ACE Network Subject Information Guide

Vector Calculus and Mathematical Modelling of Fluid Flows

Semester 2, 2020

Administration and contact details

Host Department	Department of Mathematics
Host Institution	Swinburne University of Technology
Name of lecturer	Prof. Sergey A. Suslov
Phone number	(03) 9214-5952
Email Address	ssuslov@swin.edu.au
Homepage	https://www.swinburne.edu.au/research/our-research/access-our-research/find-a-researcher-or-supervisor/researcher-profile/?id=ssuslov
Name of Honours coordinator	Dr Ant Edwards
Phone number	03 9214 5393
Email Address	awedwards@swin.edu.au

Subject details

Handbook entry URL	TBA
Subject homepage URL	TBA
Honours student hand-out URL	TBA
Start date:	01.09.2020
End date:	13.11.2020
Contact hours per week:	3
Lecture day and time:	TBA
Description of electronic access arrangements for students (for example, WebCT)	Lecture notes will be distributed weekly by email, Zoom videoconferencing will be used for lectures

Subject content

1. Subject content description

While discussing in detail the topics listed below, this subject has a wider ambition. It intends to demonstrate the inherent connection between formal mathematical methods and the world around us. Physical reality motivates abstract analysis via the development of specialised mathematical tools known as mathematical models or equations. In turn, solutions of such equations explain why and how the real world evolves the way it does. Modelling fluid flows provides a rich context for exploring such a link thanks to the abundance of fluid flow phenomena in our everyday life.

In addition to standard lectures the subject will include weekly homework that will ask you to answer a set of short but insightful questions stemming from and extending the lecture material just studied. You will be challenged to take a critical view of the lectures encouraging your creative independent thinking. While this activity will contribute substantially to the final grade, it is not designed to assess the knowledge that you already acquired but rather to motivate you to initiate a dialog with the lecturer during which the knowledge complementary to that received in class will be obtained. It is envisaged that this will be accomplished via individual or group video-conferencing or email exchange that will occur on **your** request in addition to the regular lectures. The remaining assessment items (2 mid-semester assignments and a 2-hour written final examination) will consist of quantitative problems that you will need to solve completely on your own.

2. Week-by-week topic overview

Weeks 1-3: Revision of vector and scalar fields; differential operators (divergence, gradient, curl, material derivative, Laplacian) in the context of fluid flows; potential functions and vector identities reconsidered in the context of flows of an ideal fluid.

Weeks 4-6: Modelling of inviscid fluid flows: continuity equation for incompressible and compressible fluids; streamfunction and its physical and geometrical meanings, rotational and irrotational flows, Laplace's equation for irrotational flows; Euler and Bernoulli equations and Venturi effect; water waves and wave equation.

Weeks 7-10: Modelling of viscous fluid flows: viscosity and Navier-Stokes equations; vorticity equation; non-dimensionalisation and Pi-theorem; selected exact solutions of Navier-Stokes equations: Couette and Poiseuille flows; introduction to asymptotic methods and their application in modelling fast (boundary layer on a at plate and wake behind it, Prandtl and Blasius equations) and slow (thin film, lubrication) flows.

3. Assumed prerequisite knowledge and capabilities

Basic undergraduate differential and integral calculus (including exposure to ordinary and partial differential equations) and linear algebra (working knowledge of vector and matrix operations, understanding of the concepts of linear dependence and the rank of a system).

4. Learning outcomes and objectives

1. Understand the geometric meaning of basic differential vector operators and apply them to characterise main physical features of fluid flows.
2. Learn mathematical features and physical meaning of equations modelling inviscid fluid flows.
3. Learn and apply analytical methods for analysing realistic viscous fluid flows in various asymptotic limits.
4. Appreciate a close link between mathematical methods and physical reality.

AQF specific Program Learning Outcomes and Learning Outcome Descriptors (if available):

AQF Program Learning Outcomes addressed in this subject	Associated AQF Learning Outcome Descriptors for this subject
1	K1, S1-S3, A2, A3
2	K1, K2, S1-S4, A2, A3
3	K1, K2, S1-S4, A2, A3
4	K1, K2, S1-S3, A1, A2

Learning Outcome Descriptors at AQF Level 8
Knowledge
K1: coherent and advanced knowledge of the underlying principles and concepts in one or more disciplines
K2: knowledge of research principles and methods
Skills
S1: cognitive skills to review, analyse, consolidate and synthesise knowledge to identify and provide solutions to complex problem with intellectual independence
S2: cognitive and technical skills to demonstrate a broad understanding of a body of knowledge and theoretical concepts with advanced understanding in some areas
S3: cognitive skills to exercise critical thinking and judgement in developing new understanding
S4: technical skills to design and use in a research project
S5: communication skills to present clear and coherent exposition of knowledge and ideas to a variety of audiences
Application of Knowledge and Skills
A1: with initiative and judgement in professional practice and/or scholarship
A2: to adapt knowledge and skills in diverse contexts
A3: with responsibility and accountability for own learning and practice and in collaboration with others within broad parameters
A4: to plan and execute project work and/or a piece of research and scholarship with some independence

5. Learning resources

It is expected that students will mostly follow the provided lecture notes and rely on materials distributed weekly via email. Access to MATLAB and basic familiarity with this software could be beneficial but not essential. The book "Viscous Flow" by H. Ockendon and J.R. Ockendon, Cambridge University Press may be used as an additional reference for the second part of the course.

6. Assessment

Exam/assignment/classwork breakdown					
Exam	50%	**Assignments**	30%	**Weekly homework**	20%
Assignment due dates		Week 4	Week 8		
Approximate exam date				End of November 2020	

Institution Honours program details

Weight of subject in total honours assessment at host department	12.5%
Thesis/subject split at host department	Thesis 62.5%, coursework 37.5%
Honours grade ranges at host department:	
H1	80-100%
H2a	70-79%
H2b	60-69%
H3	50-59%