Course Outline

Semester 1 2015

Never Stand Still | Faculty of Engineering | School of Mechanical and Manufacturing Engineering

AERO3660

FLIGHT PERFORMANCE AND PROPULSION

Contents

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COURSE OUTLINE

1. STAFF CONTACT DETAILS

Contact details and consultation times for course convener

Dr John Olsen
Building F21, Room 107J
Tel +61 2 9385 5217
Email j.olsen@unsw.edu.au

Consultation 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 involved in the course

A/Prof N. Ahmed
Electrical Engineering (G17), Level 4, Room 464K
Tel +61 2 9385 4080
Email n.ahmed@unsw.edu.au

Dr Zoran Vulovic
Building F21, Room 107D
Tel +61 2 9385 6261
Email z.vulovic@unsw.edu.au

Mr John Page
Building F21, Room 107H
Tel +61 2 9385 4090
Email j.page@unsw.edu.au

Contact details and consultation times for additional lecturers and tutorial/laboratory teaching staff

Nil.

2. COURSE DETAILS

Class contact

The class contact will include the following sessions:

- **Lecture periods**
  Wednesday 9.00am to 11:00am (Electrical Eng 224)
  Thursday 1:00pm to 2:00pm (Webster Theatre B (F Hall B))

- **Dr John Olsen is only available for consultation on:**
  Thursday 2:00pm to 3:00pm (REDC 1040)

Tutorial work

It is essential that you make full use of the consultation periods and attempt relevant problems as soon as possible after a topic has been covered in lectures periods. The problems I suggest you look at are essential to consolidate understanding of the subject and to reveal aspects of the course which you have not understood. You should use a notebook for your worked solutions.

Units of credit

This is a 6 unit-of-credit (UoC) course, and involves 5 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."

For a standard 24 UoC in the session, this means 600 hours, spread over an effective 15 weeks of the session (thirteen weeks plus stuvac plus one effective exam week), or 40 hours per week, for an average student aiming for a credit grade Various factors, such as your own ability, your target grade, etc., will influence the time needed in your case. Some students spend much more than 40 h/w, but you should aim for not less than 40 h/w on coursework for 24 UoC.

This means that you should aim to spend not less than about 10 h/w on this course, i.e. an additional 4 h/w of your own time. This should be spent in making sure that you understand the lecture material, completing the set assignments, further reading about the course material, and revising and learning for the examination.

There is no parallel teaching in this course.

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

- 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 realise that there is no energy crisis and to calculate the work potential of and exergy flows through gas turbine engines.
- 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.
- To appreciate the differences between commercial and military gas turbines.
- To understand the workings of rocket engines.

Graduate attributes

UNSW's graduate attributes are shown at
https://my.unsw.edu.au/student/atoz/GraduateAttributes.html

UNSW aspires to develop graduates who are rigorous scholars, capable of leadership and professional practice in a global community. The university has, thus, articulated the following Graduate Attributes as desired learning outcomes for ALL UNSW students.

UNSW graduates will be

1. Scholars who are:
   - (a) understanding of their discipline in its interdisciplinary context ✓
   - (b) capable of independent and collaborative enquiry ✓
   - (c) rigorous in their analysis, critique, and reflection ✓
   - (d) able to apply their knowledge and skills to solving problems ✓
   - (e) ethical practitioners
   - (f) capable of effective communication ✓
   - (g) information literate ✓
   - (h) digitally literate ✓

2. Leaders who are:
   - (a) enterprising, innovative and creative
   - (b) capable of initiating as well as embracing change
   - (c) collaborative team workers

3. Professionals who are:
   - (a) capable of independent, self-directed practice ✓
   - (b) capable of lifelong learning ✓
   - (c) capable of operating within an agreed Code of Practice

4. Global Citizens who are:
   - (a) capable of applying their discipline in local, national and international contexts ✓
   - (b) culturally aware and capable of respecting diversity and acting in socially just/responsible ways
   - (c) capable of environmental responsibility ✓

✓ = Developed in this course

3. RATIONALE FOR INCLUSION OF CONTENT AND TEACHING APPROACH

This course is intended to do two things. Firstly, to introduce you to the fundamentals of flight performance and secondly, to introduce you to the basic methods by which aircraft are propelled. It is obvious why most of the topics in the course schedule are there. They need no justification. Perhaps you don't realise that at speeds above a Mach number of 0.3, the behaviour of gases changes. This is why we need to do some work on compressible flows especially in this course for internal flows. Last year, I included some work on exergy analysis. I intend to take this work further in the years to come. The exergy approach seems be becoming popular in other parts of the world and so we will follow. In semester 2, you will be doing a set of flying exercises in light aircraft (Diamonds, Cessnas or Piper Warriors) which will help to strengthen your grasp of flight performance.

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 will be such that the students know how to approach complex engineering calculations required in the real world.

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.

5. ASSESSMENT

There will be a final exam which covers all the material which will be worth 60% of the final mark. I will set two assignments during the semester (each worth 14%) but if necessary, one of these assignments will be a class test. You will be notified well in advance. You will get 2% of your final marks if you turn up for your nominated flight simulation. The final 10% of the marks for the course will come from an assignment which will be based on data collected at Bankstown in the second semester.

Break up of marks

2 × assignments/class test	**30%** of final mark
1 × flight simulation	**2%** of final mark
1 × flight assignment	**8%** of final mark
1 × final exam	**60%** of final mark
	100%

At the end of semester 1, you will have a mark out of 90. The flying component of this course will take place in semester 2. The assignment that you will do based on this flying program will be marked out of 10, bringing the total mark up to 100.

Firstly, if your mark at the end of semester 1 is less than 42/90, then you will not be permitted to attend the flying program at Bankstown in semester 2 and you will fail the course. Secondly, you need to do the flight simulation exercise or else you will be banned from flying at Bankstown.

Assignments

See above

Laboratory work

The flight exercises at Bankstown might be considered as a lab. You will be briefed in semester 2 on what to do, take and how to behave at Bankstown.

Also the simulation exercise might be considered as a lab too. The simulation exercise will be carried out by each student individually on the flight simulator in room Building F21 Room 107F. The exercise is booked by writing your name and surname on the list provided outside room L204 next to the time slot you chose. Please note that a successful completion of the flight simulation is a **pre-requisite** for the flight experiments.

As far as flight simulation is concerned students will be allowed to book their own times for the exercise. Once you book a simulation session it becomes compulsory. You are allowed to cancel the booking, otherwise you will **lose marks** for not turning up or for being late.

The flight exercises will require an extremely high level of punctuality and discipline. A special briefing session will be held on the first day of the exercise where you are going to be introduced with the rules governing in-flight and air-side behaviour. The most important part is to always obey instructions given by the flight personnel and your lecturers.

Presentation

A standard specification is available from the school website to aid presentation of your assignments (in all courses). https://www.engineering.unsw.edu.au/mechanical-engineering/forms-and-guidelines

All submissions should have a standard school cover sheet. All submissions are expected to be neat, and clearly set out. All calculations should be shown as, in the event of incorrect answers, marks are awarded for method and understanding.

The preferred set-out of any numerical calculation is similar to the following:

$\Delta = \rho\nabla$	(Equation in symbols)
$= 1.025 \times 200$	(Numbers substituted)
$= 205$ t	(Answer with units)

Examination

There will be one three-hour examination at the end of the session, covering all material for the whole session.

You will need to provide your own calculator, of a make and model approved by UNSW, for the examination. The list of approved calculators is shown at: https://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 Administrative Matters, available from the School website.

Note that the following will apply to this course:

The School guidelines recommend that late submissions incur a penalty of 10% of the total marks awarded for each calendar day the assignment is late. For example, if you received a mark of 40 out of 50 for an assignment that you handed in 2 days late you would receive a penalty of 8 marks and your mark would be reduced to 32. If the same assignment were handed in 4 days late the mark would be reduced to 24.

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 https://student.unsw.edu.au/special-consideration.*

Please note that late penalties are at the discretion of the course convenor and in some cases late work may not be assessed.

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.

6. ACADEMIC HONESTY AND PLAGIARISM

Plagiarism is using the words or ideas of others and presenting them 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 booklet which provides essential information for avoiding plagiarism: https://my.unsw.edu.au/student/academiclife/Plagiarism.pdf

There is a range of resources to support students to avoid 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. Information is available on the dedicated website Plagiarism and Academic Integrity website: http://www.lc.unsw.edu.au/plagiarism/index.html

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 a honours thesis) even suspension from the university. The Student Misconduct Procedures are available here: http://www.gs.unsw.edu.au/policy/documents/studentmisconductprocedures.pdf

Further information on School policy and procedures in the event of plagiarism is presented in a School handout, *Administrative Matters*, available on the School website.

7. COURSE SCHEDULE

- The atmosphere, airspeeds, introduction to lift and drag.
- Straight and level flight. Steady climb and descent.
- Reciprocating piston engines, actuator disk theory, blade element theory.
- Compressible flows.
- Introduction to gas turbines, net thrust, propulsive & component efficiency.
- Exergy analysis of open systems.
- Range and endurance equations.
- Polytropic efficiency and gas turbine analysis.
- Turning flight. Gliding flight.
- Energy methods. Take off and landing analysis.
- Gas mixtures and chemical reactions.
- Military gas turbines and rockets.

The course will not be taught in the order presented above. Due to difficulties in establishing the new degrees, some students have not passed either flight performance or propulsion. This year, we will have to cater for these students as best we can.

A separate document has been produced to explain in more detail what is happening this year. Please note that the course schedule as outlined above could change at short notice.

8. RESOURCES FOR STUDENTS

Textbooks

N. Cumpsty, 2003, *Jet Propulsion. A simple guide to the aerodynamic and thermodynamic design and performance of jet engines*, 2nd edition, Cambridge University Press.

This book available in the UNSW bookshop. You also might like to consider buying either:

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

or:

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

Suggested additional readings

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.

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

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.

9. 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 tutorial 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.

10. ADMINISTRATIVE MATTERS

You are expected to have read and be familiar with Administrative Matters, available on the School website. This document contains important information on student responsibilities and support, including special consideration, assessment, health and safety, and student equity and diversity.

Dr J. Olsen
February 2015