UNSW AUSTRALIA

# Course Outline

Semester 1, 2015

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

# MMAN2700 THERMODYNAMICS

# Contents

# MMAN2700 THERMODYNAMICS
# COURSE OUTLINE

## 1. STAFF CONTACT DETAILS

**Contact details and consultation times for course convener**

Dr John Olsen
Building F21, Room 107J
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.

**Contact details and consultation times for additional lecturers and demonstrators/laboratory teaching staff**
Nil.

## 2. COURSE DETAILS

**Class contact**

The class contact will include the following sessions:

- **Lecture periods**

| | |
|---|---|
| Monday | 4:00pm to 6:00pm (Central Lecture Block 7) |
| Friday | 9:00am to 10:00am (Science Theatre) |

***There will be two, one-hour, mid-session tests during the semester. They will be held on the 17$^{st}$ April and the 8$^{th}$ May.***

**Be early and bring both your calculator and non-marked steam tables.**

- **Two hour laboratory period.**
  There are 4 compulsory 2-hour laboratories periods on the weeks indicated for your group in the attached laboratory timetable.
- The laboratory periods take place in the Tyree Building and the Willis Annexe, Room L211. You will be notified which the week before.
- **Dr John Olsen is only available for consultation on:**
  T.B.A.

- **Consultation periods with demonstrators.**

You have already enrolled in consultation periods and so you already have the details.

**Consultation periods**

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 and consultation periods. The problems are essential to consolidate understanding of the subject and to reveal aspects of the course which you have not understood. The problems in the mid-session tests will be similar to these problems. 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 the student to the terminology, principles and methods used in engineering thermodynamics.

Thermodynamics is a subject which deals with energy which is essential for life. Thermodynamics has long been an essential part of engineering curricula all over the world. It has a broad application area ranging from microscopic organisms to common household appliances, transportation vehicles, power generation systems and even philosophy.

The knowledge of thermodynamics gained in this course is essential to many other courses studied in the mechanical engineering degree programme such as advanced thermofluids, aerospace propulsion, internal combustion engines, refrigeration and air conditioning and solar energy.

**Aims of the course**

The objectives of the course are to:

- familiarise students with the terminology associated with thermodynamics. I would like students to develop an understanding of the deeper meanings of familiar words like *energy*, heat, work, temperature, reversible & irreversible as well as not so familiar words like entropy;
- teach students to identify whether a thermodynamic system is open, closed or isolated;
- familiarise students with both the 1st and 2nd laws of thermodynamics and teach students how to apply these laws;
- teach students how to use tabulated thermodynamic data for vapours, liquids and solids. Also to recognise under which circumstances it is best to use this data or the ideal gas laws;
- familiarise students with air standard cycle analysis of reciprocating piston engines like spark ignition engines and compression ignition engines;
- familiarise students with air standard cycle analysis for gas turbine engines;
- familiarise students with the analysis of vapour power cycles for large power plants, and finally;
- familiarise students with the analysis of vapour compression refrigeration cycles.

**Student learning outcomes**

On completion of the course, it is expected that you:

- are familiar with the terminology associated with thermodynamics and have developed an understanding of the deeper meanings of familiar words like *energy*, heat, work, temperature, reversible as well as not so familiar words like entropy.
- can identify whether a thermodynamic system is open, closed or isolated.
- are familiar with both the 1st and 2nd laws of thermodynamics and can apply these laws.
- can use tabulated thermodynamic data for vapours, liquids and solids and recognise under which circumstances it is best to use this data or the ideal gas laws.

- are familiar with air standard cycle analysis of reciprocating piston engines like spark ignition engines and compression ignition engines.
- are familiar with air standard cycle analysis for gas turbine engines.
- are familiar with the analysis of vapour power cycles for large power plants, and finally,
- are familiar with the analysis of vapour compression refrigeration cycles.

**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 give you the skills to analyse thermodynamic systems. My hope is that you ultimately will be able to develop how thermodynamics relates to other subjects such as heat transfer and fluid mechanics. I would like to develop skills within you that will enable you to learn for the rest of your life. A subject such as thermodynamics should help you to become more environmentally aware. The inclusion of a section of work on the generation of power should help here.

Effective learning is supported when you are actively engaged in the learning process and by a climate of enquiry, and these are both an integral part of the lectures and consultation periods. You become more engaged in the learning process if you can see the relevance of your studies to professional, disciplinary and/or personal contexts, and the relevance is shown in the lectures and assignments by way of examples drawn from industry. Dialogue is encouraged between you, others in the class and the lecturers. Diversity of experiences is acknowledged.

## 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 so that the students know how to approach complex engineering calculations required in industry.
- To present a wealth of real-world engineering examples to give students a feel for how thermodynamics is applied in engineering practice

Consultation periods are designed to provide you with feedback and discussion on the assignments, and to investigate problem areas in greater depth to ensure that you understand the application and can avoid making the same mistake again.

## 5. ASSESSMENT

| There will be two, one-hour, mid-session tests during the semester. *They will be held on the 17st April and the 8th May.* |
|---|

**Break up of marks**

| | |
|---|---|
| 4 × laboratories | **10%** of final mark (2.5% each) |
| 2 × mid-session tests | **30%** of final mark (15% each) |
| 1 × final exam | **60%** of final mark |
| | **100%** |

***In order to pass the course, you must achieve an overall mark of at least 50%.***

### Assignments

There will be no assignments in MMAN2700 Thermodynamics.

### Laboratory work

**You are required to obtain a bound laboratory book** (alternate lined and graph pages) to record results of each experiment and analysis carried out whilst in the laboratory. The laboratory demonstrators will mark your preliminary work at the start of the laboratory period and mark your data collection and analysis at the end of the laboratory period. Ensure that your work is marked before you leave the laboratory and that your mark is entered in the class record and your laboratory book and initialled by the demonstrator. **You will not be admitted to the laboratory unless you are appropriately dressed for safe working, have a laboratory book, a calculator and present the assigned preliminary work.**

The laboratory demonstrators will give instructions on how to operate the equipment, and will explain what is required of you. **If in doubt**, ask. It is important that you fully understand the experiment at the time it is being carried out, when instruction is available. In some experiments you are only required to take readings at intervals, use the intermediate time to ask questions and find out what other members of your group are doing. Little is learned merely by sitting waiting to make a measurement - much is learned by inquiry and discussion.

**Attendance at all laboratory experiments to which you are assigned is compulsory and a register is taken.** If you are unable to attend, due to illness, it is important that you inform your lecturer as soon as possible so that you may be reassigned to that experiment at a later date.

**Transfer from other groups.** The laboratory groups are large so transfers between groups must be arranged through the lecturer.

Assessment of laboratory reports will contribute 10% to the final mark. Marks will be allocated for completion of preliminary analysis, results obtained and calculations made during the laboratory period (2 marks for preliminary work, 3 marks for measurements, data analysis and conclusions). You do not have to submit a formal report; results of any calculations must be shown to the laboratory demonstrators for checking during the laboratory period.

**Preparation prior to the laboratory periods is essential.** Study the laboratory notes so that you know what the experiment is about in advance of each laboratory session. If you arrive without the necessary preparation you may not be allocated the laboratory mark. Bring a calculator to all laboratory periods. **Submission of preliminary work which is not your own, or copying during the laboratory period, will result in a mark of <u>0</u> for the laboratory.**

### Safety

All staff and students must observe all safety requirements in the laboratory. You must come to the laboratory dressed for work, **NO LOOSE OR BAGGY CLOTHING, NO SANDALS OR BARE FEET**. Before beginning any experiment inspect all equipment you will use for potential hazards. While using laboratory equipment keep alert for any developing hazard, e.g. unusual noise, vibration, unusual data trends etc.

### Presentation

A standard specification is available from the school website to aid presentation of your assignments (in all courses). 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 for All Courses*, available from the School website.

## 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 an 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 for All Courses*, available on the School website.

## 7. COURSE SCHEDULE

| Week | Topic | Text Reference |
|---|---|---|
| 1 | 1. *Basic Concepts and Definitions*<br>• Systems, property, state, path, process, cycle<br>• Units, Specific volume, density and pressure<br>• Temperature and the zeroth law<br>• The equation of state for a perfect gas<br>• P-v-T surfaces for a perfect gas | Read Chapters 1 and 2 and sections 9, 12, 13 and 15 from Chapter 3. |
| 2 | 2. *Work and Heat*<br>• Definition of work<br>• Work processes<br>• Work done at the moving boundary of a closed system<br>• Definition of heat<br>• Examples of work and heat | |
| 3 | 3. *First Law of Thermodynamics for a Closed System*<br>• The first law<br>• Internal energy and enthalpy- thermodynamic<br>• properties, specific heats and property relations | |
| 4 | 4. *Properties of a Pure Substance*<br>• Vapour-liquid equilibrium in a pure substance<br>• P-v-T surfaces for real substances<br>• Tables of Thermodynamic properties (steam)<br>• Equations of state for real substances | Sections 1, 2, 3, 4, 5 and 6 of Chapter 3. |

| | | |
|---|---|---|
| 5 | 5. *First Law of Thermodynamics for an Open System*<br>• Energy entering the system, enthalpy<br>• The first law<br>• Steady flow steady state system - examples | Chapter 4. |
| 5 | 6. *Analysis of Open and Closed Systems*<br>• Throttling process, Joule-Thomson experiment<br>• Closed system applications<br>• Steady flow applications<br>• Filling and discharging of rigid vessels | All of the above along with section 5.3 of Chapter 11. |
| 6-8 | *7. Second Law of Thermodynamics*<br>• Definitions<br>• Clausius and Kelvin-Planck statements<br>• Carnot's principle, Carnot cycle<br>• Clausius Inequality<br>• Entropy as a property, irreversible processes<br>• $\delta Q$ = Tds equation<br>• Property relations of entropy<br>• Temperature-entopy and enthalpy-entropy diagrams<br>• Ideal and actual processes, isentropic efficiencies<br>• Carnot cycle<br>• Entropy change of an ideal gas<br>• T-s and h-s diagrams<br>• Isentropic efficiencies | Chapters 5 and 6. |
| 9-11 | *8. Air-standard power cycles*<br>• Reciprocating engine analysis<br>• Otto, Diesel and dual cycles<br>• Gas turbine analysis<br>• Simple Brayton cycle | Sections 1, 2, 3, 4, 5,6 and 11 of Chapter 9. |
| 12 | 9. *Vapour cycles*<br>• Rankine, reheat and regenerative cycles<br>• Basic refrigeration cycle | Sections 1, 2, 3 and 4 of Chapter 8 as well as sections 1 and 2 of Chapter 10. |

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

## 8. RESOURCES FOR STUDENTS

### Textbooks

| |
|---|
| M. J. Moran, H. N. Shapiro, D. D. Boettner & M. B. Bailey, (2012) Fundamentals of Engineering Thermodynamics, SI version, 7th Edition, John Wiley & Sons.<br>Y.R. Mayhew and G.F.C. Rogers, *Thermodynamic and Transport Properties of Fluids*, S.I. Units, Basil Blackwell. |

Both of these are available in the UNSW bookshop.

***You really must buy these books.*** If you are going to be a professional engineer, you will need references in the future. Some of the questions you are expected to try are in the first reference. Although the first reference contains a set of steam tables, they are of a different type to those found in Mayhew & Rogers. You will be required to be able to use those found in Mayhew & Rogers as these will be supplied in the final exam.

### Suggested additional readings

Y. A. Çengel and M. A. Boles, (2005) *Thermodynamics, an engineering approach*, 4th, 5th or 6th Edition, McGraw Hill Higher Education.

Sonntag and G. J. Van Wylen, (1991) *Introduction to thermodynamics classical and statistical*, 3rd Edition, John Wiley & Sons.

P. W. Atkins (2008), *Four laws that drive the universe*, Oxford University Press, or P. W. Atkins (2010), *The laws of thermodynamics. A Very Short Introduction,* Oxford University Press. They are the same book.

P. W. Atkins (1994), *The 2nd Law, energy, chaos & form*, Scientific American Publications.

P. W. Atkins (2003), *Galileo's finger, the ten great ideas of science*, Oxford University Press (Chapters 3 & 4).

H. C. von Baeyer (1999), *Warmth disperses and time passes, the history of heat, (previously published as Maxwell's demon),* The Modern Library, New York.

These are all available in the UNSW Library and are useful as additional reading material, giving good descriptions.

### Additional materials provided in Moodle

This course has a website on Moodle which includes:

- copies of the laboratories handouts;
- the consultation period notes (questions and numerical answers;
- a Mollier diagram.

### Recommended Internet sites

Be very careful when looking at websites that discuss thermodynamics. The sign conventions used in thermodynamics are not uniform around the world and some of these websites can therefore ***strongly mislead students***. For example, the following website gives a very good definition of temperature: http://www.chemistryexplained.com/St-Te/Temperature.html. You should read this sometime.

But if you go to: http://www.chemistryexplained.com/Te-Va/Thermodynamics.html, you will notice that the first law (equation (1)) is not written with the sign convention we use here in Australia. This may get students into a lot of trouble. The best approach for beginners is to use the texts recommended for the course.

### 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 consultation period 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.

## 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.

### Equity and disability

Students who have a disability that requires some adjustment in their teaching or learning environment are encouraged to discuss their study needs with the course convenor prior to, or at the commencement of, their course, or with the Equity Officer (Disability) in the Student Equity and Disability Unit (SEADU) by phone on 9385 4734, email seadu@unsw.edu.au or via the website www.studentequity.unsw.edu.au

The office is located on the Ground Floor of the John Goodsell building (F20). Issues to be discussed may include access to materials, signers or note-takers, the provision of services and additional exam and assessment arrangements. Early notification is essential to enable any necessary adjustments to be made.

*Dr J. Olsen*
February 2015

## LABORATORY TIMETABLE

| | | Week number and date at beginning of week | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **01 MONDAY 9am - 11am** | **GROUP** | **3** 16/3 | **4** 23/3 | **5** 30/3 | **6** 13/4 | **7** 20/4 | **8** 27/4 | **9** 4/5 | **10** 11/5 |
| | **1** | T1 | | T2 | | T3 | | T4 | |
| | **2** | | T1 | | T2 | | T3 | | T4 |

| | | Week number and date at beginning of week | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **02 MONDAY 11am – 1pm** | **GROUP** | **3** 16/3 | **4** 23/3 | **5** 30/3 | **6** 13/4 | **7** 20/4 | **8** 27/4 | **9** 4/5 | **10** 11/5 |
| | **1** | T1 | | T2 | | T3 | | T4 | |
| | **2** | | T1 | | T2 | | T3 | | T4 |

| | | Week number and date at beginning of week | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **03 MONDAY 1pm – 3pm** | **GROUP** | **3** 16/3 | **4** 23/3 | **5** 30/3 | **6** 13/4 | **7** 20/4 | **8** 27/4 | **9** 4/5 | **10** 11/5 |
| | **1** | T1 | | T2 | | T3 | | T4 | |
| | **2** | | T1 | | T2 | | T3 | | T4 |

| | | Week number and date at beginning of week | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **04 WEDNESDAY 9am – 11am** | **GROUP** | **3** 16/3 | **4** 23/3 | **5** 30/3 | **6** 13/4 | **7** 20/4 | **8** 27/4 | **9** 4/5 | **10** 11/5 |
| | **1** | T1 | | T2 | | T3 | | T4 | |
| | **2** | | T1 | | T2 | | T3 | | T4 |

| | | Week number and date at beginning of week | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **05 WEDNESDAY 11am – 1pm** | **GROUP** | **3** 16/3 | **4** 23/3 | **5** 30/3 | **6** 13/4 | **7** 20/4 | **8** 27/4 | **9** 4/5 | **10** 11/5 |
| | **1** | T1 | | T2 | | T3 | | T4 | |
| | **2** | | T1 | | T2 | | T3 | | T4 |

| | | Week number and date at beginning of week | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **06 WEDNEESDAY 1pm – 3pm** | **GROUP** | **3** 16/3 | **4** 23/3 | **5** 30/3 | **6** 13/4 | **7** 20/4 | **8** 27/4 | **9** 4/5 | **10** 11/5 |
| | **1** | T1 | | T2 | | T3 | | T4 | |
| | **2** | | T1 | | T2 | | T3 | | T4 |

| | | Week number and date at beginning of week | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **07 THURSDAY 12pm – 2pm** | **GROUP** | **3** 16/3 | **4** 23/3 | **5** 30/3 | **6** 13/4 | **7** 20/4 | **8** 27/4 | **9** 4/5 | **10** 11/5 |
| | **1** | T1 | | T2 | | T3 | | T4 | |
| | **2** | | T1 | | T2 | | T3 | | T4 |

| | | Week number and date at beginning of week | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **0T TUESDAY 12pm – 2pm** | **GROUP** | **3** 16/3 | **4** 23/3 | **5** 30/3 | **6** 13/4 | **7** 20/4 | **8** 27/4 | **9** 4/5 | **10** 11/5 |
| | **1** | T1 | | T2 | | T3 | | T4 | |
| | **2** | | T1 | | T2 | | T3 | | T4 |

T1 Thermodynamics Processes
T2 Reciprocating Air Compressor
T3 2nd Law of Thermodynamics
T4 Refrigeration

## CONSULTATION PERIODS

| Group | Day | Time | Location |
|---|---|---|---|
| 1 | Tuesday | 9am-10am | RC Theatre |
| 2 | Tuesday | 12pm-13pm | WEBST 256 |
| 3 | Tuesday | 2pm-3pm | WEBST 256 |
| 4 | Wednesday | 12pm-1pm | WEBST 256 |
| 5 | Thursday | 10am-11am | OMB145 |
| 6 | Thursday | 5pm-6pm | WEBST 256 |
| 7 | Thursday | 5pm-6pm | ElecEng418 |
| T | Monday | 10am-11am | WEBST 256 |

Consultation periods start in week 2 and finish in week 13.