

DEPARTMENT OF PHYSICS AND ASTRONOMY

PHY101	<u>Mechanics, Waves, Optics and Special Relativity</u>
Autumn	20 Credits
Staff contact	<i>Dr Matt Mears - Mechanics and Dynamics - m.mears@shef.ac.uk</i> <i>Prof Neil Spooner - Vibration and Waves - n.spooner@sheffield.ac.uk</i> <i>Dr William Durham - Optics -w.m.durham@sheffield.ac.uk</i> <i>Dr Vickey - Special Relativity - t.vickey@sheffield.ac.uk</i>

Outline Description	This module covers the basic physics in Year 1 regarding mechanics, waves, optics and relativity. Key topics include kinematics for motion with constant acceleration, Newton's laws, moment of inertia and angular momentum, gravitation and Kepler's laws, electromagnetic radiation, speed of light in material, dispersion, refraction, Snell's law, Huygens' principle, polarisation, reflection and transmission of waves, thin lenses, single and double slit diffraction and interference, simple harmonic motion with damping, wavelength and frequency, sound waves, the Doppler effect, standing waves, interference and superposition, Lorentz transformations, length contraction, time dilation, Minkowski space, the relativistic Doppler effect and addition of velocities, Lorentz invariance and the metric.
Core for Programmes	PHYU01, PHYU02, PHYU04, PHYU05, PHYU06, PHYU10, PHYU11, PHYU12, PHYU14, PHYU16, PHYU18, PHYU19, PHYU22, PHYU23, PHYU24, PHYU25, PHYU30
Prerequisites	A-level Mathematics or equivalent. A-level Physics or equivalent.
Co requisites	None
Approx Time allocation (hours)	Lectures: 44, Online problem classes: 10, Tutorials: 10, Examination: 4 (2 x 2hrs). Independent learning 132. Mechanics and Dynamics - Lectures: 12 Optics - Lectures: 12 Special Relativity - Lectures 10 Vibrations and Waves - Lectures 10
Assessment (%)	Written examination -80%, Tutorial homework-10%, Problems solving work - 10%
Aims	General To provide a fundamental understanding of the key elements of physical mechanics including motion in one and two dimensions, conservation of momentum and energy illustrated by considering collisions, rotational motion including the concept of moment of inertia, angular momentum and its conservation and periodic motion. The overriding teaching objective is to demonstrate the importance of how these topics can be combined to highlight further important physical principles. Further, fundamental aspects of vibrations and waves motion are described and the basic ideas behind the concepts of electric charge, electric force, field and potential, capacitance and simple networks are covered. Special Relativity is introduced and illustrated with lively examples. Mechanics 1. Kinematic equations for motion with constant acceleration, free-fall and terminal velocity 2. Projectile motion, trajectory equation 3. Newton's laws

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4. Momentum and energy conservation in elastic and inelastic collisions, ballistic pendulum
5. Rotational motion, rotational kinematic equations, moment of inertia calculations, torque and angular momentum and its conservation
6. Rotational kinetic energy, rolling motion
7. Introduction to gravitation, Kepler's laws

Optics

1. The nature of light

Electromagnetic radiation, Converting between energy and wavelength, Electromagnetic waves, Waves and rays, Speed of light in a material, Dispersion, Refractive index effects on wave characteristics

2. Reflection and refraction at plane surfaces

Law of reflection, Image formation by a plane mirror, Law of refraction (Snell's Law), Huygen's principle, Total internal reflection,

3. Polarisation of light

Polarising filters. Combinations of linear polarisers, Polarisation by reflection, Circular polarisation.

4. Reflection and refraction at spherical surfaces

Sign rules, Refraction at spherical surface, Reflection by spherical concave mirror. Point object, focal point and focal plane, Reflection by spherical concave mirror. Image of an extended object, Reflection by spherical convex mirror, Graphical methods for mirrors

5. Thin lenses

Sign rules, Converging thin lens. Image of an extended object, Diverging thin lens, Principal ray diagrams, The lensmaker's equation, A lens in liquid, Lens combinations. Simple optical instruments.

6. Interference

Constructive and destructive interference, Young's double slit experiment. Intensity distribution for very narrow slits, Phasors, Thin film interference

7. Diffraction

Single slit. Intensity distribution, Double slits including diffraction effects, Missing orders

Waves

1. Simple Harmonic Motion: Elastic forces and oscillations, Damped and forced oscillations, Resonance, Introduction to waves, Waves in physical media, Transverse and longitudinal waves, The wave equation, Group velocity
2. Harmonic waves and wave pulses, Wavelength and frequency, Relevant mathematics
3. Sound waves, Nature of sound waves, Intensity and loudness, Frequency and pitch
4. The Doppler effect
5. Standing waves, Interference and superposition, Standing waves on strings and in tubes, Resonance

Relativity

1. Motivation and some pre-relativity physics
2. First principles of special relativity and time dilation
3. Measurement of the mean lifetimes of muons in cosmic rays
4. Past, future, elsewhere
5. Lorentz transformations
6. Lorentz contraction, what we mean by observations, relativistic addition of velocities
7. The relativistic Doppler shift of light
8. Relativistic energy and momentum
9. Lorentz invariants and the metric

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Outcomes	<p>General</p> <p>The ability of a student to answer both descriptive and (especially) numerical questions on the syllabus covered by way of formal examination, formal homework and face-to-face discussion with tutors.</p> <p>By the end of the unit, candidates will be able to demonstrate a knowledge and understanding of physical laws and principles, and competence in application of these principles to diverse areas of physics.</p> <p>By the end of the unit, a candidate will be able to demonstrate the ability to solve problems in physics that is covered by the module aims.</p>
Teaching Methods	<p>Through formal lectures, small group tutorial classes, online problems resources which includes weekly set assignments, problem solving skill development within the tutorial and online learning environment.</p>
Recommended Books	<p>Mechanics and Dynamics</p> <p>“University Physics with Modern Physics - with Mastering Physics” 14th edition, by Young and Freedman (ISBN 978-1292100401) published by Pearson Addison-Wesley.</p> <p>Special Relativity</p> <p>"Special Relativity: For the Enthusiastic Beginner", by David J. Morin (ISBN 978-1542323512) published by CreateSpace Independent Publishing Platform.</p> <p>Vibration and Waves</p> <p>“University Physics with Modern Physics - with Mastering Physics” 14th edition, by Young and Freedman (ISBN 978-1292100401) published by Pearson Addison-Wesley.</p>
Syllabus	<p>Mechanics and Dynamics</p> <p>Newton’s Laws of Motion, gravitation, work, simple harmonic motion, linear momentum, rotational motion, torque, angular momentum. The course is supplemented by a wide range of questions; answers are also provided.</p> <ol style="list-style-type: none"> 1. Kinematic equations for motion with constant acceleration, free-fall and terminal velocity. 2. Projectile motion – trajectory equation. 3. Newton’s laws. 4. Momentum and energy conservation in elastic and inelastic collisions, ballistic pendulum. 5. Rotational motion – rotational kinematic equations, moment of inertia calculations, torque and angular momentum and its conservation. 6. Rotational kinetic energy, rolling motion. 7. Introduction to gravitation. <p>Optics</p> <ol style="list-style-type: none"> 1. The nature of light: Converting between energy and wavelength, Electromagnetic radiation, Electromagnetic waves, Waves and rays, Speed of light in a material, Dispersion, Refractive index effects on wave characteristics 2. Reflection and refraction at plane surfaces: Law of reflection, Image formation by a plane mirror, Law of refraction (Snell’s Law), Huygen’s principle, Total internal reflection, Dispersion by prisms 3. Polarisation of light: Polarising filters, Combinations of linear polarisers, Polarisation by reflection, Circular polarisation 4. Reflection and refraction at spherical surfaces: Sign rules, Refraction at spherical surface, Reflection by spherical concave mirror. Point object, focal point and focal plane, Reflection by spherical concave mirror. Image of an extended object, Reflection by spherical convex mirror mirror, Graphical methods for mirrors 5. Thin lenses: Sign rules, Converging thin lens. Image of an extended object, Diverging thin lens,

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	<p>Principal ray diagrams, The lensmaker's equation, A lens in liquid, Lens combinations</p> <ol style="list-style-type: none"> 6. Interference: Constructive and destructive interference, Young's double slit experiment, Intensity distribution for very narrow slits, Phasors, Thin film interference 7. Diffraction: Single slit. Intensity distribution, Double slits including diffraction effects, Missing orders, Diffraction gratings <p>Special Relativity</p> <p>Pre-relativistic coordinate transformations, Einstein's fundamental postulates of special relativity, time dilation, Lorentz contraction, the Lorentz transformations, relativistic addition of velocities, relativistic Doppler shift, energy and momentum in special relativity, kinematics and dynamics problems.</p> <ol style="list-style-type: none"> 1. Motivation and some pre-relativity physics 2. First principles of special relativity and time dilation 3. Measurement of the mean lifetimes of muons in cosmic rays 4. Past, future, elsewhere 5. Lorentz transformations 6. Lorentz contraction, what we mean by observations, and relativistic addition of velocities 7. The relativistic Doppler shift of light 8. Relativistic energy and momentum 9. Lorentz invariants and the metric <p>Vibration and Waves</p> <p>Simple Harmonic Motion, damped and forced oscillators. Transverse and longitudinal waves, wave propagation in strings, the physics of sound, Doppler effect, beats and interference</p> <ol style="list-style-type: none"> 1. Harmonic Motion: Elastic forces and oscillations, Damped and forced oscillations, Resonance 2. Harmonic waves and wave pulses, Wavelength and frequency, Relevant mathematics. 3. Sound waves, Nature of sound waves, Intensity and loudness, Frequency and pitch. 4. The Doppler effect 5. Standing waves, Interference and superposition, Standing waves on strings and in tubes, Resonance.
Academic Notes	