

ES3D6-15 Fluid Mechanics for Mechanical Engineers

20/21

Department

School of Engineering

Level

Undergraduate Level 3

Module leader

Peter J. Thomas

Credit value

15

Module duration

10 weeks

Assessment

100% exam

Study location

University of Warwick main campus, Coventry

Description

Introductory description

ES3D6-15 Fundamental Fluid Mechanics for Mechanical Engineers

[Module web page](#)

Module aims

The module is part of the suite of core modules for Mechanical Engineering. It builds upon the Fluid Dynamics part of ES2BO Mechanics and Thermofluids module in Year 2 and prepares students for specialist modules in fluid dynamics in Year 4: ES440 Computational Fluid Dynamics and ES441 Advanced Fluid Dynamics. All Mechanical Engineers require a sound understanding of fluid mechanics. Issues involving aspects of fluid mechanics are involved in the vast majority of engineering problems. This module introduces the elementary principles and concepts and the fundamental theoretical and applied tools required for solving typical problems in mechanical engineering. At the end of the course students should have an understanding of how broad physical principles (conservation of mass, momentum, energy) determine fluid behaviour and lead to mathematical descriptions of key features. Students should be able to utilise the results of such descriptions, together with appropriate modelling, to carry out calculations/estimations of such

engineering quantities as pressure, forces (e.g. friction, drag, lift), power requirements, efficiency.

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.

1. Introduction (mostly brief revision from fluid dynamics part of ES2B0 module): Continuum hypothesis, control surface, control volume, Streamlines, Newton's law of viscosity, Non-Newtonian fluids, Reynolds number, hydrostatic pressure.
2. Conservation principles (in integral and differential form): Mass conservation, momentum equation, Reynolds transport theorem, 1-D energy equation, Euler equation, Navier-Stokes equation & its non-dimensionalization.
3. Bernoulli equation: Derivation, limitations, physical interpretation, Flow-measuring devices.
4. Stream function: Continuity equation - existence of stream function to describe flow field; relationship to streamlines.
5. Ideal flow: Assumptions, definition of vorticity, velocity potential. Rotational vs. Irrotational flow, Potential flow theory: mathematical description of incompressible, inviscid, irrotational flow - Laplace equation. Fundamental solution to Laplace equation, linear superposition, modelling of bodies in ideal flow (Rankine bodies). Cylinder in uniform flow, cylinder with circulation in uniform flow, Magnus effect: circulation and lift, Helmholtz vortex theorems, Principle of lifting aerofoils, Kutta-Joukowski- theorem.
6. Internal viscous flows: Laminar and turbulent pipe flows. Application of laminar flow – Darcy's law, Velocity profiles, shear stress, wall friction, pressure gradient. Effect of wall roughness; Moody chart.
7. Boundary-layer flows: Limitations of ideal flow - concept of viscous boundary layer. Momentum-integral equation, displacement and momentum thickness. Laminar and turbulent boundary layers; velocity profiles, skin-friction drag. Modelling of slender-body drag.
8. Transition, Turbulence, Kolmogorov's theory of turbulence and energy spectrum/energy cascade (very brief introduction only), separation and wakes: Mechanisms for boundary-layer transition. Separation and wake drag; aerofoil stall. Drag coefficients for bluff bodies; dynamic similarity. Strategies for drag reduction.
9. Compressible flows: flow regimes (subsonic, transonic, supersonic, ultrasonic flows), Mach number, oblique shock waves and expansion fans, area-velocity relation, Laval nozzle.
10. Rotating flows: Coriolis force, effects of Coriolis force (Taylor-curtains, Taylor-Proudman theorem).
11. Computational methods: Partial differential equations (classification scheme: elliptic, parabolic, hyperbolic). Solution strategies (finite differences, finite volumes, finite elements, method of characteristics), illustrate basic principle of finite-difference method in an example.

Learning outcomes

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

- Critically evaluate the importance and role of fluid mechanics within the Mechanical Engineering profession, consolidate and advance existing knowledge of fluidic systems;

- Communicate how broad physical principles (consideration of mass, momentum, energy) are applied in the solution of complex fluidic problems;
- Determine fluid behaviour in complex situations, and devise mathematical descriptions to communicate key features;
- Distinguish between differing fluid based phenomena and demonstrate ability to abstract solutions;
- Devise appropriate modelling and carry out calculations/estimations of such engineering quantities as pressure, forces [e.g. friction, drag, lift, power requirements, efficiency.];
- Apply complex numerical skills to the solution of fluid mechanics problems.

Indicative reading list

The main recommended textbook options are:

(1) Potter, M.C., Wiggert, D.C., Ramadan, B.H., 2017, Mechanics of Fluids (5th Edition), Cengage Learning, Stamford. ISBN 978-1-305-63761-0.

(2) White, F.M., 2016, Fluid Mechanics (8th Edition), McGraw-Hill, New York. ISBN 9789814720175.

(3) Douglas, J.F., Gasiorek, J.M., Swaffield, J.A., Jack, L.B., 2011, Fluid Mechanics (6th Edition, or latest edition whenever new editions become available), Prentice Hall, Pearson Education Limited, Harlow, UK.

Subject specific skills

1. Ability to conceive, make and realise a component, product, system or process
2. Ability to develop economically viable and ethically sound sustainable solutions
3. Ability to be pragmatic, taking a systematic approach and the logical and practical steps necessary for, often complex, concepts to become reality
4. Ability to seek to achieve sustainable solutions to problems and have strategies for being creative and innovative
5. Ability to be risk, cost and value-conscious, and aware of their ethical, social, cultural, environmental, health and safety, and wider professional engineering responsibilities

Transferable skills

1. Numeracy: apply mathematical and computational methods to communicate parameters, model and optimize solutions
2. Apply problem solving skills, information retrieval, and the effective use of general IT facilities
3. Communicate (written and oral; to technical and non-technical audiences) and work with others
4. Plan self-learning and improve performance, as the foundation for lifelong learning/CPD
5. Exercise initiative and personal responsibility, including time management, which may be as a team member or leader
6. Awareness of the nature of business and enterprise in the creation of economic and social value
7. Overcome difficulties by employing skills, knowledge and understanding in a flexible manner
8. Ability to formulate and operate within appropriate codes of conduct, when faced with an

ethical issue

9. Appreciation of the global dimensions of engineering, commerce and communication
 10. Be professional in their outlook, be capable of team working, be effective communicators, and be able to exercise responsibility and sound management approaches.
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Study

Study time

| Type | Required |
|----------------|-----------------------------|
| Lectures | 30 sessions of 1 hour (20%) |
| Other activity | 11 hours (7%) |
| Private study | 109 hours (73%) |
| Total | 150 hours |

Private study description

Guided Independent Learning 109 hours

Other activity description

10 hours example classes (5 x 2 hour sessions)
1 hour example class (Revision) just prior to exam

Costs

No further costs have been identified for this module.

Assessment

You must pass all assessment components to pass the module.

Students can register for this module without taking any assessment.

Assessment group B1

| | Weighting | Study time |
|--------------------|-----------|------------|
| Online Examination | 100% | |
| 2 X 1 HR QMP | | |
| ~Platforms - QMP | | |

- Online examination: No Answerbook required
- Students may use a calculator
- Engineering Data Book 8th Edition

Feedback on assessment

Model solutions to past papers.

Support through advice and feedback hours.

[Past exam papers for ES3D6](#)

Availability

Pre-requisites

To take this module, you must have passed:

- All of
 - [ES2C5-15 Dynamics and Fluid Mechanics](#)

Post-requisite modules

If you pass this module, you can take:

- ES4E4-15 Fuels and Combustion

Courses

This module is Core for:

- Year 3 of UESA-H310 BEng Mechanical Engineering
- Year 3 of UESA-H315 BEng Mechanical Engineering
- Year 4 of UESA-H314 BEng Mechanical Engineering with Intercalated Year
- Year 3 of UESA-H311 MEng Mechanical Engineering
- UESA-H316 MEng Mechanical Engineering
 - Year 3 of H315 Mechanical Engineering BEng
 - Year 3 of H316 Mechanical Engineering MEng
- Year 4 of UESA-H317 MEng Mechanical Engineering with Intercalated Year

This module is Core optional for:

- Year 3 of UESA-H115 MEng Engineering with Intercalated Year
- UESA-H317 MEng Mechanical Engineering with Intercalated Year
 - Year 3 of H317 Mechanical Engineering with Intercalated Year
 - Year 4 of H317 Mechanical Engineering with Intercalated Year

This module is Optional for:

- Year 3 of UESA-H113 BEng Engineering
- Year 3 of UESA-H114 MEng Engineering
- Year 4 of UESA-H115 MEng Engineering with Intercalated Year
- Year 1 of TESA-H341 Postgraduate Taught Advanced Mechanical Engineering

This module is Option list A for:

- Year 4 of UESA-H111 BEng Engineering with Intercalated Year
- UESA-H112 BSc Engineering
 - Year 3 of H112 Engineering
 - Year 3 of H112 Engineering