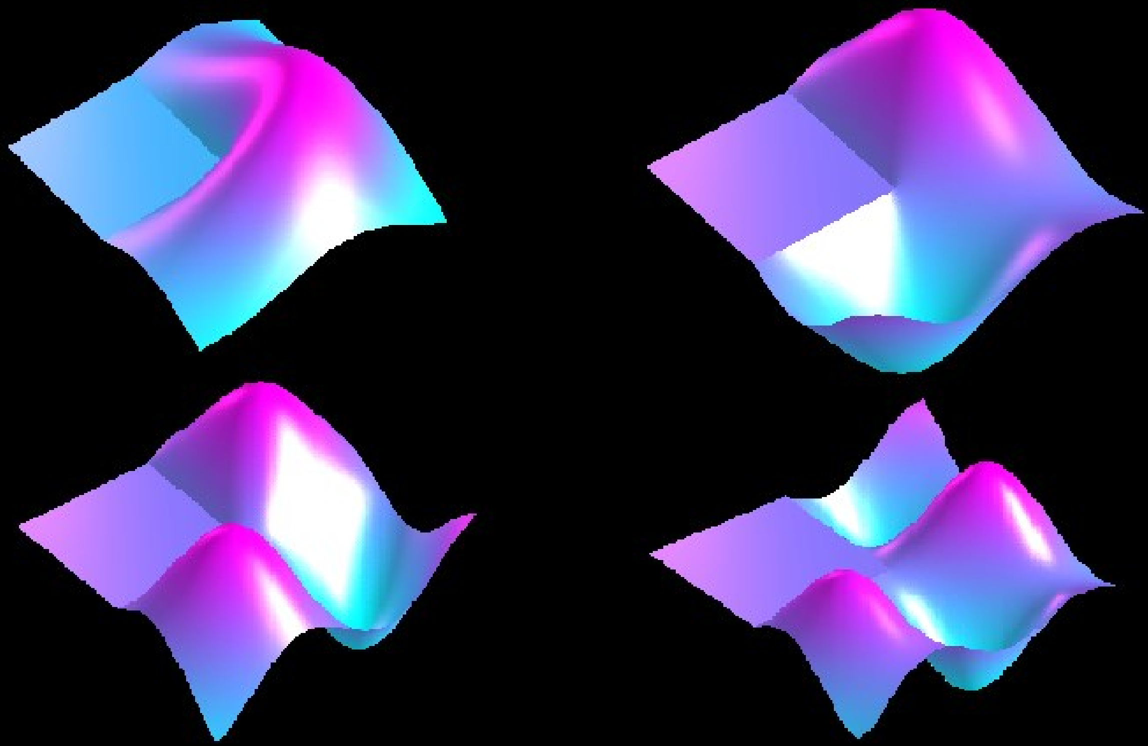
University of Glasgow | School of Physics & Astronomy



PHYS4057 Waves & Diffraction (Dec. Exam)

Course Information Guide 2023-24

1 Course Details

PHYS 4057 is identical to PHYS 4031. It is only available to Exchange students who are unable to attend the May exam diet.

Lecturer:	Dr Caroline Müllenbroich	Schedule:	18 lectures, Mon. 11am; Fri. 10am
SCQF Credits:	10	ECTS Credits:	5
Assessment:	Examination (100%)	Co-requisites:	PHYS4030,PHYS4025, PHYS4011
Level:	Honours		
Typically Offered:	Semester 1	Prerequisites:	Physics 2

2 Course Aims

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

- Transverse waves on a string;
- Discontinuity and boundary value problems;
- Waves in other physical situations;
- 2-dimensional waves;
- Waves in discontinuous and dispersive media;
- Diffraction;
- Fourier transforms in diffraction problems.

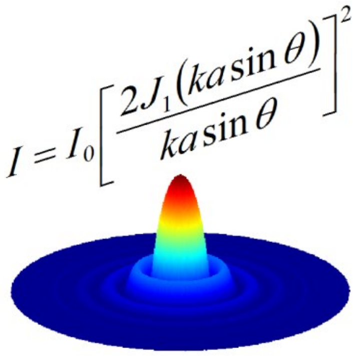


Figure 1: Diffraction from a circular aperture produces a ring pattern known as the Airy disc.

3 Intended Learning Outcomes

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

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

4 Course Outline

Notation and Mathematical Methods: Symbols and definitions, general and harmonic waves, complex number representation and its interpretation, energy and intensity. Waves in 2- and 3-dimensions.

Transverse waves on a string: Introduction to general methods. Derivation of the wave equation for transverse waves on a string. General solution for positive- and negative-moving waves. Superposition and its mathematical basis. Particle velocity and wave velocity. Energy density and energy flux. Lateral force and particle velocity, wave impedance. Relation to impedance of an oscillator. Rate of working

Discontinuity problems: Density discontinuities in strings; reflection and transmission coefficients for travelling waves from wave impedances; the energy reflection coefficient. More complex problems involving masses, complex impedances.

Boundary value problems: Reflection of wave on a string from fixed ends, standing waves, string fixed at both ends, allowed frequencies and normal modes, musical harmony, normal modes as a complete set. Fourier series and fitting of arbitrary initial conditions.

Waves in other physical situations: Longitudinal waves in bars and gases, wave equation, velocity and impedance. Discontinuity and boundary value problems. Similarity in behaviour of all types of (real) waves in discontinuity and boundary value problems. Extension of impedance arguments to waves on transmission lines and electromagnetic waves in free space. Relation to (complex) matter waves.

2-Dimensional waves: Transverse waves on membranes. 2-D standing waves, allowed frequencies. Mode density for higher order waves. Quantisation of 2-D matter waves.

Waves in discontinuous media: The linear chain of masses and springs. Longitudinal waves with one mass, dispersion relation. Application to vibrations of solids. Transverse waves (qualitative). Extension to alternate different masses.

Waves in dispersive media: Wave groups and group velocity. Application to matter waves.

Diffraction: General ideas, elementary model (Huygens principle), qualitative account of formal justification (Kirchhoff equation). Linear and quadratic variation of phase across aperture (Fraunhofer and Fresnel diffraction). Fraunhofer diffraction pattern as Fourier transform of aperture transmittance.

General properties of Fourier transforms: Physical interpretation of meaning of a Fourier transform for one variable case. Time-frequency transforms. Reciprocity in Fourier transform. The convolution theorem and its physical meaning. Some simple Fourier transform pairs.

Fourier transform in diffraction problems: 1-dimensional problems, single slit, δ-function as limit of single slit and calculated directly. Multiple slits using convolution theorem. More complex apertures, phase gratings, systematic absences. 2-dimensional problems; square apertures; circular apertures. Multiple apertures using convolution theorem; relation to crystal diffraction.

5 Further Information

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

- [Course specification]
- [Reading list]

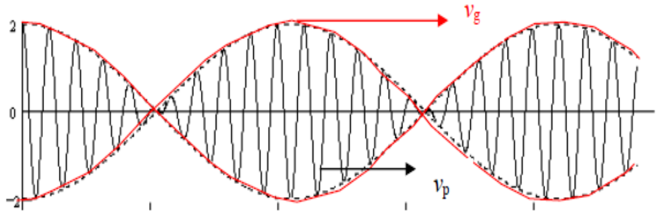


Figure 2: Phase and group velocities in a medium