Course Outline

Semester 1 2016

Never Stand Still | Engineering | Mechanical and Manufacturing Engineering

AERO3660

FLIGHT PERFORMANCE & PROPULSION

Contents

1. Staff Contact Details

Contact details and consultation times for course convenor

Dr John Olsen
J17 Ainsworth Building 311/C
Tel (02) 9385 5217
Fax (02) 9663 1222
Email j.olsen@unsw.edu.au

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

Others who may be involved in the course

Dr Zoran Vulovic
J17 Ainsworth Building 311/D
Tel +61 2 9385 6261
Fax (02) 9663 1222
Email z.vulovic@unsw.edu.au

Mr John Page
J17 Ainsworth Building 311/J
Tel +61 2 9385 4090
Fax (02) 9663 1222
Email j.page@unsw.edu.au

A/Prof Con Doolan
J17 Ainsworth Building 408/F
Tel +61 2 9385 5696
Fax (02) 9663 1222
Email c.doolan@unsw.edu.au

2. Course details

Credit points:

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

The UNSW website states "The normal workload expectations of a student are approximately 25 hours per semester for each UoC, including class contact hours, other learning activities, preparation and time spent on all assessable work. Thus, for a full-time enrolled student, the normal workload, averaged across the 16 weeks of teaching, study and examination periods, is about 37.5 hours per week."

This means that you should aim to spend about 9 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. There is no parallel teaching in this course.

Contact hours

	Day	Time	Location
Lectures	Tuesday	1pm - 3pm	Ainsworth G02
	Wednesday	11am – 12pm	Ainsworth 102
Consultations	Wednesday	12pm – 1pm	Ainsworth 102

Summary of the course

This course introduces students to aspects of flight performance and aerospace propulsion.

Aircraft that have no means of propulsion are at best gliders, so in this course, a lot of emphasis is placed on teaching students the fundamentals of propulsion. We look at three main means of propulsion, namely, propellers driven by reciprocating piston engines, gas turbines and rockets. To understand these devices, it is important that students understand some further aspects of thermodynamics and fluid mechanics, that is, the basics of compressible flows, gas mixtures and chemical reactions. In keeping with modern developments in the area, we introduce some work on exergy analysis.

To understand the impact of these propulsion devices on the behaviour of aircraft (with the exception of gliding flight performance), we need to study some flight mechanics. The theory will later be backed up by the flight exercises done at Bankstown airport in semester 2.

Aims of the course

- To clearly differentiate between true and equivalent airspeeds.
- To give students an understanding of the atmosphere.
- To introduce the analysis of compressible flow.
- 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 wings and the usual approach to the decomposition of drag and to make them aware of this approach's limitations.
- To introduce students to methods for calculating the properties of gas mixtures and to the basics of chemical reaction thermodynamics.
- 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 emphasis the fact that the world is not undergoing an energy crisis as energy is always conserved. Instead, the students need to realise that it is the work potential (exergy or availability) of our energy sources that is be degraded.
- In 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 students to the differences between commercial and military gas turbines. Also to discuss the need to control the engine depending on operating conditions.
- To introduce students to rocket engine analysis.

Student learning outcomes

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 short comings 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.
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.

3. 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 so that the 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.

4. Course schedule

Week	Concepts
1	The atmosphere, airspeeds, an introduction to lift and drag, straight and level flight.
2	Introduction to gas turbines, net thrust, propulsive & component efficiencies. Internal compressible flows, convergent nozzles, convergent-divergent nozzles, normal and oblique shocks.
3	Breguet range and endurance equations, steady climb and descent.
4	Reciprocating piston engines, air-standard Otto cycle analysis, air-standard Dual (Seiliger) cycle analysis, air-standard Atkinson cycle analysis, the effect of supercharging (turbocharging), fuel systems, engine breathing, in-cylinder turbulence.
5	Introduction to propellers, dimensional analysis, actuator disk theory, Glauert blade element theory.
6	Turning flight, gliding flight, energy methods, takeoff and landing.
7	Gas turbine layouts (turbojet, turboprop, turboshaft and turbofan) and component characteristics (inlets, compressors, turbines, combustors, fuel systems, nozzles, etc.) Polytropic efficiencies of compressors and turbines.
8	Gas turbine engine matching in off-design conditions (plotting engine working lines with respect to compressor diagrams following Cumpsty's analytical approach) for single-spool turbojet, two-spool turbojet, single-spool turbofan, two-spool turbofan.
9	Exergy analysis of open and closed systems. Gas mixtures, the partition function and the effect of translational, rotational and vibrational modes of energy storage on the specific heat capacities of high-temperature gases. Constraints on combat gas turbine engines, the afterburner, fighter aircraft nozzles.
10	Chemical reactions, the air/fuel ratio, enthalpy of formation, 1st law analysis, enthalpy of combustion, adiabatic flame temperature.
11	Introduction to chemical rockets, specific impulse, the Tsiolkovsky rocket equation, introduction to ion thrusters.
12	Introduction to heat transfer, conduction, convection and radiation.

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

5. Assessment

Assessment overview

Assessment	Length	Weight	Learning outcomes assessed	Assessment criteria	Due date and submission requirements	Marks returned
Assignment	-	15%	1, 2, 3, 4, 5, 6, 7.	All lecture material up to the date of the assignment.	Tuesday, 1pm April 12, submit in class.	Two weeks later
Assignment	-	15%	1, 2, 3, 4, 5, 6, 7.	All lecture material up to the date of the assignment.	Tuesday, 1pm May 10, submit in class.	Two weeks later
Flight Simulation	1 hour	2%	1, 2, 3, 4, 5, 6, 7.	-	On the day.	On the day
Bankstown Flight Experiments	Four Days	8%	1, 2, 3, 4, 5, 6, 7.	All course content from weeks 2-12 inclusive.	2nd session mid-session break	Two weeks later
Final exam	3 hours	60%	1, 2, 3, 4, 5, 6, 7.	All course content from weeks 2-12 inclusive.	Exam period	Upon release of final results

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. Presenting them clearly gives the marker the best chance of understanding your method; even if the numerical results are incorrect.

Submission

Late submissions will be penalised 5 marks per calendar day (including weekends). An extension may only be granted in exceptional circumstances. Where an assessment task is worth less than 20% of the total course mark and you have a compelling reason for being unable to submit your work on time, you must seek approval for an extension from the course convenor ***before the due date***. Special consideration for assessment tasks of 20% or greater must be processed through student.unsw.edu.au/special-consideration.

It is always worth submitting late assessment tasks when possible. Completion of the work, even late, may be taken into account in cases of special consideration.

Examinations

You must be available for all tests and examinations. Final examinations for each course are held during the University examination periods, which are June for Semester 1 and November for Semester 2.

Provisional Examination timetables are generally published on myUNSW in May for Semester 1 and September for Semester 2

For further information on exams, please see the Exams section on the intranet.

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 shown 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 School Office or the Engineering Student Centre prior to the examination. Calculators not bearing an "Approved" sticker will not be allowed into the examination room.

Special Consideration and Supplementary Assessment

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

6. Expected resources for students

Textbooks

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.

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

These books are available in the UNSW bookshop.

Suggested additional readings

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.

Additional materials provided in Moodle

This course has a website on UNSW Moodle which includes:

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

Recommended internet sites

Be very careful when looking at websites that discuss the thermodynamic aspects of propulsion. The sign conventions used in thermodynamics are not uniform around the world and some of these websites can therefore ***strongly mislead students***.

Other resources

If you wish to explore any of the lecture topics in more depth, then other resources are available and assistance may be obtained from the UNSW Library.

One starting point for assistance is: www.library.unsw.edu.au/servicesfor/students.html.

Please be aware of: http://info.library.unsw.edu.au/web/services/services.html

7. Course evaluation and development

Feedback on the course is gathered periodically using various means, including the Course and Teaching Evaluation and Improvement (CATEI) 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.

More markers will be used this year to speed up the return of class tests to students.

8. 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: 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

Further information on School policy and procedures in the event of plagiarism is available on the intranet.

9. Administrative matters

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

- Attendance, Participation and Class Etiquette
- UNSW Email Address
- Computing Facilities
- Assessment Matters (including guidelines for assignments, exams and special consideration)
- Academic Honesty and Plagiarism
- Student Equity and Disabilities Unit
- Health and Safety
- Student Support Services

Dr John Olsen
February, 2016

Appendix A: Engineers Australia (EA) Professional Engineer Competency Standards

	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