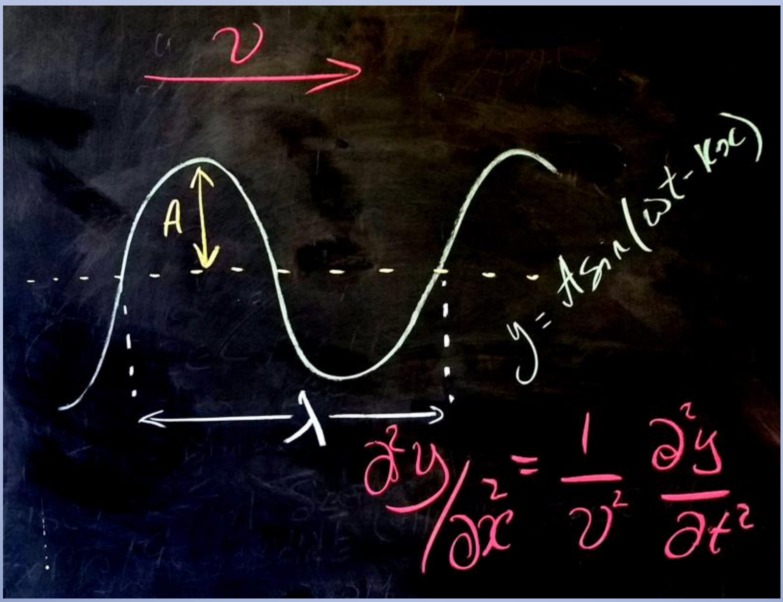
Physics 2

Course Information Guide 2023-24

University of Glasgow | School of Physics & Astronomy



Classical & Quantum Waves, Semester 2

1. Welcome from Head of School

As the Head of School of Physics and Astronomy, I would like to welcome you to your new class. The School prides itself in providing an excellent and supportive learning and teaching environment that is fully integrated with our research; you will have the opportunity to interact with world-leading researchers working at the cutting edge of a wide range of fields of physics and astronomy, who are tackling some of the biggest contemporary challenges in science and technology.

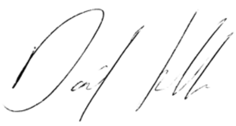
Having said that, this year may still be subject to some effects of the ongoing pandemic. Our staff have all been in learning mode during the past year, developing new ways of delivering high quality teaching. We hope to be able to take some of the new ways of learning and teaching and combine this with the best of our traditional approaches in the coming year. I ask that you not only bear with us as we continue to develop, but engage with us through any of the available communication channels in letting us know what works and what does not.

One thing that will not change is the School's firm commitment to supporting equally the careers and development of all its students and staff, as exemplified by our receipt of an Athena Swan Silver award. We value the diversity of our student body and recognise that this diversity improves the quality of our work by bringing a wide range of skills and viewpoints. We therefore expect that all staff and students will work productively and professionally together in an atmosphere of mutual respect.

To support this, all our staff and graduate students undertake equality and diversity training, our lab guides include a code of conduct for students, supplementing the University code[i], and we support the University's Dignity at Work and Study policy[ii]. You can be assured that any instances of bullying, harassment, or offensive language or behaviour will be both taken seriously by the School and treated with sensitivity. Points of support for students are your adviser of studies, your Class Head and Lab Head, and in addition the School has two appointed Equality and Diversity offices, to whom students may speak in confidence.

I wish you success with your current and future studies

Best wishes



Professor David Ireland
Head of School

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[i] https://www.gla.ac.uk/myglasgow/senateoffice/studentcodes/studentconductstaff/
[ii] https://www.gla.ac.uk/myglasgow/humanresources/equalitydiversity/dignityworkstudyover/

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2. General Information

Course title	Physics 2 [Physics 2 (Half)]
Course Credits	60 credits [30 credits]
Semesters taught	Semesters 1 and 2 [Semester 1, or 2 by special arrangement]
Essential Prerequisites	Prerequisites are: Physics 1 at D3 or above Mathematics 1 at D3 or above Exceptionally, entry is at the discretion of the Head of School, with advice from the Physics 2 Class Head.
Corequisites	Co-requisites for progression in a Physics degree: Mathematics 2A, 2B, and 2D(*) Additional co-requisite for students on Theoretical Physics degree programmes: Physics 2T (Programming under Linux) (*) Maths 2D is waived for students on the degree programmes Chemical Physics and Physics & Computing Sci.
Lectures:	Lectures are daily at 12 noon.
Laboratories:	Laboratories (practical sessions of the Skills module) run 2-5pm on every afternoon except Tuesday. Students attend one a week.
Supervisions:	You will participate in approximately 8 small-group supervisions, scheduled with your supervisor. (Note this is a compulsory component of this course.)
Class tests	There are four Class Tests during the year: CT1 in October, CT2 in November, CT3 in February and CT4 in March. In addition, there are 9 homework exercises throughout the year.
Class Exams	There are two 2-hour exam papers in April/May.
Class Head Lab Head Deputy Class Head Deputy Lab Head Technician Senior Adviser in P&A	Dr E. Yao (eric.yao@glasgow.ac.uk) Dr J. Taylor (jonathan.taylor@glasgow.ac.uk) Dr I. MacLacren (Ian.MacLaren@glasgow.ac.uk) Prof. S. Franke-Arnold (sonja.franke-arnold@glasgow.ac.uk) Mr L. Combs (Leo.combs@glasgow.ac.uk) Dr D. MacLaren (phas-senioradviser@glasgow.ac.uk) ***Please use: phas-classhead-P2@glasgow.ac.uk***
Prizes	A small number of prizes will be awarded to those students with the best record of work over the year.
Moodle site	https:// moodle.gla.ac.uk/course/view.php?id=40799

3. Course Description

Physics 2 is intended for students who want to take Honours Physics in third and fourth year, and also for others who do not wish to continue with Physics beyond second year. The course will increase your understanding of physics, extend your education, train you in particular techniques, and inform you of modern developments in physics. The skills you learn in physics can also be transferred to a wide variety of careers in other Physical Sciences, in Engineering, in the Biological Sciences and in many sectors of industry.

3.1 Intended Learning Outcomes

On completion of this course you should:

- have an improved and deeper understanding of the basic laws of physics, and know when and how to apply them in a wider range of contexts;
- know the experimental basis of these laws, and appreciate how they fit together;
- be able to solve problems by applying these laws;
- be able to apply mathematical concepts, particularly to describe continuous change with time and position and continuous distributions of charge and matter;
- know the definitions of many technical terms used in physics;
- be familiar with experimental equipment;
- know how to make measurements and assess their accuracy;
- be able to keep laboratory records, to write reports and to use the Library and online repositories to research a subject of your choice.

3.2 Content delivery and how to succeed

The course comprises the following activities:

- 85 lectures: 8 lecture courses of 10 lectures each plus 1 lecture course of 5 lectures with 4 learning hours per lecture; (*340 hours*)
- 4 full class tutorials with 2 learning hours per tutorial; (*8 hours*)
- 6 peer-to-peer tutorials with 2 learning hours per tutorial; (*12 hours*)
- 8 small group supervisions with 4 learning hours per supervision; (*32 hours*)
- Laboratory/skills course; (*135 hours*)
- TOTAL learning hours: 527

The laboratory/skills course contains a blend of experimental work, IT, and practice in transferable skills, and is continuously assessed. A separate lab guide will be provided (the Skills Handbook).

Lecture Courses

We hope to increase your interest in physics and reinforce your belief that physics underlies almost all other scientific activities. You will learn more about the fundamental laws of nature in this course, and more about how the universe works. The lecture courses will consolidate and extend the work you did in first year, and introduce you to new concepts that you will need in the future. Note that with each hour of lecture you are expected to spend a further three hours studying the material: consolidating your notes, reading textbooks, studying preparatory material where provided, and most importantly trying problems and examples (see below). If you don't understand something from your lecture notes then try looking in the recommended text, asking someone else in the class, or asking your supervisor or lecturer.

Supervision

The class will be divided into small groups and a member of staff will supervise the work of each group. Your supervisor will meet you regularly to help you with your work. The primary purpose of supervision sessions is to help you to overcome the difficulties you have with the course, not the difficulties we think you have. We cannot do this unless you tell us about the things that you personally find difficult. Make a habit of noting problems as they arise, and take them to your next supervision. You will be expected to have attempted the problem sheets before each meeting. Supervision arrangements will be posted on the Moodle site.

Peer to Peer Tutorials

During the course there is a series of Peer-to-Peer tutorials. In these sessions, students in the honours years of their degrees (levels 3/4/5) act as tutors. They will be there to provide guidance and advice on questions set during the tutorials. The questions you attempt during these Peer-to-Peer tutorials will not contribute to your overall grade for the course, but they are an excellent opportunity to improve your physics skills and understanding with the assistance of your undergraduate peers. Your tutors were in your shoes not so long ago - they understand all too well what it's like to be a second-year physics student. These sessions will give you the chance to make use of their experience, both relating to the physics you are learning and the wider world of being a student in this School.

Problems and Examples

We cannot over-emphasise the importance of doing problems to improve your familiarity with physics. All the lecturers will give you a set of examples on their course. Lecturers and supervisors will set problems for you to try and some of these will be discussed in class or in supervision sessions. Before the end of each semester, we will make available to you solutions to all examples in the sheets. You might want to try forming a study group and solving problems together. It’s not cheating! Your goal is to understand the content of the course. Learning from someone who already understands something is normally much faster than learning on your own, while having to explain something to someone else is a great way to test your understanding. Closer to the exams you should be trying past papers as well.

3.3 Assessment

The overall grade for the course is calculated from the following elements of assessment:

- Class tests (4 in total, each contributing 6.25%): 25%
- Skills Course (laboratories): 25%
- Degree Exams (two papers, 25% each): 50%

The class tests will last ~50 minutes. It will be scheduled during a lecture hour and will each comprise of questions from courses immediately preceding the tests.

The degree examinations for Physics 2 will be in April/May, with a resit opportunity in August. There will be 2 papers, each lasting 2 hours. There are four questions in each paper and all questions are compulsory. In 2020–21 these will be:

PAPER 1:

1. 15 marks from Oscillating Systems.
2. 15 marks from Thermal Physics.
3. 15 marks from Newtonian Dynamics.
4. 15 marks from Electricity & Magnetism.

PAPER 2:

1. 15 marks from Physics of Solids.
2. 15 marks from Nuclear & Particle Physics.
3. 15 marks from Classical & Quantum Waves.
4. 15 marks from Optics.

Students should note that an opportunity to re-take assessed work ('re-assessment') will be provided only for the degree examination papers for Physics 2; see Section 3.6. For all other assessment components of Physics-2 there will be no re-assessment opportunity available, owing to the impracticality of such provision. This policy has been adopted with the approval of the Head of School and following the recommendation of the Physics and Astronomy Learning and Teaching Committee.

Calculators in examinations

Students are expected to bring a **simple** scientific calculator (with only the facility for numerical display) to use in examinations. Students should note that calculators or devices with the facility to display information graphically, or having the capacity to manipulate formulae symbolically, are banned from use during examinations and must not be taken into the examination hall. Thus, graphical calculators, or the calculator function on a mobile telephone or device such as iPad or tablet, may not be used in an examination.

Physics 2 (Half) assessment

Students enrolled in the 30-credit Physics 2 (Half) course should attempt EITHER Paper 1 (if they attended in semester 1) OR Paper 2 (if they attended in semester 2). Both exams are held in April/May, with a resit opportunity in August. Continuous assessment for such students will be calculated pro rata from work submitted during the semester in which they were in attendance.

Homework exercises

There are 9 online homework exercises. These are self-paced formative assessment with timetabled deadlines. They will be marked and provides vital continuous feedback about your progress.

3.4 Feedback

You will receive feedback on your work in many ways throughout the year. Your marked class test scripts will be returned to you, along with specimen solutions and a commentary from the marker on what was generally done well or badly and grade distributions, in line with the School's Exam Feedback policy. You will also have the opportunity to discuss your class tests with your supervisor at supervisions. Your lab books will be marked with individual comments and returned to you in time for your next lab, and you will have the opportunity to discuss this with lab demonstrators. You will receive marks and individual comments on other elements of the lab course, such as the literature report, long write-up, and individual talk. Marks and feedback on submitted work will normally be returned within three working weeks, in line with the university's guidance, and of course sooner where possible. The School's full Exam Feedback Policy is available on the Physics 2 moodle site.

3.5 Course materials

Lecturers will normally post notes and other materials on moodle to assist you with your studies. Please note that lecture recordings and ALL course materials provided are for your own personal use and can only be used in relation to your studies. Any unauthorised distribution of course materials, including uploading them onto unauthorised web sites and social media sites, such as YouTube or Course Hero, will be considered in breach of the code of conduct and will be subject to disciplinary action.

The course textbook is University Physics by Young and Freedman – 13th edition (Pearson). If you took Physics 1 last year, your Mastering Physics login will remain valid for one more year. You will be able to access the electronic copy of the textbook and, depending on the specific lecture course, some self-directed Mastering Physics exercises.

The following books are recommended for further reading with some being re-used in Physics 3 or Physics 4.

They are also linked from the following library reading list: https://tinyurl.com/y6258q7q, which gives access to those that are available as e-texts.

Essential Text	University Physics, Young and Freedman (13th Edition, Pearson)
Further Reading	The Feynman Lectures on Physics, R. P. Feynman

Recommended further reading for each course

Lecture Course	***Further usage***	***Suggested reading***
Classical & Quantum Waves	Physics 3 (core)	The Physics of Vibration and Waves, H.J. Pain (ISBN 0-471-98543-0)
Electricity and Magnetism	Physics 3 (core)	Introduction to Electrodynamics, David J. Griffiths (ISBN 129202142X)
Mathematical Techniques	No	Measurements and their Uncertainties, I. Hughes and T. Hase (ISBN 0-199-566-33X)
Optics	Physics 3 (elective)	Optics, E. Hecht (ISBN 1292021578)
Oscillating Systems	No	Vibrations and Waves, A.P. French
Physics of Solids	Physics 4 (core)	Introductory Solid State Physics, H.P. Myers (ISBN 0-7484-0660-3) Introduction to Solid State Physics, C. Kittel
Newtonian Dynamics	No	Physics, Volume 1, K.S. Krane R. Resnick, D. Halliday (ISBN 0471559172)
Nuclear & Particle Physics	No	Relativity: A Very Short Introduction, Russell Stannard (ISBN 978-0-19-923622-0)
	No	Special Relativity, N.M.J. Woodhouse (ISBN 1-85233-426-6)
	Physics 4 (elective)	Introduction to Elementary Particle Physics, Alessandro Bettini (ISBN 978-0-521-88023)
	Physics 4 (core, elective)	Introductory Nuclear Physics, S. Krane (ISBN 0471859141)
Thermal Physics	Physics 3 (core)	Thermal Physics, C.B.P. Finn

3.6 Minimum requirements for credit

There are several requirements for the award of grade letter G or better, all of which must be met:

- Attendance at 50% or more of the skills sessions and submission of the associated work for marking.
- Attendance at 50% or more of the small-group supervision sessions.
- Submission of 50% or more of the homework exercises.
- Attendance at class tests.
- Attendance at the Degree examinations.
- The attainment of an overall mark of at least 15% for the course.

Note that candidates who do not meet these minimum requirements (except in the case of illness or other good cause) by the end of the April/May diet of examinations will normally be awarded the grade CW ("Credit Withheld") for Physics 2.

If these requirements are not met by the end of the academic year (August), this grade will normally be updated to CR ("Credit Refused"). The award of CR means that credits associated with the course are not counted towards the minimum graduating curriculum, nor used in calculating the grade point average. This is a serious impediment to progress towards any degree from the University.

A resit examination will be available in August for candidates scoring E1 or below (but not CR) in the first diet of examinations. For progression, the grade obtained at resit is capped at D3. Candidates with extenuating circumstances awarded MV ("medically validated") after the April/May diet do not have any cap applied on the August results. Candidates' marks for other assessment components (class test and laboratory course assignments) will be carried forward to the August Board of Examiners.

Information about how to inform the School of extenuating circumstances is given in section 6 of this Course Guide, "Attendance, Adverse Circumstances, and 'Good Cause' claims".

3.7 Disabilities and special needs

If you have a disability or special needs that may affect your studies, course work, or examinations, then please inform one of the University's Disability Advisers: details can be found on the web at:

http://www.gla.ac.uk/services/disability/

Please also ensure that the Class Head is aware in plenty of time, so that your needs can be accommodated.

3.8 Progression: the next steps

There are three options: BSc designated (3-year degree), BSc Honours (4-year degree), MSci (5-year degree).

- There are two sets of entrance regulations to which you must adhere: School (i.e.: Physics & Astronomy) and College (i.e.: Science and Engineering).
- The School regulations can be found in the "P345HM Course Guide" which is in the "Course Guides" section of Moodle. (https://moodle.gla.ac.uk/course/view.php?id=4326)
- The College regulations can be found here, specifically sections 15.1 and 15.2 of the Generic Undergraduate Regulations on page 6, a copy of which are given below.

The College regulations for entrance to Honours are overall higher than the School regulations for entry to Physics 3. To get into Physics 3 you will need **D3 or above in Physics 2, and D3 averaged over Maths 2A, Maths 2B and Maths 2D** (plus D3 in Astronomy if you wish to carry on with Astronomy). This will get you into the designated degree program. The College regulations (15.1c) basically specify that you need to get a **C3 or above in Physics 2 to get into Honours**. If you only get into the designated program, there is the possibility for transfer to Honours at the end of third year so long as you obtain C3 or above in third year courses – please read the School's course guide.

Whatever your intended progression following Physics 2, you are encouraged to speak to your Adviser of Studies about your plans for the next academic year.

Excerpt from pages 6 and 7, Generic Undergraduate Regulations:

15. Entry to an Honours or Integrated Masters Degree Programme[4]

15.1 In order to obtain entry to an Honours or Integrated Masters degree programme at the end of the second year of full-time study[5], a candidate must:

a) achieve 240 credits at levels 1 and 2 with a grade point average[2] of at least 9; at least 140 of these credits must be derived from the list of recognised courses for the degree; and

b) achieve a grade D or better in 200 credits; and

c) achieve a minimum of 40 credits at level 2 at a grade point average of 12 in the subject of the Honours programme[6] at the first attempt: and

d) meet any further requirements set out in the degree's supplementary regulations; and

e) meet any additional requirements set by the School or Schools in which the candidate is applying for entry to the Honours or Integrated Masters programme.

15.2 In order to obtain entry to an Integrated Masters degree programme, a candidate must normally, in addition to meeting the requirements in §15.1 above:

[4] Where a programme has specific requirements in relation to the average aggregation score derived from Schedule B (§16.29 and §16.34(b) of the Code of Assessment), these shall be stated in the programme documentation.

[5] This regulation only applies to degree programmes which select for entry to Honours at the end of second year.

[6] For entry to a Joint Honours degree, this requirement applies to each Joint Honours Subject.

a) meet the requirements set out in the degree's supplementary regulations; and

b) meet any additional requirements set by the School or Schools in which the candidate is applying for entry to the Honours or Integrated Masters programme.

4. Course Component Details

The intended learning outcomes for individual lecture courses are given below.

4.1 Mathematical Techniques

Aims

- To explain how the variations observed in the measurement of a physical quantity can be represented by a frequency distribution, e.g. Poisson and Gaussian.
- To be able to determine the mean, standard deviation and standard error from a data set, including combining errors.
- To understand and apply straight line fitting using the least squares technique.
- To study basic techniques in differential and integral calculus.

Objectives

- Construct a frequency distribution from measurements of a physical quantity.
- Define the mean and standard deviation for a distribution.
- State the standard error in the mean and know how it relates to the standard deviation.
- Explain the difference between random and systematic errors.
- List important properties of the Poisson and Gaussian distributions.
- Explain the application of Gaussian distributions in the treatment of random errors.
- Explain the significance of the Poisson distribution for randomly occurring events such as radioactive decay.
- Combine errors in functions of several variables.
- Describe the principle of least squares fitting (simple and weighted), apply to fitting a straight line to determine the gradient and intercept.
- Calculate derivatives and apply them to physics problems.
- Be able to apply all of these concepts to unseen problems.

4.2 Oscillating Systems

Aims

- To introduce the ideas of periodic and simple harmonic motion.
- To study free and forced vibrations of mechanical systems.

Objectives

- Describe oscillating systems using complex exponentials.
- Write down the differential equation of simple harmonic motion.
- Verify that the solution of this equation is a harmonic function with a phase and amplitude depending on the initial conditions.
- Write the solution in complex notation.
- Show the relations of position, velocity and acceleration using an Argand diagram.
- Write an account of energy relations in the harmonic oscillator.
- Derive the quadratic form for the potential energy given a linear force relation.
- Write down the form of the potential energy for a pair of atoms as a function of their separation for ionic and Van der Waals bonding.
- Explain which terms have a physical justification and which are used to make a simple approximation.
- Explain the conditions under which the interatomic potential can be taken to be quadratic.
- Obtain the characteristic frequency of small oscillations of a diatomic molecule.
- Write an account of the infra-red spectroscopy of molecules and solids.
- Summarize the steps to solve second order homogeneous differential equations with boundary conditions.
- Solve the equation of motion for a damped simple harmonic oscillator and categorize damping as weak, strong and critical.

- Use the solution of the equation of motion to describe and graph the behaviour of a system given particular initial conditions.
- Define quality factor, and obtain an expression for it in terms of the parameters of the system.
- Explain the behaviour of oscillatory systems subject to a periodic driving force.
- Solve the steady state equation of motion of undamped and damped simple harmonic oscillators driven by a periodic driving force.
- Discuss the importance of transients.
- Obtain expressions for, and draw graphs of, the amplitude and phase of a forced oscillator for varying amounts of damping.
- Give an account of the effects of varying the amount of damping.
- Explain the relation between the shape of the amplitude resonance curve and the quality factor.
- Be able to apply all of these concepts to unseen problems.

4.3 Thermal Physics

Aims

- To revise the basic concepts of heat, temperature, work and energy in thermal systems.
- To relate microscopic and macroscopic descriptions of thermal systems and to demonstrate the statistical nature of the macroscopic approach.
- To investigate properties of the ideal gas.
- To investigate the laws of classical thermodynamics.

Objectives

- Express the meanings of "heat", "temperature", "work" and "internal energy".
- Understand the concept of "temperature" in terms of several different scales and measurement techniques.
- Select appropriate conjugate variables to describe a given thermal system.
- State the First Law of Thermodynamics.
- Derive expressions for the work done in thermodynamic processes.
- Explain what is meant by an "equation of state" and give suitable examples.
- Distinguish between microscopic and macroscopic variables.
- Express the meaning of thermodynamic degrees of freedom.
- State the "equipartition of energy" theorem.
- Derive molar specific heat capacities for an ideal gas: C_p and C_V. Show that $C_p – C_V = R$.
- Demonstrate that pV^γ is a constant in an adiabatic expansion of an ideal gas.
- State Dalton's Law of Partial Pressures and apply it in appropriate situations.
- Relate the temperature of a thermal system to the microscopic description of the system.
- Explain why molecules of an ideal gas have a distribution of energies and velocities.
- Describe the general form of the energy distribution of molecules.
- Discuss the distribution of the velocities of an ideal gas, and the temperature dependence of this distribution.
- Distinguish between reversible and irreversible processes.
- Understand the concept of entropy and its relationship to disorder.
- Discuss changes of entropy for reversible and irreversible processes.
- State the Second Law of Thermodynamics.
- Understand the concept and be able to explain the operation of heat engines, refrigerators and heat pumps.
- Describe the Carnot cycle and obtain an expression for its efficiency.
- State Carnot's Theorem.
- Describe a Carnot engine and show that no heat engine can be more efficient than a Carnot engine.
- Be able to apply all of these concepts to unseen problems.

4.4 Newtonian Dynamics

Aims

- To solve the Newton equation for constant acceleration.
- To describe multi-dimensional motion of rigid bodies, including rotation.
- To introduce the effects of damping into the Newton equation.

Objectives

- Understand the importance of dimensions and units.
- Perform sanity checks on answers to physics problems.
- Use ideas of dimensional analysis to understand dynamical systems.
- Know that the laws of physics should not depend on choice of coordinate system or orientation.
- Write down Newton's Laws of Motion.
- Solve equations of motion for constant linear acceleration.
- Calculate the position of the centre of mass of rigid bodies of simple laminar shapes.
- Derive the equation of motion for the centre of mass of a rigid body under the action of an external force.
- Relate linear velocity and acceleration to angular velocity and acceleration for circular motion.
- Solve equations of motion for constant angular acceleration.
- Derive the kinetic energy of a rigid body rotating about a fixed axis.
- Calculate the moment of inertia of bodies of simple laminar shapes.
- State and use the perpendicular and parallel axes theorems.
- Calculate torques from given forces around given axes of rotation.
- Relate the angular acceleration and torque about an axis.
- Solve equations of motion for a rigid body rotating about a moving axis using conservation of energy.
- Calculate the work done by a torque and the power generated.
- Define angular momentum and show how its component about an axis is related to the angular velocity about that axis.
- Show the relationship between torque and angular momentum.
- Derive the condition under which angular momentum is conserved.
- Use the concept to solve for problems in which angular velocity changes (e.g. the twirling skater).
- Connect change of momentum with impulse and solve for the motion of bodies acted on by an impulse.
- Know what is meant by the terms time-dependent force, position-dependent force, and velocity-dependent force.
- Write down Kepler's Laws of planetary motion.
- Prove Kepler's 2nd Law for any central force.
- Solve equations of motion for simple time-dependent forces.
- Solve equations of motion for simple velocity-dependent forces.
- Be able to apply all of these concepts to unseen problems.

4.5 Electricity & Magnetism

Aims

- To introduce the concepts of capacitance, inductance, impedance, reactance.
- To investigate electric and magnetic fields.

Objectives

- Write an account of Faraday's experiments on electromagnetic induction.
- Define magnetic flux.
- State Faraday's law of electromagnetic induction and Lenz's law.
- Find the current induced by a varying magnetic field in a circuit of given dimensions and resistance.
- Calculate the emf induced in a straight wire moving in a magnetic field.

- Calculate the emf induced in a plane coil rotating in a magnetic field.
- Define self-inductance *L* and explain its relation to the current flowing in a circuit and the resulting magnetic flux linking the circuit.
- Derive an expression for the emf induced when the current varies.
- Relate *L* to the number of turns in a uniformly wound coil of wire, the relative permeability of the surrounding material and the self inductance of one turn.
- Calculate the self-inductance of a solenoid.
- Derive an expression for the growth of current in a series LR circuit when connected to a battery and the decay when shorted.
- Define and derive an expression for the time constant of an RL circuit.
- Define electric flux through a surface.
- Write down and prove Gauss's law of electrostatics.
- Use Gauss's law to derive the electric field surrounding and within spherically symmetric or cylindrically symmetric charge distributions.
- Use Gauss's law to calculate the electric field due to a plane sheet of charge.
- Show that, on passing through a sheet of charge, the component of electric field parallel to a sheet is unchanged, while the component normal to the sheet has a discontinuity.
- Define electric potential.
- Explain what is meant by an equipotential surface.
- Define capacitance.
- Derive expressions for the capacitance of a parallel plate capacitor.
- Define relative permittivity in terms of capacitance.
- Show that the voltage and electric field in a capacitor are reduced if a dielectric is introduced between the plates.
- Analyse an RC circuit.
- Write down and derive expressions for the complex impedance of a resistor, inductor and capacitor.
- Explain how a complex impedance contains information on amplitude and phase change.
- Combine impedances in series and in parallel.
- Be able to apply all of these concepts to unseen problems.

4.6 Physics of Solids

Aims

- To show how interatomic forces determine the structure of simple crystalline materials.
- To demonstrate the utility of diffraction experiments in probing the properties of materials.
- To explain basic electrical and magnetic properties of metals and semiconductors.

Objectives

- Describe the general characteristics of the force between atoms, and why there is in condensed matter an equilibrium spacing and a binding energy.
- Describe the main features of ionic, covalent, metallic, hydrogen, and Van der Waals bonding.
- Explain how different types of atomic bonding give rise to particular crystal structures.
- Describe the following crystal structures: close packed (fcc and hcp), bcc, diamond.
- Explain the concept of a crystal structure being composed of a lattice plus a basis of atoms.
- Define the unit cell and draw the unit cells of the cubic and hexagonal lattices.
- Draw, from co-ordinate information, diagrams giving atomic positions for cubic structures and calculate interatomic distances.
- Describe the concept of crystal planes and define the Miller indices for a set of planes.
- Determine the separation of the planes for crystals with orthogonal axes.
- Construct the potential energy functions for atoms bound by Van der Waals and ionic forces.
- Manipulate these potential energy functions to obtain the force between the atoms and the equilibrium spacing.

- Calculate the binding energy and the bulk modulus of Van der Waals and ionic solids given the interaction energy of a pair of atoms.
- Describe and draw diagrams for the experimental arrangements used for X-ray diffraction studies.
- Derive the Bragg law for diffraction from lattice planes.
- Explain how the distribution of scattering angles from a polycrystalline sample or powder crystal gives information about the lattice spacing.
- Derive the lattice parameter from diffraction data for cubic crystals.
- Calculate the de Broglie wavelength of electrons or thermal neutrons used in diffraction experiments.
- Calculate typical diffraction angles for such experiments.
- Describe how electrons may be used to image thin samples.
- Explain the principal features of the free electron gas model of a metal.
- Explain what is meant by the Fermi energy.
- Calculate the following properties of metals from the crystal structure: free electron concentration, Drude conductivity, resistivity.
- Explain the concept energy bands and show how it leads to the basic properties of semiconductors.
- Calculate the wavelength of photons emitted or absorbed in semiconductors from their bandgaps.
- Describe the Hall effect and be able to calculate parameters associated with this.
- Explain different types of magnetic order, such as ferromagnetism and antiferromagnetism.
- Explain why neutron scattering is useful in the study of magnetic crystals.
- Be able to apply all of these concepts to unseen problems.

4.7 Nuclear & Particle Physics

Aims

- To introduce the idea of radioactive decay.
- To introduce some of the properties of the atomic nucleus, of nucleons, and of elementary particles.
- To explore the composition of elementary particles in terms of quarks, leptons, and force carriers.
- To introduce the concepts of special relativity, Lorentz transformations, and four-vectors.
- To solve simple relativistic kinematic problems, involving invariant mass.

Objectives

- Describe the properties of alpha, beta and gamma radiation.
- Derive the exponential law of radiation decay.
- Use the law of radioactive decay to calculate mean life and half-life.
- Discuss the neutron-proton model of the nucleus and nuclear reactions.
- Explain the energy loss of charged particles by ionization.
- Calculate Q-values and threshold energies.
- Explain nuclear energy by fission and fusion reactions.
- State the Lorentz transformation equations for space-time.
- Calculate the effects of time dilation and Lorentz contraction.
- Define simultaneity and the interval between two events.
- Explain what is meant by a Lorentz invariant quantity.
- Explain what is meant by a four-vector.
- Define the four-momentum of a particle.
- Calculate the invariant mass of a pair of particles.
- Calculate the total energy of a particle.
- Calculate particle reaction thresholds in the centre of mass and laboratory frames.
- Investigate the kinematics of simple two-body decays.

- Describe the four fundamental interactions: their force carriers, ranges and strengths.
- Discuss the properties of the particles in the standard model of particle physics.
- Describe the quark model of baryons and mesons.
- Discuss conserved quantities in particle interactions.
- Explain the relation between matter and anti-matter.
- Draw Feynman diagrams to represent particle interactions and decays.
- Be able to apply all of these concepts to unseen problems.

4.8 Optics

Aims

- To discuss both qualitatively and quantitatively the superposition of light waves, their interference and diffraction.
- To study in detail the properties of electromagnetic waves, in particular in the visible region of the spectrum.

Objectives

- Describe wave propagation in terms of Huygens secondary wavelets.
- Write down the equation of a wave in real and complex form.
- State the relationship between optical path difference and phase difference.
- Obtain an expression for the resultant amplitude due to addition of two waves of arbitrary amplitude and phase using complex notation and Argand diagrams.
- Explain the concept of coherence and its influence on superposition of waves.
- State and use various mathematical relationships: series expansions for sin(x), cos(x),and tan(x) for small x; sum of geometrical series.
- Describe examples of the division of wavefront and division of amplitude methods of producing interference.
- Derive the fringe intensity equation for Young's double slit arrangement.
- Explain the factors influencing fringe visibility.
- Explain how Lloyd's mirror experiment shows evidence for a phase change on reflection.
- Describe the Michelson interferometer and explain how circular and straight line fringes are produced.
- Derive an equation for positions of circular fringes and give the fringe intensity formula for the Michelson.
- Describe and explain various uses for the Michelson interferometer.
- Explain how interference in thin films can be used to make non-reflecting glass.
- Explain qualitatively how a Fabry-Perot interferometer produces fringes, and describe what the fringe intensity pattern looks like compared to the Michelson.
- State the conditions under which Fraunhofer and Fresnel diffraction are observed.
- Derive the intensity distribution in the Fraunhofer diffraction pattern for a single slit.
- State Rayleigh's criterion and apply it to resolving power of telescopes.
- Derive the intensity distributions for a double slit and N slits - the diffraction grating.
- Derive the chromatic resolving power of a diffraction grating.
- Explain the meaning of unpolarised and polarised light and describe the different polarisation states.
- Describe the processes through which polarised light can be produced. Explain, using Malus's law, how plane polarisers affect the intensity and polarisation state of light. Derive the Brewster angle.
- Explain the concept of birefringence and describe how quarter and half wave plates work.
- Be able to apply all of these concepts to unseen problems.

4.9 Classical & Quantum Waves

Aims

- To develop the mathematical techniques needed to discuss physics of waves and vibrations both classical and quantum.
- To look in detail at standing and travelling wave solutions to the wave equation.
- To introduce the ideas of matter waves, standing waves as a representation of a particle in a box and the time

independent Schrödinger wave equation.

Objectives

- Manipulate and evaluate partial derivatives of functions of two variables.
- Write down the 1-D wave equation.
- Solve the wave equation for harmonic travelling and standing waves.
- Solve the wave equation for waves on a string and apply boundary conditions.
- Apply the principle of superposition and express standing waves sum of travelling waves.
- Calculate phase and group velocity.
- Explain the meaning of normal modes.
- Calculate the allowed vibration modes of a string as a function of the boundary conditions and explain the generalisation to modes in a box.
- Explain qualitatively how a Fourier series may be used to express an arbitrary vibration of a string of fixed length as a superposition of normal modes.
- Calculate the de Broglie wavelength of a particle given its momentum.
- Calculate the allowed energies of a particle in a 1D box from the normal modes.
- Estimate optical excitation energies of atoms and molecules by treating the atom as an electron in a 1D well.
- Write down the 1-D Schrödinger equation for a particle and appreciate its significance.
- Be able to apply all of these concepts to unseen problems.

5. Information for Exchange students

Physics 2 and Physics 2 (Half) can be taken by incoming international exchange students as part of an approved programme of study. Please note exams are scheduled for the April/May exam diet. Please consult the Physics & Astronomy International coordinator for advice.

6. Attendance, Adverse Circumstances, and 'Good Cause' claims

Students are expected to attend all lectures, tutorials and laboratory sessions. Attendance will be monitored at lectures, tutorials and labs. These attendance records will form part of the performance assessment. Attendance at the class tests and degree examinations is also compulsory.

If you miss an examination or an assessment deadline, or if you believe your assessment performance has been affected by adverse circumstances, you should submit a **Good Cause Claim**, and this must be via MyCampus.

Submission of a Good Cause Claim is the mechanism that allows your circumstances to be considered by the Board of Examiners. Please note all Good Cause Claims must be submitted within **one week** of the date of the affected assessment. Contact your Class Head or Lab Head (as relevant) if you foresee difficulty in meeting this deadline.

Students should note that the University's Code of Assessment allows grades to be awarded only on the basis of demonstrated work. So, if you feel that some piece of assessed work has been affected by adverse circumstances, and if staff agree, then the only course of action available is for the grade for that piece of work to be set aside (in the case of continuously assessed work and Class Tests) or to allow a resit (in the case of Degree Exams) – marks cannot be adjusted.

To submit a Good Cause Claim on MyCampus:

1. Go to the 'Student Centre' and select *My Good Cause* from the Academics menu.
2. Select the relevant course(s).
3. Complete the report in MyCampus (there is provision for particularly sensitive information to be provided separately, outwith the system, but a claim report must still be entered into MyCampus).

4. Add supporting evidence by uploading documents. (Pull-print printers in the Kelvin Building and around the campus all have a scan-and-email facility or you can upload a photograph of the document). It is the responsibility of the student to keep all original documentation and submit it to the Class Head on request.

If you encounter any difficulties with this process please contact the Class Head immediately to let him or her know you have a problem with your Good Cause Claim.

What will happen to your Good Cause Claim

The Course Administrator and/or Class Head will ensure that your claim is considered and this will be in accordance with the section of the Code of Assessment which covers incomplete assessment and good cause (paragraphs 16.45 to 16.53). The outcome of your claim will be posted into the Approval Information section on your Good Cause Claim in MyCampus. If it is accepted that your assessment was affected by good cause, the work in question will be set aside and you will (as far as is practicable – see comments above) be given another opportunity to take the assessment with the affected attempt discounted.

For absences that are significant but for which a good cause claim is not being filed, students must complete a **MyCampus absence report**. A significant absence is defined to be:

- an absence of **more than seven consecutive days** during working periods
- an absence of **any duration** if it prevents a student from, for example, fulfilling any minimum requirement for the award of credit (e.g. missing attendance at one day of a two-day laboratory, but where the work was nonetheless submitted and therefore not involving a Good Cause claim).

All potentially significant absences should be reported as soon as is practical, by completing part 1 of the MyCampus absence report. Part 2 of the MyCampus absence report should be completed on return to university. The normal submission deadline for the completed absence report is 7 days after return to university. Documentary evidence is required when reporting any significant absence.

See also the Senate Office Absence Policy:
http://www.gla.ac.uk/services/senateoffice/policies/studentsupport/absencepolicy/

More information about submission of Good Cause claim forms and Absence Reports (and how to decide which one is appropriate) is provided on the Physics 2 Moodle site.

7. Student societies

PhySoc and AstroSoc are student-run societies that arrange evening lectures and events during the year. oSTEM-Glasgow is a society set up by physics students to support gay, lesbian, bisexual, transgender and other students in science and engineering subjects. Additionally, "Glasgow Women in Physics" organises lunchtime talks on careers, research culture and academia to which **all** are welcome. Links to all these groups are provided on the Physics 2 moodle site and students are encouraged to participate.

8. Getting help and advice

Your adviser of studies, Physics 2 supervisor, Class and Lab Heads, lecturers and demonstrators are all here to help you and you should feel free to approach them for help and advice during the year. Particularly if you are getting into difficulties, it is very important that you talk to someone at an early stage. The university also provides counselling services and study advice, and you can find information about that on the web:

http://www.gla.ac.uk/students/wellbeing/

9. Ethical Working Practices

Each physicist and astronomer is a citizen of the greater science community, and has a shared responsibility for the professional integrity of their chosen discipline. We can only evolve a deeper understanding of science when we can trust the results of others working in the field; any deception or fabrication undermines that trust, and damages progress and comprehension. As a community of professionals, therefore, we must deplore any and all attempts at deliberate deception, fabrication of results or misrepresentation of the facts, and eradicate all such behaviour by openness and vigilance.

We must ensure that our subject discipline has professional integrity at every level, including all student work. Undergraduates and postgraduates must have trustworthiness and honesty at the heart of all that they do professionally: plagiarism, forgery and distortion have no place in our laboratories, tutorials, seminars or written submissions. All our work should be open to scrutiny by peers and supervisors, and all results must be defensible, and produced in honest pursuit of knowledge and understanding

Whilst there may be special considerations of privacy in certain circumstances (commercial sensitivity, for example) that may limit scrutiny, this does not change the central requirement to conduct all investigations in an ethical and professional manner.

Mistakes can be made as knowledge is pursued (for example, in the performance of a lab exercise or tutorial submission); if there is no intention to deceive then the errors and their consequences are not in conflict with ethical working practices: we learn from our mistakes. However, results that are manufactured to conceal a known flaw in procedure or basis, or to imply an enhanced knowledge on the part of the author, are not acceptable, and constitute intellectual fraud. Such actions constitute a breach of the Code of Student Conduct and may result in disciplinary action.

The Code of Ethical Working in Physics and Astronomy is based on the universal ethical code for scientists[iii], and is built on three central concepts:

1. **Rigour, honesty and integrity**
   - act with skill and care in all scientific work. Maintain up-to-date skills and assist their development in others
   - take steps to prevent corrupt practices and professional misconduct. Declare conflicts of interest
   - be alert to the ways in which research derives from and affects the work of other people, and respect the rights and reputations of others.
2. **Respect for life, the law and the public good**
   - ensure that your work is lawful and justified
   - minimise and justify any adverse effect your work may have on people, animals and the natural environment
3. **Responsible communication: listening and informing**
   - seek to discuss the issues that science raises for society. Listen to the aspirations and concerns of others
   - Do not knowingly mislead, or allow others to be misled, about scientific matters. Present and review scientific evidence, theory or interpretation honestly and accurately.

[iii] "Rigour, respect, responsibility: a universal ethical code for scientists" BIS/07/1430 https://www.gov.uk/government/publications/universal-ethical-code-for-scientists

10. If things go wrong…

We hope you will be happy in your physics studies here.

If things are not going well, then please raise issues of any kind that are affecting your studies. Talk to teaching staff or your adviser, as early as you can so that we can help.

The University is committed to providing an excellent experience for our students. However, if you are in the situation of having a complaint, then the University has a Complaints Procedure in line with the Scottish Public Services Ombudsman requirements. If you have a formal complaint, then in the first instance please raise it with a member of staff in the area concerned. We aim to provide a response to the complaint within five working days. This is Stage 1.

If you are not satisfied with the response provided at Stage 1 you may take the complaint to Stage 2 of the procedure. Similarly, if your complaint is complex, you may choose to go straight to Stage 2. At this stage the University will undertake a detailed investigation of the complaint, aiming to provide a final response within 20 working days.

You can raise a Stage 2 complaint in the following ways:

by e-mail: complaints@glasgow.ac.uk; by phone: 0141 330 2506

by post: The Senate Office, The University of Glasgow, Glasgow, G12 8QQ

in person: The Senate Office, Gilbert Scott Building, The University of Glasgow.

Complaints do not have to be made in writing but, you are encouraged to submit the completed Complaint Form (available at http://www.gla.ac.uk/services/senateoffice/studentcodes/students/complaints/) whether it is at Stage 1 or Stage 2. This will help to clarify the nature of the complaint and the remedy that you are seeking.
Remember that the SRC Advice Centre (Students Representative Council) is available to provide advice and assistance if you are considering making a complaint. (Tel: 0141 339 8541; e-mail: advice@src.gla.ac.uk)