PX264-7.5 Physics of Fluids

23/24

Department
Physics
Level
Undergraduate Level 2
Module leader
Nicholas d'Ambrumenil
Credit value
7.5
Assessment
100% exam
Study location
University of Warwick main campus, Coventry

Description

Introductory description

The field of fluids is one of the richest and most easily appreciated in physics. Tidal waves, cloud formation and the weather generally are some of the more spectacular phenomena encountered in fluids. The module establishes the basic equations of motion for a fluid - the Navier-Stokes equations - and shows that in many cases they can yield simple and intuitively appealing explanations of fluid flows. The module concentrates on incompressible fluids.

Module web page

Module aims

The module should explain why PDEs (with associated boundary conditions) are an appropriate model for fluids. You should learn how physical ideas and limiting cases can help analyse these PDEs which, in general, cannot be solved. These include the role of the Reynolds number, laminar viscous flow, the boundary layer concept and irrotational flow. The module also prepares you for future applied mathematics modules.

Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

Introduction: Fluids as materials which do not support shear. Idea of a Newtonian fluid. Plausibility of $\tau = \mu \, \partial u/\partial y$ from assumption of a relaxation time for stress.

Equations of Motion:
Hydrostatics, forces due to pressure and gravity. Hydrodynamics: acceleration, continuity and incompressibility. Euler equation.

Streamlines: Integrating Euler for steady flow along a streamline to give Bernoulli. Energy considerations. Applications of Bernoulli, flux through a hole, Pitot-static tube, aerofoil, waves on shallow water.

Hydrodynamics of Viscous Flow: Forces due to viscosity, Navier-Stokes equation. Derivation of Poiseuille's formula for laminar flow between plates.

Turbulence: Laminar flow only one possibility. Need for dimensionless number, Re, Pressure gradient as a function of Re. 2 Regimes: Physical interpretation of Re as Inertial forces/Viscous forces. Poiseuille works when Re small.

Irrotational Flow: Definition of vorticity and circulation. Importance of irrotational flow, Kelvin's circulation theorem. Examples of irrotational flow such as uniform flow, flow past a cylinder. Derivation of lift on thin aerofoil, as example for Magnus Effect.

Circulation around a cylinder. The vortex. Circulation constant round vortex line, need to close or end on surfaces. Advection of unlike vortices. The vortex ring. Circling of like vortices. Vortices at edges of wings.

Real Flows: Idea of boundary layer; Boundary layer separation and drag crisis.

Learning outcomes

By the end of the module, students should be able to:

- Use dimensional analysis to analyse fluid flows. In particular, they should appreciate the relevance of the Reynolds number
- Recognise and write down the equations of motion for incompressible fluids (the Navier-Stokes equations) and understand the origin and physical meaning of the various terms including the boundary conditions
- Derive Poiseuille's formula and understand the conditions for it to be a valid description of fluid flow
- Simplify the equations of motion in the case of incompressible irrotational flow and solve them for simple cases including vortices
- Explain the boundary layer concept

Indicative reading list

LD Landau and EM Lifshitz, Fluid Mechanics, Pergamon; DJ Tritton, Physical Fluid Dynamics, OUP; TE Faber Fluid Dynamics for Physicists, CUP

View reading list on Talis Aspire

Interdisciplinary

The study of fluids has always crossed the boundaries between mathematics, physics and engineering. This module, taken by large numbers of physics, maths and maths/physics students, introduces the discipline from a physicist's perspective. It leads on to modules taught in later years by Maths.

Subject specific skills

Knowledge of mathematics and physics. Skills in modelling, reasoning, thinking.

Transferable skills

Analytical, communication, problem-solving, self-study

Study

Study time

Type	Required
Lectures	20 sessions of 1 hour (100%)
Total	20 hours

Private study description

Working through lecture notes, solving problems, wider reading, discussing with others taking the module, revising for the exam, practising on past exam papers

Costs

No further costs have been identified for this module.

Assessment

You must pass all assessment components to pass the module.

Assessment group B2

	Weighting	Study time
In-person Examination	100%	
Answer two questions		

	Weighting	Study time

- Answerbook Pink (12 page)
- Students may use a calculator

Feedback on assessment

Personal tutor, group feedback

Past exam papers for PX264

Availability

Courses

This module is Core for:

- Year 2 of UPXA-FG33 Undergraduate Mathematics and Physics (BSc MMathPhys)

This module is Option list A for:

- Year 2 of UPXA-F3N1 Undergraduate Physics and Business Studies