School of Mechanical and Manufacturing Engineering

UNSW Engineering

AERO9660

Advanced Aerospace Propulsion

Term 3, 2021

Course Overview

Staff Contact Details

Convenors

Name	Email	Availability	Location	Phone
John Olsen	j.olsen@unsw.edu.au	During lecture periods	Ainsworth Building 311/C	9385 5217

School Contact Information

Location

UNSW Mechanical and Manufacturing Engineering

Ainsworth building J17, Level 1

Above Coffee on Campus

Hours

9:00–5:00pm, Monday–Friday*

*Closed on public holidays, School scheduled events and University Shutdown

Web

School of Mechanical and Manufacturing Engineering

Engineering Student Support Services

Engineering Industrial Training

UNSW Study Abroad and Exchange (for inbound students)

UNSW Future Students

Phone

(+61 2) 9385 8500 – Nucleus Student Hub

(+61 2) 9385 7661 – Engineering Industrial Training

(+61 2) 9385 3179 – UNSW Study Abroad and UNSW Exchange (for inbound students)

(+61 2) 9385 4097 – School Office**

**Please note that the School Office will not know when/if your course convenor is on campus or available

Email

Engineering Student Support Services – current student enquiries

- e.g. enrolment, progression, clash requests, course issues or program-related queries

Engineering Industrial Training – Industrial training questions

UNSW Study Abroad – study abroad student enquiries (for inbound students)

UNSW Exchange – student exchange enquiries (for inbound students)

UNSW Future Students – potential student enquiries

- e.g. admissions, fees, programs, credit transfer

School Office – School general office administration enquiries

- NB: the relevant teams listed above must be contacted for all student enquiries. The School will only be able to refer students on to the relevant team if contacted

Important Links

- Student Wellbeing
- Urgent Mental Health & Support
- Equitable Learning Services
- Faculty Transitional Arrangements for COVID-19
- Moodle
- Lab Access
- Computing Facilities
- Student Resources
- Course Outlines
- Makerspace
- UNSW Timetable
- UNSW Handbook

Course Details

Units of Credit 6

Summary of the Course

This course aims to enable you to:

- gain a deeper appreciation of gas turbine operation and to make high-level predictions of gas turbine behavior in various flight scenarios. This will be achieved by comparing analytical and numerical predictions of turbine behaviour with physical observations made in a laboratory setting.
- develop a strong understanding of rocket engines for different mission profiles. This will include reaching Earth orbits from sea-level (chemical rockets) and for satellite station keeping & interplanetary missions (ion-thrusters).
- develop a deeper understanding of the thermodynamic aspects of reciprocating piston internal combustion engines and the role that energy harvesting of exhaust gases can have on aircraft fuel consumption in an era of greater powertrain hybridization.

Specific topics include:

- Polytropic efficiencies of compressors and turbines. 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.
- Exergy analysis of open systems (gas turbine compressors and turbines) using stagnation properties. The exergy of lift.
- Temperature control of aircraft and spacecraft.
- Introduction to chemical rockets, specific impulse, the Tsiolkovsky rocket equation, the concept of maximum dynamic pressure.
- Thermodynamic analysis of rockets, introduction to ion thrusters.
- High-speed aircraft propulsion operation. Constraints on combat gas turbine engine operation, the afterburner, fighter aircraft nozzles. Ramjets and Scramjets.
- Finite time thermodynamics. Overview of basic Curzon-Novikov-Alhborn theory. Quasi-dimensional simulation of reciprocating piston, internal combustion engines.
- Introduction to electrical motor and generators, batteries, solar cells. Fully electric propulsion and hybrid propulsion.

Course Aims

This course aims to enable you to:

- gain a deeper appreciation of gas turbine operation and to make high-level predictions of gas turbine behavior in various flight scenarios. This will be achieved by comparing analytical and numerical predictions of turbine behaviour with physical observations made in a laboratory setting.
- develop a strong understanding of rocket engines for different mission profiles. This will include reaching Earth orbits from sea-level (chemical rockets) and for satellite station keeping & interplanetary missions (ion-thrusters).
- develop a deeper understanding of the thermodynamic aspects of reciprocating piston internal combustion engines and the role that energy harvesting of exhaust gases can have on aircraft

fuel consumption in an era of greater powertrain hybridization.

Course Learning Outcomes

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

Learning Outcome	EA Stage 1 Competencies
1. Analyse and predict the behaviour of gas turbine, two-spool and turbofan engines in various flight scenarios, using both analytical and simulation approaches, and compare the results with a physical turbine engine.	PE1.1, PE1.2, PE1.3, PE1.4, PE2.1
2. Evaluate engines for high-speed propulsion and space missions including: reaching Earth orbits from sea-level; satellite station keeping; and interplanetary missions.	PE1.1, PE1.2, PE1.3, PE2.1
3. Describe the thermodynamic aspects of various engine configurations and assess the role that energy harvesting of exhaust gases can have on aircraft fuel consumption in an era of greater powertrain electrification.	PE1.1, PE1.2, PE1.3, PE1.4, PE2.1
4. Perform thermodynamic analyses	PE1.1, PE1.2, PE1.3, PE1.4, PE2.1

Teaching Strategies

This course is a Master's level course with a high expectation for student-directed learning. The course will feature a blended delivery mode which includes:

- On-line lectures

Assessment

Assessment task	Weight	Due Date	Course Learning Outcomes Assessed
1. Assignment 1	10%	Week 3, Monday 27/09/2021 09:00 AM	1, 3
2. Assingment 2, Problem/s yet to be determined, but will be on work from week 1 to week 5	20%	Week 9, Monday, 15/11/2021 09:00 AM	1, 2, 3, 4
3. Class Test	20%	25/10/2021 10:10 AM	1, 2, 3, 4
4. Final Exam	50%	Not Applicable	1, 2, 3, 4

Assessment 1: Assignment 1

Start date: Week 1, 13/09/2021 09:00 AM
Assessment length: Relatively Short
Submission notes: Moodle Submission Box
Due date: Week 3, Monday 27/09/2021 09:00 AM
Deadline for absolute fail: One week after due by date
Marks returned: Two weeks after due date

The Meredith Effect and Gas Turbines

Assessment criteria

We require a sensible answer for the problem.

We require a logical solution to the problem.

Marks awards for both.

The second part is smaller. I just want to see what yoy come up with.

Assessment 2: Assingment 2, Problem/s yet to be determined, but will be on work from week 1 to week 5

Start date: Week 8, 01/11/2021 09:00 AM
Assessment length: Relatively Long
Submission notes: Moodle Box Submission
Due date: Week 9, Monday, 15/11/2021 09:00 AM
Deadline for absolute fail: One week after submision date
Marks returned: Two weeks after due by date

To be determined

Assessment criteria

We require a sensible answer for the problem.

We require a logical solution to the problem.

Marks awards for both.

Assessment 3: Class Test

Start date: 25/10/2021 09:00 AM
Assessment length: 1 hour
Submission notes: Moodle Submission Box
Due date: 25/10/2021 10:10 AM
Deadline for absolute fail: 30 minutes after due by time
Marks returned: Two Weeks Later

1 hour test during class time

This is not a Turnitin assignment

Assessment criteria

We require a sensible answer for the problem.

We require a logical solution to the problem.

Marks awards for both.

Assessment 4: Final Exam

Assessment length: 2 hrs
Submission notes: Moodle Submission Box
Deadline for absolute fail: 30 minutes after due by time.
Marks returned: with final grade

Final Exam. You will be tested on everything in the course.

Assessment criteria

We require a sensible answer for the problem.

We require a logical solution to the problem.

Marks awards for both.

Attendance Requirements

Students are strongly encouraged to attend all classes and review lecture recordings.

Course Schedule

	MoNDAY	WEDNESDAY
Week 1: 13/9/2021	turbofan analysis	introduction to heat transfer
Week 2: 20/9/2021	heat exchangers	radiation
Week 3: 27/9/2021	radiation	introduction to rockets, high-temperature gases
Week 4: 4/10/2021	long weekend holiday	further rocket analysis, electrothermal thrusters, solid rocket motors and nuclear rockets
Week 5: 11/10/2021	finite-time thermodynamics	internal combustion engine technologies
Week 6: 18/10/2021	FLEXIBILITY WEEK	FLEXIBILITY WEEK
Week 7: 25/10/2021	class test	exergy analysis
Week 8: 1/11/2021	ion thrusters	ion thruster optimization
Week 9: 8/11/2021	electrical machines, paschen’s law	hybrid powertrains
Week 10: 15/11/2021	military jet engines, RAM, and scram jets	betz limit, fuel cells

Resources

Prescribed Resources

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.

Recommended Resources

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.

J. Kurzke & I. Halliwell, 2018, *Propulsion and power, an exploration of gas turbine performance modelling*, Springer.

Rolls Royce, 2005, *The jet engine*, Rolls Royce Technical Publications.

A. Schmidt, 2019, *Technical thermodynamics for engineers, basics and applications*, Springer.

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

A. Bejan, 1993, *Heat transfer*, John Wiley & Sons, Hoboken, New Jersey.

A. Medina, P.L. Curto-Risso, A.C. Hernandez, L. Guzman-Vargas, F. Angulo-Brown & A.K. Sen, 2014, *Quasi-dimensional simulation of spark ignition engines*, Springer.

K. Hoag & B. Dondlinger, 2016. *Vehicluar engine design*, 2nd edition, Springer.

H. Hiereth & P. Prenninger, 2003, *Charging the internal combustion engine*, Springer.

G.P. Merker, C. Schwarz, G. Stiesch, & F. Otto, 2006, *Simulating combustion, Simulation of combustion and pollutant formation for engine-development*, Springer.

J.L. Lumley, 1999, *Engines, an introduction*, Cambridge University Press.

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

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

M. J. L. Turner, 2009, *Rocket and spacecraft propulsion, principles, practice and new developments*, 3rd edition, Springer.

U. Walter, 2019, *Astronautics, the physics of space flight*, 3rd edition, Springer.

J. D. Clark, 2017, *Ignition! An informal history of liquid rocket propellants*, Rutgers University Press Classics.

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

P. Fortescue, G. Swinerd & J. Stark, 2011, *Spacecraft systems engineering*, 4th edition, Wiley.

A. Hughes & B. Drury, 2013*, Electric motors and drives, Fundamentals, types and applications*, 4th Edition, Newnes.

Q. Quan, 2017, Introduction to multicopter design and control, Springer.

L. Guzzella & A. Sciarretta, 2013, *Vehicle propulsion systems, Introduction to modeling and optimization*, 3rd Edition, Springer.

W. W. Pulkrabek, 2004, *Engineering fundamentals of the internal combustion engine*, 2nd edition, Pearson Prentice Hall.

J.B. Heywood, 1988, *Internal combustion engines fundamentals*, McGraw Hill.

D. Crane, *Powerplant*, 2nd Edition, ASA AMT-P2.

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.

J.E.A. John, 1969, Gas Dynamics, Allyn & Bacon.

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

Course Evaluation and Development

This is the third time this course has run.

Some material has been more heavily upgraded than between the first and second times the course ran.

Laboratory Workshop Information

N/A

Submission of Assessment Tasks

Assessment submission and marking criteria

Should the course have any non-electronic assessment submission, these should have a standard School cover sheet.

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.

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.

Late policy

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, for a minimum of zero marks.

The late penalty is applied per calendar day (or part thereof), including weekends and public holidays, that the assessment is overdue.

Work submitted after the ‘deadline for absolute fail’ is not accepted and a mark of zero will be awarded for that assessment item. For example:

- Your course has an assessment task worth a total of **30 marks (Max Possible Mark)**
- You submit the assessment **2 days after the due date**
- The assessment is marked as usual and achieves a score of **20 marks (Awarded Mark)**
- The late policy is applied using **Late Mark = Awarded Mark - (Days*Penalty per Day)*Max Possible Mark**. Your adjusted final score is **8 marks** (20 - ((2*0.2)*30)).

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:

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

Examinations

You must be available for all quizzes, tests and examinations. For courses that have final examinations, these 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.

Special Consideration

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.

UNSW now has a Fit to Sit / Submit rule, which means that if you attempt 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.

Please note that students will **not** be required to provide **any** documentary evidence to support absences from any classes missed **because of COVID-19 public health measures such as isolation**. UNSW will **not** be insisting on medical certificates from anyone deemed to be a positive case, or when they have recovered. Such certificates are difficult to obtain and put an unnecessary strain on students and medical staff.

Applications for special consideration **will** be required for assessment and participation absences – but no documentary evidence **for COVID-19 illness or isolation** will be required.

Special Consideration Outcomes

Assessments have default Special Consideration outcomes. The default outcome for the assessment will be advised when you apply for Special Consideration. Below is the list of possible outcomes:

Outcome	Explanation	Example
Time extension	Student provided more time to submit the assessment	e.g. 1 more week of time granted to submit a report
Supplementary assessment	Student provided an alternate assessment at a later date/time	e.g. a supplementary exam is scheduled during the supplementary exam period of the term
Substitute item	The mark for the missed assessment is substituted with the mark of another assessment	e.g. mark for Quiz 1 applied also applied as mark for Quiz 2, meaning if a student achieved a mark of 20/30 for Quiz 1 and was granted Special Consideration for Quiz 2, a mark of 20/30 would be applied for Quiz 2, etc
Exemption	All course marks are recalculated excluding this assessment and its weighting	e.g. The course has an assessment structure of: - Assignments 30%, - Lab report 30%, - Final Exam 40%. If the Lab report is missed and student is granted Special Consideration, then the assessment structure may be reweighted as follows: - Assignments 50% - Final Exam 50% as though the Lab report did not exist
Non-standard	Course Coordinator is contacted for the outcome when special consideration is granted as the outcome differs on a case-by-case basis	e.g. typical for group assessments where time extension supplementary assessment could be granted to the group member, time extension could be granted to the whole group, etc. Clarify with your Course Convenor for

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

Academic Information

Credit points

Course credit is calculated in Units-Of-Credit (UOC). The normal workload expectation for one UOC is approximately 25 hours per term. This includes class contact hours, private study, other learning activities, preparation and time spent on all assessable work.

Most coursework courses at UNSW are 6 UOC and involve an estimated 150 hours to complete, for both regular and intensive terms. Each course includes a prescribed number of hours per week (h/w) of scheduled face-to-face and/or online contact. Any additional time beyond the prescribed contact hours should be spent in making sure that you understand the lecture material, completing the set assignments, further reading, and revising for any examinations.

On-campus class attendance

****T3-2021 UPDATE****
Classes will be entirely ONLINE until at least Week 6, after which we will receive further advice from UNSW about the return of face-to-face classes. Students who are enrolled in face-to-face classes will have access to the course's online content but NO classes will be changed to reflect online delivery until Week 6 due to uncertainty regarding delivery mode for the rest of the term. Please go to your course's Moodle modules and MS Teams sites for further information about accessing course resources and content.

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Public distancing conditions must be followed for all face-to-face classes. To ensure this, only students enrolled in those classes will be allowed in the room. No over-enrolment is allowed in face-to-face classes. Students enrolled in online classes can swap their enrolment from online to a **limited** number of on-campus classes by Sunday, Week 1. Please refer to your course's Microsoft Teams and Moodle sites for more information about class attendance for in-person and online class sections/activities.

Your health and the health of those in your class is critically important. You must stay at home if you are sick or have been advised to self-isolate by NSW health or government authorities. Current alerts and a list of hotspots can be found here. **You will not be penalised for missing a face-to-face activity due to illness or a requirement to self-isolate.** We will work with you to ensure continuity of learning during your isolation and have plans in place for you to catch up on any content or learning activities you may miss. Where this might not be possible, an application for fee remission may be discussed. Further information is available on any course Moodle or Teams site.

In certain classroom and laboratory situations where physical distancing cannot be maintained or there is a high risk that it cannot be maintained, face masks will be considered **mandatory PPE** for students and staff.

For more information, please refer to the
FAQs: https://www.covid-19.unsw.edu.au/safe-return-campus-faqs

Guidelines

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

Image Credit

Photo by Stephen Blake March 2017, Willis Annexe (J18) Thermofluids lab

CRICOS

CRICOS Provider Code: 00098G

Acknowledgement of Country

We acknowledge the Bedegal people who are the traditional custodians of the lands on which UNSW Kensington campus is located.

Appendix: Engineers Australia (EA) Professional Engineer Competency Standard

Program Intended Learning Outcomes	
Knowledge and skill base	
PE1.1 Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline	✓
PE1.2 Conceptual understanding of the mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline	✓
PE1.3 In-depth understanding of specialist bodies of knowledge within the engineering discipline	✓
PE1.4 Discernment of knowledge development and research directions within the engineering discipline	✓
PE1.5 Knowledge of engineering design practice and contextual factors impacting the engineering discipline	
PE1.6 Understanding of the scope, principles, norms, accountabilities and bounds of sustainable engineering practice in the specific discipline	
Engineering application ability	
PE2.1 Application of established engineering methods to complex engineering 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	
Professional and personal attributes	
PE3.1 Ethical conduct and professional accountability	
PE3.2 Effective oral and written communication in 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	