UNSW SYDNEY Australia's Global University

Mechanical and Manufacturing Engineering

Course Outline

Term 1 2020

AERO3660

FLIGHT PERFORMANCE AND PROPULSION

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1. Staff contact details

Name: Dr John Olsen
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Consultation with me concerning this course will be available at a time to be decided. Consultation by email should only be used as a very last resort as it is clumsy and inefficient.

Contact details and consultation times for additional lecturers/demonstrators/lab staff

Name: Dr Zoran Vulovic
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Moodle:

2. Important links

- Moodle
- Lab Access
- Health and Safety
- Computing Facilities
- Student Resources
- Course Outlines
- Engineering Student Support Services Centre
- Makerspace
- UNSW Timetable
- UNSW Handbook
- UNSW Mechanical and Manufacturing Engineering

3. Course details

Credit points

This is a 6 unit-of-credit (UoC) course, and involves 3 hours per week (h/w) of face-to-face contact.

The normal workload expectations of a student are approximately 25 hours per term for each UOC, including class contact hours, other learning activities, preparation and time spent on all assessable work.

You should aim to spend about 6 h/w on this course. The additional time should be spent in making sure that you understand the lecture material, completing the set assignments, further reading, and revising for any examinations.

Contact hours

	Day	Time	Location
Lectures	Tuesday	11am – 1pm	Ainsworth 102
	Wednesday	2pm – 3pm	Ainsworth 102
(Web stream)	Any	Any	Moodle
Consultations	Wednesday	3pm – 4pm	Ainsworth 102
Flight Simulations	TBA		

Please refer to your class timetable for the learning activities you are enrolled in and attend only those classes.

Summary and Aims of the course

In this course, we will develop equations for simple phases of flight performance such as straight & level flight, climbing flight, descending flight, turning flight, take-off and landing. These equations will enable you to determine the various aerodynamic forces acting on the aircraft. In particular, we will be interested in finding the thrust required. In the case of propeller driven aircraft, we will then be able to determine the power that an engine/motor must be able to make available for climb as this is usually the case when maximum power is required.

During flight, most aircraft burn fuel, which means that the weight of the aircraft varies non-linearly over the course of a flight mission. This can make it complicated to estimate the quantity of fuel required for a mission. You will be introduced to approaches to estimating the quantity of fuel required.

As the course deals with propulsion, you will learn the thermodynamic basics of engines, namely of reciprocating piston engines and gas turbine engines.

The aims of the course are:

- to clearly differentiate between true and equivalent airspeeds;
- to introduce students to wings and the usual approach to the decomposition of drag and to make them aware of this approach's limitations;
- to introduce the different atmospheric layers and to the equations needed to predict the density, temperature and pressure at different altitudes;
- to introduce the analysis of steady-state climb and descent, turning flight and gliding flight and to link this Newtonian approach to energy methods;
- to introduce take-off and landing analysis;
- to introduce the analysis of compressible flow;
- to introduce students to the Brequet range and endurance equations and to enable them firstly to see how the assumptions used in the development of this equation

limits its validity and secondly to suggest approaches to improve the accuracy of range prediction;
- to introduce a mathematical approximation to the behaviour of gas turbine engines so as to enable students to develop a deeper understanding of how these engines work;
- to review air-standard analysis of Otto cycle reciprocating piston engines and to introduce the air-standard analysis of the Dual cycle;
- to introduce students to actuator disk theory and blade element theory for propeller analysis to ensure that students understand why propellers are shaped the way they are;
- to introduce students to methods for calculating the properties of gas mixtures and to the basics of chemical reaction thermodynamics;

Student learning outcomes
- To clearly differentiate between true and equivalent airspeeds.
- To understand how the properties of the atmosphere change with altitude.
- To understand when and how to use compressible flow analysis.
- To develop a deeper understanding of how gas turbine engines work.
- To appreciate the benefits of Dual cycle analysis over Otto cycle analysis.
- To understand actuator disk theory and blade element theory for propeller analysis and to be able to articulate why propellers are shaped the way they are.
- To gain an initial understanding of how wings develop lift and to understand the limitations of the usual approach to the decomposition of drag.
- To be able to calculate the properties of gas mixtures and the energy released during chemical reactions.
- To estimate range and endurance but more importantly understand the limits to the validity of the current methods.
- To be able to analyse steady-state climb and descent, turning flight and gliding flight.
- To calculate take-off and landing distances and to see which parameters have to greatest influence.

This course is designed to address the learning outcomes below and the corresponding Engineers Australia Stage 1 Competency Standards for Professional Engineers as shown. The full list of Stage 1 Competency Standards may be found in Appendix A.

After successfully completing this course, you should be able to:

Learning Outcome		EA Stage 1 Competencies
1	Understand the difference between true and equivalent airspeeds.	PE1.1, PE1.2.
2	Understand compressible flow analysis.	PE1.1, PE1.2, PE1.3.
3	Understand how to apply mathematical analysis to predict flight performance and to recognise the shortcomings of analysis.	PE1.1, PE1.2, PE1.3.
4	Understand the workings of modern propulsion systems (gas turbines, reciprocating piston engines, propellers, chemical rockets and ion thrusters)	PE2.1, PE2.2.
5	To appreciate the strengths and weaknesses of Cumpsty's approach in analysing the behaviour of gas turbines.	PE1.1, PE1.2, PE1.3, PE2.1, PE2.2.

Learning Outcome		EA Stage 1 Competencies
6	Understand further thermodynamic analysis and the basic mechanisms of heat transfer.	PE1.1, PE1.2, PE1.3, PE2.1.
7	Understand the effects of altitude on propulsion.	PE1.1, PE1.2, PE1.3, PE2.1.

4. Teaching strategies

"Give a man a fish and you feed him for a day. Teach him how to fish and you feed him for a lifetime." **Lao Tzu**

Presentation of the material in lectures and discussions enables students know how to approach complex engineering calculations required in industry.

The problems I suggest you look at are intended to provide you with feedback and to allow you to investigate topics in greater depth. This is to ensure that you understand what you are being taught.

Consultation periods are designed to provide you with feedback and discussion on the problems that I would like you to do.

5. Course schedule

Week	Lecture Content
1	The atmosphere, airspeeds, an introduction to lift and drag, straight and level flight.
2	Breguet range and endurance equations, steady climb and descent.
3	Turning flight and gliding flight.
4	Energy methods, take-off and landing.
5	Introduction to gas turbines, net thrust, propulsive & component efficiencies. Internal compressible flows, convergent nozzles, convergent-divergent nozzles, normal and oblique shocks.
6	Gas turbine layouts (turbojet, turboprop, turboshaft and turbofan) and component characteristics (inlets, compressors, turbines, combustors, fuel systems, nozzles, etc). Review and extension of Brayton-Joule cycle analysis.
7	Reciprocating piston engines, review of air-standard Otto cycle analysis, air-standard Dual (Seiliger) cycle analysis, air-standard Atkinson cycle analysis, the effect of supercharging (turbocharging).
8	Engine breathing and valve trains, in-cylinder turbulence. AVGAS fuel (injection and carburation) and ignition systems. CI engines and common rail fuel injection systems. Specific weight comparison between SI and CI engines.
9	Introduction to propellers, dimensional analysis, actuator disk theory, Glauert blade element theory.
10	Chemical reactions, the air/fuel ratio, enthalpy of formation, 1st law analysis, enthalpy of combustion, adiabatic flame temperature.

The schedule shown may be subject to change at short notice to suit exigencies.

6. Assessment

Assessment overview

Task	Assessment	Group Project? (# Students per group)	Length	Weight	Learning outcomes assessed	Assessment criteria	Due date and submission requirements	Deadline for absolute fail	Marks returned
T1	Assignments (2)	N/A	One short, One long	40% (1 x 10% and 1 x 30%)	1 - 7	All course content up to the date of the assignments.	At the start of the Tuesday lecture in weeks 3 and 10.	The start of the Tuesday lecture in weeks 4 and 11.	Two weeks after submission
T2	Flight Simulation	N/A	1 hours	2%	1 – 7	-	On the day.	N/A	On the day
	Bankstown Flight Experiments	N/A	4 days	8%	1 – 7	All course content from weeks 1-10 inclusive.	One week after the flight exercises.	Two weeks after the flight exercises.	Two weeks after submission.
T3	Final exam	N/A	2 hours	50%	1 – 7	All course content from weeks 1-10 inclusive.	Exam period, date TBC.	N/A	Upon release of final results
			TOTAL	100%					

All assessment materials can be found on Moodle. Assignment One will uploaded to Moodle in Week Two, while Assignment Two will uploaded to Moodle in Week Seven. The length of the assignment solutions will depend on you, but you need to show all working.

You will be assessed by a final examination as well as your continuous participation in completing two assignments. They will involve calculations. The assessments are based to allow you to obtain an understanding of the material being taught and will allow you to apply the concepts learnt in the course. In order to achieve a PASS (PS) in this course, you need to both achieve a total mark of at least 50%.

Assignments

Presentation

All submissions should have a standard School cover sheet, which is available from this course's Moodle page.

All submissions are expected to be neat and clearly set out. Your results are the pinnacle of all your hard work and should be treated with due respect. Presenting results clearly gives the marker the best chance of understanding your method; even if the numerical results are incorrect.

Submission

Work submitted late without an approved extension by the course coordinator or delegated authority is subject to a late penalty of 20 percent (20%) of the maximum mark possible for that assessment item, per calendar day.

The late penalty is applied per calendar day (including weekends and public holidays) that the assessment is overdue. There is no pro-rata of the late penalty for submissions made part way through a day.

Work submitted after the 'deadline for absolute fail' is not accepted and a mark of zero will be awarded for that assessment item.

For some assessment items, a late penalty may not be appropriate. These are clearly indicated in the course outline, and such assessments receive a mark of zero if not completed by the specified date. Examples include:

a. Weekly online tests or laboratory work worth a small proportion of the subject mark, or
b. Online quizzes where answers are released to students on completion, or
c. Professional assessment tasks, where the intention is to create an authentic assessment that has an absolute submission date, or
d. Pass/Fail assessment tasks.

Marking

Marking guidelines for assignment submissions will be provided at the same time as assignment details to assist with meeting assessable requirements. Submissions will be marked according to the marking guidelines provided.

Examinations

You must be available for all tests and examinations. Final examinations for each course are held during the University examination periods: February for Summer Term, May for T1, August for T2, and November/December for T3.

Please visit myUNSW for Provisional Examination timetable publish dates.

For further information on exams, please see the Exams webpage.

Calculators

You will need to provide your own calculator of a make and model approved by UNSW for the examinations. The list of approved calculators is available at student.unsw.edu.au/exam-approved-calculators-and-computers

It is your responsibility to ensure that your calculator is of an approved make and model, and to obtain an "Approved" sticker for it from the Engineering Student Supper Services Centre prior to the examination. Calculators not bearing an "Approved" sticker will not be allowed into the examination room.

Special consideration and supplementary assessment

If you have experienced an illness or misadventure beyond your control that will interfere with your assessment performance, you are eligible to apply for Special Consideration prior to submitting an assessment or sitting an exam.

Please note that UNSW now has a Fit to Sit / Submit rule, which means that if you sit an exam or submit a piece of assessment, you are declaring yourself fit enough to do so and cannot later apply for Special Consideration.

For details of applying for Special Consideration and conditions for the award of supplementary assessment, please see the information on UNSW's Special Consideration page.

7. Expected resources for students

Textbooks

E. Torenbeek & Wittenberg, 2002, *Flight Physics, Essentials of Aeronautical Disciplines and Technology, with Historical Notes*, Springer.

and possibly:

N. Cumpsty & A. Heyes, 2015, *Jet Propulsion. A simple guide to the aerodynamic and thermodynamic design and performance of jet engines*, 3rd edition, Cambridge University Press.

These books are available in the UNSW bookshop.

Suggested additional readings

D. G. Hull, 2007, *Fundamentals of airplane flight mechanics*, Springer.

A. Terari, 2016, *Basic Flight Mechanics: A Simple Approach Without Equations*, Springer.

J. Kurzke & I. Halliwell, 2018, Propulsion and Power, Springer International Publishing AG.

G. P. Sutton & O. Biblarz, 2017, Rocket propulsion elements, 9th edition, Wiley.

A. Miele, 2016, Flight Mechanics, Theory of flight paths, Dover Publications Inc, Mineola, New York.

C. B. Millikan, 1941, Aerodynamics of the airplane, Dover Publications, Inc, Mineola, New York.

A. Filippone, 2012, *Advanced aircraft flight performance*, Cambridge University Press.

D. P. Raymer, 1992, *Aircraft design: A conceptual approach*, 2nd edition, AIAA, Washington, DC.

J. D. Anderson Jr., 2012, *Introduction to flight*, McGraw Hill, New York, 10020NY.

R. D. Archer & M. Saarlas, 1996, *An introduction to aerospace propulsion*, Prentice-Hall, Inc., Upper Saddle River, New Jersey, 07458.

T. S. Taylor, 2009, *Introduction to rocket science and engineering*, CRC Press, Boca Raton, FL 33487-2742.

D. F. Anderson & S. Eberhardt, 2010, Understanding flight, 2nd edition, McGraw Hill.

B. Gunston, 2006, *The development of jet and turbine aero engines*, 4th edition, Patrick Stephens Limited (an imprint of Haynes publishing).

B. Gunston, 1999, *Development of piston aero engines*, 2nd edition, Patrick Stephens Limited (an imprint of Haynes publishing).

K. Hünecke, 1997, Jet engines. *Fundamentals of theory, design and operation*, Airlife Publishing Limited, Shrewsbury, England.

A. Bejan, 2006, *Advanced engineering thermodynamics*, 3rd edition, John Wiley & Sons, Hoboken, New Jersey.

E. L. Houghton & P. W. Carpenter, 2003, *Aerodynamics for engineering students*, Butterworth-Heinemann (an imprint of Elsevier Science), Oxford.

J. A. Camberos & D. J. Moorhouse, 2011, *Exergy analysis and design optimization for aerospace vehicles and systems*, Editor-in-chief, F. K. Lu, Vol. 28, Progress in astronautics and aeronautics, AIAA, resto, Virginia.

M. H. Sadraey, 2013, *Aircraft design, A systems engineering approach*, Wiley.

Some of these books are available in the UNSW Library and are useful as additional reading material.

UNSW Library website: https://www.library.unsw.edu.au/

Additional materials provided in Moodle

This course has a website on UNSW Moodle which includes:

- course notes
- assignments
- consultation notes (questions and numerical answers);

Moodle: https://moodle.telt.unsw.edu.au/login/index.php

8. Course evaluation and development

Feedback on the course is gathered periodically using various means, including the UNSW myExperience process, informal discussion in the final class for the course, and the School's Student/Staff meetings. Your feedback is taken seriously, and continual improvements are made to the course based, in part, on such feedback.

This course undergoes continual upgrading and improvement based on student feedback.

9. Academic honesty and plagiarism

UNSW has an ongoing commitment to fostering a culture of learning informed by academic integrity. All UNSW students have a responsibility to adhere to this principle of academic integrity. Plagiarism undermines academic integrity and is not tolerated at UNSW. *Plagiarism at UNSW is defined as using the words or ideas of others and passing them off as your own.*

Plagiarism is a type of intellectual theft. It can take many forms, from deliberate cheating to accidentally copying from a source without acknowledgement. UNSW has produced a website with a wealth of resources to support students to understand and avoid plagiarism, visit: student.unsw.edu.au/plagiarism. The Learning Centre assists students with understanding academic integrity and how not to plagiarise. They also hold workshops and can help students one-on-one.

You are also reminded that careful time management is an important part of study and one of the identified causes of plagiarism is poor time management. Students should allow sufficient time for research, drafting and the proper referencing of sources in preparing all assessment tasks.

If plagiarism is found in your work when you are in first year, your lecturer will offer you assistance to improve your academic skills. They may ask you to look at some online resources, attend the Learning Centre, or sometimes resubmit your work with the problem fixed. However more serious instances in first year, such as stealing another student's work or paying someone to do your work, may be investigated under the Student Misconduct Procedures.

Repeated plagiarism (even in first year), plagiarism after first year, or serious instances, may also be investigated under the Student Misconduct Procedures. The penalties under the procedures can include a reduction in marks, failing a course or for the most serious matters (like plagiarism in an honours thesis) even suspension from the university. The Student Misconduct Procedures are available here:
www.gs.unsw.edu.au/policy/documents/studentmisconductprocedures.pdf

10. Administrative matters and links

All students are expected to read and be familiar with UNSW guidelines and polices. In particular, students should be familiar with the following:

- Attendance
- UNSW Email Address
- Special Consideration
- Exams
- Approved Calculators
- Academic Honesty and Plagiarism
- Equitable Learning Services

Appendix A: Engineers Australia (EA) Competencies

Stage 1 Competencies for Professional Engineers

	Program Intended Learning Outcomes
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing
	PE1.3 In-depth understanding of specialist bodies of knowledge
	PE1.4 Discernment of knowledge development and research directions
	PE1.5 Knowledge of engineering design practice
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice
PE2: Engineering Application Ability	PE2.1 Application of established engineering methods to complex problem solving
	PE2.2 Fluent application of engineering techniques, tools and resources
	PE2.3 Application of systematic engineering synthesis and design processes
	PE2.4 Application of systematic approaches to the conduct and management of engineering projects
PE3: Professional and Personal Attributes	PE3.1 Ethical conduct and professional accountability
	PE3.2 Effective oral and written communication (professional and lay domains)
	PE3.3 Creative, innovative and pro-active demeanour
	PE3.4 Professional use and management of information
	PE3.5 Orderly management of self, and professional conduct
	PE3.6 Effective team membership and team leadership