a quantum spin chain model. Lecture 3 will discuss the role of spatial structure in biological populations of constant size, and in populations expanding into a previously unoccupied territory. The course will also highlight physicists' contribution to biological evolution. Lectures will combine PPT slides and blackboard derivations.

Bartlomiej (Bartek) is a statistical/biological physicist from Edinburgh, and a holder of the Royal Society of Edinburgh/Scottish Government Personal Research Fellowship. He has published research articles on random matrix theory, complex networks, random walks, and spin glasses. More recently, he has been working on applications of statistical physics to biological evolution, in particular the evolution of antibiotic resistance, and cancer progression.

DFT: A Practical guide to Density Functional Theory

Martin Lueders (Daresbury)

Density functional theory is one of the key computational techniques available today in condensed matter physics. While the theoretical background was introduced in the electrons in solids course in the first week, this short course will involve a practical session and will allow students to see for themselves how to run DFT code, and what you get out of it.

MES: Mesoscopic Physics
Edward McCann (University of Lancaster)

Mesoscopic physics is the name given to electronic behaviour in solid state nanostructures that are so small that their size is similar to relevant characteristic length scales. Examples of such length scales include the elastic mean free path (which governs the scale for ballistic transport), the phase coherence length (quantum interference effects), and the electronic wavelength (quantum confinement). The aim of this course is to describe key experimental transport phenomena including weak localisation, universal conductance fluctuations, Aharonov-Bohm oscillations, and conductance quantisation whilst giving an overview of theoretical methods such as the tight binding model, the Landauer-Büttiker formulism, scattering theory, and scaling theory.

Ed is a reader in physics at the university of Lancaster. His research lies in the area of theoretical condensed matter physics, and he is particularly interested in the electronic properties of nanostructures, graphene and other two-dimensional materials.

QIP: Quantum Information Processing
Andrew Fisher (London Centre for Nanotechnology, UCL)

Quantum Information Processing is one of the most exciting applications of modern quantum physics, and has become a flourishing interdisciplinary field in its own right. In this short course we will concentrate on some aspects of the subject most relevant to condensed matter systems. We will start by defining qubits and quantum gates, then introduce quantum operations as a model for the action of a quantum system in a noisy environment and the Kraus representation theorem which provides a composite way to represent them. Then we will move on to quantum error correction and its connection to classical codes, and briefly discuss the physics of two of the most important solid-sate qubits: impurity spins in semiconductors and superconducting circuits. Finally we will talk about two alternatives to the standard gate model of quantum computation that particularly lend themselves to solid-state systems: adiabatic quantum computation (and the related topic of quantum annealing), and the topological computation (and related topological codes).

Andrew is Professor of Physics in the London Centre for Nanotechnology and the UCL Department of Physics and Astronomy; formerly Junior Research Fellow at St John's College Oxford (1989-93), Postdoctoral Fellow at the IBM Zurich Research Laboratory (1991-92), and Lecturer in Physics at the University of Durham (1993-95). He is Director of the new EPSRC Centre for Doctoral Training in Delivering Quantum Technologies, starting in 2014.

SCM: Soft Condensed Matter

Buddhapriya Chakrabarti (Sheffield University)

This course deals with the physics of soft materials. As the name suggests these materials are soft to touch (e.g. jello, creams, pastes etc.) as opposed to hard ones (e.g. metals, alloys)which fall under the purview of "Solid State Physics". The important distinction between soft materials as opposed to their hard counterparts is that entropy and not internal energy dictates their equilibrium properties. Further these materials mostly comprise of organic molecules that interact weakly and as a result their properties are strongly influenced by thermal fluctuations, external fields, and boundary effects. This strong 'susceptibility' of soft matter leads to many fascinating properties. We will review a few generic features of soft materials, e.g. dominance of entropy, interplay between broken-symmetry and dynamic mode structure and topological defects that are common to such systems. The outline is as follows i) Introduction to soft condensed matter physics, (ii) Liquid Crystals and Polymers (iii) Fluid Membranes, (iv) Fluctuations and response of non-equilibrium soft systems.

Buddhapriya (Buddho) is a senior lecturer in the biological physics group at the University of Sheffield. His main research interests include soft condensed matter physics and biological physics.

TOP: Topological phases

Sam Carr (University of Kent)

The well-known Landau theory of phase transitions classifies phases of matter according to broken symmetries and local order parameters, such as solids that break translational symmetry, or magnets that break magnetic rotation symmetry. It has been long known that there are phases of matter that defy this classification — the quantum Hall state being the most obvious (but by no means only) example. With the discovery of topological insulators about 10 years ago, interest in this field has exploded, and we now know of many distinct phases of matter with no local order parameter, but instead characterised by a topological invariant. This short lecture course will focus mostly on non-interacting band theory, and introduce topological invariants, boundary states, and the bulk-boundary correspondence necessary to understand the modern topic of topological insulators. Other manifestations of topology in modern condensed matter physics will also be exposed, although not discussed in detail.

Sam works on the theory of strongly correlated systems, specialising in low-dimensional systems both in and out of equilibrium. He has worked in groups in the US, Italy and Germany, and since 2013 has been a lecturer at the University of Kent in Canterbury.

Seminars

Metallic Hydrogen: The Holy Grail of High Pressure Physics

Graeme Ackland (University of Edinburgh)

At sufficiently high pressure, the electrons in the hydrogen molecules are squeezed out of their covalent bonds to become metallic. The basic properties of metallic hydrogen were already well described by the early theories of quantum mechanics in the 1930. Since then various predictions suggest it might be a room temperature superconductor, and superfluid, and supersolid or a supersonic rocket propellant. None of these has been detected experimentally, yet. In this after-dinner talk, I will cover the theoretical and experimental physics underlying the search. I will also give some insights into how research physics actually works, a discussion which may continue less formally in the bar later.

Graeme is Professor of Computer Simulation in Physics at the University of Edinburgh. He is also one of the organisers of this years physics by the lake school.

The story of CASTEP

Mike Payne (Cambridge)

In this talk I shall talk about the rise of plane wave total energy pseudopotential calculations based on density functional and the role of CASTEP in establishing this methodology. I shall also describe the commercialisation of CASTEP and discuss some of the advantages and disadvantages of combining academic research with making money.

Mike is Professor of Computational Physics at the University of Cambridge, and a Fellow of the Royal Society. His research group focuses the development of new tools and technologies which are designed to be accessible to all researchers.

Spin-orbit coupling effects on electrons, magnetic anisotropy and crystal field effect

Julie Staunton (University of Warwick)

Magnetic materials are typically characterised by a set of the saturation magnetisation M, exchange A and anisotropy K constants combined into two important length quantities, an `exchange length' and a `domain wall thickness'. This talk will outline the relativistic generalisation of density functional theory and its electronic structure basis and show how it enables M, A and K to be calculated. The spin-orbit coupling influence on the electronic structure of materials will be described and its role in the origin of magnetic anisotropy, K, will be discussed in particular. The effects upon the exchange interactions within small clusters of magnetic atoms deposited on substrates or between magnetic impurities will also be described. In magnetic materials with 4f rare earth elements the strongly correlated f-electrons form a non-spherically symmetric charge and magnetisation density which interacts with the surrounding charge distribution. In the talk it will be discussed how this crystal field effect and strong spin-orbit coupling lead to significant magnetic anisotropy in rare earth - transition metal magnets.

Julie is professor of physics at the University of Warwick. Her research involves electronic structure theory to describe phenomena in materials from 'first-principles' using high performance computing techniques. Projects in theoretical magnetism, metal and alloy physics and ab-initio studies of properties of strongly correlated electron materials.

Symmetry fractionalization in quasi-one dimensional systems.

Raul Santos (Cambridge)

Symmetry plays a fundamental role in the classification of different phases on matter. In one and quasi-one dimensional systems, a complete understanding of different gapped phases is possible based on the presence of symmetry. It has been realized that among these symmetry protected states, new forms of quantum matter appear, with possible applications to quantum computing. I will review some classical examples and unveil the existence of new states in one and quasi-one dimensions.

Raul is a postdoc in Cambridge, and a tutor at this years physics by the lake school.

Schrödinger's elephants and quantum slide rules

Alexandre Zagoskin (University of Loughborough)

Alex is head of the physics department at the Univeristy of Loughborough, and works in quantum engineering, quantum metamaterials, and quantum computing.

Title TBA

Mike Gunn (University of Birmingham)

Mike is professor of theoretical physics at the University of Birmingham. His research is in the field of many body quantum physics, where he tries to determine the patterns they form at low temperatures (where quantum mechanics dominates), which might be patterns in space (a simple example would be a crystal lattice) but usually have a pattern in a more exotic sense - in their velocities or correlations between pairs of the particles. Currently the rapid experimental developments in ultracold quantum gases are providing him (along with many other people!) several interesting theoretical problems.

Tutors

Raul Santos (Cambridge)

Raul is a postdoctoral assistant at the university of Cambridge, having previously worked at the Weizmann institute in Israel, and Stony Brook university in the US. His research is in strongly correlated systems, using topics such as field theory and Bethe ansatz. Recently, he has worked a lot on topological phases of matter in strongly correlated systems.

Miriam Marques (Edinburgh)

Miriam is a research fellow in the physics department at the university of Edinburgh. Her research areas include computational materials physics and materials under extreme conditions.

Physics by the Lake

Physics by the Lake is a national summer school for PhD students in condensed matter theory in the UK. This year will be the 20th occurrence of the school. Many of the lecturers were themselves students at the school in the past – ask them about it!

The name `Physics by the Lake' comes from the original location of the school, in Ambleside beside Lake Windermere, in which it ran for more than 10 years (aside from one year in Wales – but that is another story entirely!) The location where we held the school however was mothballed in 2010, and the school had to move. After a few itinerant years, the school settled in its current location in Cumberland Lodge, which is close to Virgina water -- it was quite a challenge to find a location that filled all the usual academic requirements as well as being near a lake!

Until this year, the school has been funded by EPSRC. However, EPSRC have now withdrawn direct support for the school as their training money is routed through universities and CDTs. We do have support from a number of sponsors however – CCPmag, CM-CDT, CCP5, CCP9, psi-k and UKCP – who we would like to thank. Finally, we need to thank the Higgs center for theoretical physics for underwriting the school, and in particular Lyndsey Ballantyne for a huge amount of administrative support.

Graeme Ackland
Sam Carr