Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie

School of Engineering

Department of Mechanical and Aeronautical Engineering

STUDY GUIDE:
THERMODYNAMICS
MTX311

Lecturer: Prof WG le Roux
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ORGANISATIONAL COMPONENT

1. GENERAL PREMISE AND EDUCATIONAL APPROACH

The aim of this module is to teach the student to apply thermodynamics to solving a broad range of engineering problems. Therefore, this module emphasises **understanding** rather than memorising, in order to stimulate **creative thinking** and the development of **innovative skills** amongst students in the field of thermodynamics. A problem-driven approach to learning is followed.

The course contains lectures, tutorials, practicals and assignments. The lectures will be used to explain new theory and to show how to use it. Tutorials will allow the students to practice with this newly acquired theory, allowing them to build understanding and applicable skills. The practicals will allow the students to get acquainted with thermodynamic experiments. The assignments are based on the practicals and will teach the students how to extract reliable information from the experiments.

Assessment criteria for each lecture unit are given. These objectives must be seen as the minimum level of knowledge/skill that the student will obtain after completion of the lecture theme. The objective for the complete course can be summarised as follows:

The purpose of this course is to make the student well acquainted with the basic principles of classical thermodynamics. These basic engineering principles are then used to solve simplified engineering problems. Emphasis will be on developing the ability to apply such concepts to typical engineering problems.

2. LECTURERS, VENUES AND CONSULTING HOURS

	Name	**Room No. and Building**	**Telephone No. and E-mail Address**
Lecturer	Prof Willem le Roux	ENG. 3, RM 6.83	012 420 2446, willem.leroux@up.ac.za
	Time	**Lecture Venue**	
Monday	12:30 – 13:20	Eng 3-6 / Virtual	
Tuesday	12:30 – 13:20	Eng 3-6 / Virtual	
Wednesday	9:30 – 10:20	Eng 3-1 / Virtual	
Thursday	15:30 – 17:20	Eng 3-6 / Virtual	

Location of the Laboratory
Practicals are presented in the wind tunnel laboratory on the basement level of the Heavy Machines Laboratory Building (behind Engineering Building II). *(Practical sessions might be virtual in 2022 – please see ClickUP for announcements regarding practical sessions).*

Consulting hours
By appointment, during office hours.

3. STUDY MATERIALS AND PURCHASES

(1) Borgnakke, Sonntag, 2017/2014/2009. Fundamentals of thermodynamics. SI version, 9th edition. New York: Wiley ISBN: 978-1-119-38284-3.
(2) Notes on material not covered in the textbook will be handed out at the beginning of each appropriate section.

* For additional/further reading, the following textbook is also recommended:
Çengel, Y.A. and Boles, M.A., 2015. Thermodynamics: An Engineering Approach, 8th Edition. New York: McGraw-Hill, 2015.

4. LEARNING ACTIVITIES

4.1 Contact time and learning hours

Students should expect to need a minimum of one and a half hours of study or group activity for each hour of lecture time.

Number of lectures: 3 per week
Number of tutorials: 2 per week
Laboratory work: Two practical sessions of duration 60-120 minutes.

4.2 Lectures

Fifty minutes lectures are scheduled for Mondays, Tuesdays and Wednesdays. The module is lectured on a problem based principle; the content is explained, after which the student will be allowed to practice. Self-assessment class tests will be given to allow the student to determine up to which level he/she masters the topic.

Course material is covered in the textbook. When a deviation from this rule is encountered, references or lecture notes will be made available. Lecture slides or PowerPoint presentations will be made available to the students via CLICKUP.

The lectures will each be 50 minutes of which 10 minutes are usually set aside for questions during and after the lecture.

4.3 Tutorial classes

There would normally be two one-hour tutorial classes in a week, however, the tutorial sessions on Thursdays can also be used for lecturing. Please keep an eye on ClickUP for announcements in this regard.

4.4 Laboratory work/Practicals

Two practicals will be scheduled for this module. Practicals will be taken by groups of typically 4 persons. You will be informed of the detail on ClickUP. Laboratory work is there to help you learn how to perform thermodynamics-related experiments, how to treat measurement errors and, most importantly, how to use the results for evaluation and optimisation of process equipment and operating conditions. Attendance of all the laboratory work and submission of all reports are a sub-minimum for this module. Students are required to wear closed shoes when they enter the laboratory (NO sandals). Clothing should be tucked in to reduce the risk of becoming entangled on equipment in the laboratory. Follow the instructions given by the teaching assistant or instructor. Unauthorised handling or adjusting of any piece of equipment or set-up in the laboratory is prohibited.

4.5 Assignments

The assignments will be posted on ClickUP and specific dates on which the assignments must be handed in will be given. Assignments are done individually, unless otherwise stated. In case of group assignments, each group must hand in one solution where evaluation of the assignments will be done for the group but individual marks may be awarded for the effort or contribution of the different students in the group.

5. RULES OF ASSESSMENT

Also see the examination regulations in the Year Books of the Faculty of Engineering, Building Environment and Information Technology (Part 1: Engineering or Part 2: Building Environment and Information Technology).

Two 90-minute semester tests will be written during the official test weeks. A 180-minute final exam will be written at the end of the semester. During the tests and exam the student will be tested according to the assessment criteria of the covered material in the lecture units. Specific focus will be on evaluation of the application of knowledge rather than reproduction of knowledge.

Unless stated otherwise, both semester tests and exam are open-book tests (written online or on campus – please see ClickUP for announcements). Thermodynamic tables, which will be available on ClickUP, should be printed out and can be used during tests. The students are also allowed to take the hand-outs and 1 A4, of his/her own notes (written on both sides). No programmable calculators will be allowed. No old exam papers or old exam memos are allowed.

Any **absence** from semester tests must be supported by an official and valid statement (e.g. a medical certificate) and must be submitted as per the regulations documented in the Departmental Study Guide. A special semester test for all legitimate absentees can be taken after the second test week. This test will be based on all the work done in the module thus far.

Marking rules might be different from what most students are used to. Especially towards the end of the course, the student will be asked to solve problems which can be tackled in various ways. Quite a significant amount of the marks can be given for making valid assumptions and for a good solution strategy. Marks can be deducted when the student demonstrates an utter lack of understanding, either by using an absolutely incorrect method or by giving impossible answers (negative temperatures in Kelvins or negative irreversibilities, for example).

Pass requirements

In order to pass the module a student must:

1. obtain a final mark of at least 50%
   and
2. obtain at least 50% for the laboratory work and attend all scheduled laboratory sessions as well as handing in all the required laboratory reports
   and
3. obtain a semester mark and an examination mark of at least 40%.

If a student obtained a final mark of 50% or more but did not meet the minimum laboratory work requirements, the laboratory work must be repeated successfully before a pass will be awarded. A student may qualify to write a re-examination during the week following the official examination (please see the Departmental Study Guide).

Calculation of the final mark

The final mark is calculated as follows:

Semester mark:	50%
Examination mark:	50%

Calculation of the semester mark

The semester mark is compiled as follows:

Assignments	15%
Semester tests	70%
Practicals	10%
Class Tests	5%

Please note that each assignment (group or individual) and each practical report (group or individual) must be handed in with the appropriate signed anti-plagiarism cover page (see Departmental Study Guide).

6. GENERAL

For any further enquiries on this module please contact the lecturer/lecturers.

7. DEPARTMENTAL STUDY GUIDE

This study guide is a crucial part of the general study guide of the Department. In the study guide of the Department, information is given on the mission and vision of the department, general administration and regulations (professionalism and integrity, course related information and formal communication, workshop use and safety, grievances, support services, plagiarism, class representative duties, sick test and sick exam guidelines, vacation work, appeal process and adjustment of marks, university regulations, frequently asked questions), ECSA Graduate Attributes, ECSA knowledge areas, CDIO, new curriculum and assessment of cognitive levels. It is expected that you are very familiar with the content of the Departmental Study Guide. It is available on the Department's website:

https://www.up.ac.za/mechanical-and-aeronautical-engineering/article/21692/student-noticeboard-of-mechanical-and-aeronautical-engineering

STUDY COMPONENT

1. MODULE OBJECTIVES, ARTICULATION AND LEARNING OUTCOMES

1.1 General objectives

The aim of this module is to teach the student to apply thermodynamics to solving a broad range of engineering problems. Therefore, this module emphasises **understanding** rather than memorising, in order to stimulate **creative thinking** and the development of **innovative skills** amongst students in the field of thermodynamics. A problem-driven approach to learning is followed.

Objectives for each lecture unit are given in Section 4. The objectives must be seen as the minimum level of knowledge that the student will obtain after completion of the lecture unit. The objective for the complete course can be summarised as follows:

The purpose of this course is to teach the student to apply the basic principles of classical thermodynamic to solving engineering problems. Emphasis will be on understanding the concepts and developing the ability to apply such concepts to typical engineering problems.

At the end of the course, the student should be able to apply thermodynamics for process analysis and design. Since thermodynamics is such a widely applied discipline, it is crucial for the student to understand that he/she has to be able to apply the learned material, also to topics which are not covered in the textbook. For this reason, it is very important that the student understands the theory of thermodynamics, knows which assumptions are used for specific equations and is able to assess the validity of these assumptions. For this reason, a large variety of examples will be treated during the lectures and tutorials.

In order to achieve the objectives, attendance of and meaningful participation during lectures, laboratory sessions and tutorial classes are essential. Furthermore, students are advised to embark on a well-structured and systematic study program, in which the module material is studied in a probing, scientific and innovative manner. It is very unlikely that passive memorization will result in successful completion of this course.

1.2 Prerequisite learning

Refer to the yearbook for prerequisites. Furthermore, descriptions of the material that will be dealt with in the lectures are listed in Section 4 (Study Theme: Descriptions). The student must prepare for the lectures by revising the material that will be dealt with.

1.3 Articulation with other modules in the programme

This module is a follow up on previous Thermodynamics modules. In this module fundamentals and principles are acquired that will be used in following modules, in particular Thermomachines, Heat Transfer and Final Year Project.

1.4 Critical learning outcomes

The ECSA Graduate Attributes (see the Departmental Study Guide) are addressed in the module. The specific outcomes are given in part 4.

2. MODULE STRUCTURE

Thermodynamics MTX311 contains 11 study themes (see the table below). Study theme 1-8 will be covered using lectures, tutorials and self-study. Note that these themes can be presented in any order – please keep an eye on ClickUP for announcements.

Study theme	Number of contact sessions	Notional hours
1 Introduction	2	6
2 Combustion	5	15
3 Compressible flow	4	12
4 Power cycles (gas cycles)	3	9
5 Refrigeration cycles (phase-change cycles)	4	12
6 Gas Mixtures	6	18
7 Exergy analysis	9	27
8 Real gases	3	9
9 Preparation sem. tests and exam	4	12
10 Practicals	4	12
11 Assignments		28
Total	44	160

3. PRACTICAL SESSIONS

3.1 Air Conditioner

- **Learn to perform a simple thermodynamic experiment**
- **Learn the relevance of error analysis for thermodynamic experiments**
- **Get acquainted with the relevance of homogeneity in phase transfer**
- **Apply mass balance and 1st law to experimental results**

3.2 Refrigeration cycle

- **Learn to use PV and TS diagrams for process investigation**
- **Learn to determine first and second Law efficiencies**
- **Learn to use second law efficiency calculations for process optimisation**

4. GUIDELINES FOR USING THE STUDY THEME DESCRIPTIONS

Refer to the Departmental Study Guide.

5. STUDY THEME DESCRIPTIONS

STUDY THEME 1: REVISION OF LAST YEAR

Assessment criteria:

This section is a condensed review of a large part of the work done in the first course in Thermodynamics. Proper knowledge of the following aspects is expected after completing this section:

1. Work, heat, internal energy and enthalpy
2. Mass conservation and the first law of thermodynamics
3. **Entropy** & The second law of thermodynamics
4. PVT relations for polytropic processes involving ideal gases
5. Phase diagrams

Alternative meaning and definitions of entropy and temperature will be treated in this theme.

Study material: Notes

STUDY THEME 2: COMBUSTION, INTERNAL COMBUSTION ENGINE

After completing this section the student must:

1. Be able to understand and describe the combustion of coal and hydrocarbon fuels thermodynamically. The student is to be able to apply the latter to problems.
2. Write chemical equations for a particular combustion process and balance the equation.
3. Be able to balance the chemical equation for both theoretical excess and shortage of air.
4. Be able to calculate the heat generated during the combustion process.
5. Know and understand the following terms:
   - (a) Enthalpy of formation
   - (b) Adiabatic flame temperature
   - (c) Heat of the reaction
   - (d) Third Law of Thermodynamics
6. Be able to write and balance a chemical equation for a combustion process, based on information on the products of combustion.
7. Be able to understand characteristics and performance of Internal Combustion Engines

Study material: Borgnakke and Sonntag (Chapter 13)

STUDY THEME 3: SUPERSONIC FLOW TROUGH NOZZLES

After completion of this section the students must:

1. Know and understand the following principles :
   - (a) Sonic speed in a particular medium.
   - (b) Mach number.

(c) What a normal shock is and how it occurs.
2. Understand and be able to explain the conditions that determine whether the flow through a nozzle is subsonic or supersonic.
3. Be able to calculate where in a nozzle a shock wave will form.
4. Be able to analyse the flow through a nozzle in which shock waves exists at a certain point.

Study material: Borgnakke and Sonntag (Chapter 15)

STUDY THEME 4: POWER CYCLES

Part of this section is a condensed review of the work done in the first course in Thermodynamics on power cycles. This background will be combined with the gained knowledge from study theme 4 to teach the student to evaluate process losses.

After completing this section the students must:

1. Be able to differentiate between vapour power systems and gas power systems and its application in the internal combustion engines.
2. Be able to sketch PV and T-S diagrams of various power cycles.
3. Understand the difference between real and reversible power cycles
4. Be able to use the second law and the principles of conservation of mass and energy.
5. Be able to use above stated principles combined with property data to determine power efficiency, net power output and mass flow rates.
6. Be able to apply the exergy balance to a real power cycles.

Study material: Borgnakke and Sonntag (Chapter 9 and 10)

STUDY THEME 5: REFRIGERATION CYCLES

After completing this section the students must:

1. Be able to draw and explain the Carnot refrigeration cycle.
2. Know the differences between the Carnot and real refrigeration cycles and be able to explain why the differences are necessary.
3. Be able to draw all cycles on both T-s and p-v diagrams.
4. Be able to calculate the coefficient of performance of a particular cycle.
5. Be able to explain the principle of flash gas removal.
6. Be able to analyse systems in which more than one compressor and/or evaporator exists.
7. Understand the principle of inter cooling.

Study material: Borgnakke and Sonntag (Chapter 9 and 10)

STUDY THEME 6: MIXTURES OF GASES

Assessment criteria:

After completing this section the students must:

1. Understand and be able to explain the behaviour of ideal gas mixtures of air and water vapour, and its application to real systems.
2. Be able to explain the principle of psychometric
3. Be able to explain the humidity ratio, relative humidity and mixture enthalpy.
4. Be able to evaluate and explain the dew point temperature.
5. Be able to explain and to use psychometric charts.
6. Be able analyze the air conditioning process.

Study material: Borgnakke and Sonntag (Chapter 11)

STUDY THEME 7: IRREVERSIBILITY AND EXERGY

After completing this section the student must:

1. Be able to calculate the exergy at a particular state, both for control mass, control volume and reactive systems.
2. Understand when to use an exergy analysis and be able to perform a simple exergy analysis to a real process
3. Must understand the term irreversibility and be able to calculate the irreversibility for control mass and control volume processes of processes,
4. Be able to quantitatively identify different types of irreversibilities and have an understanding of what needs to be done to reduce the irreversibility of a particular process.

Study material: Borgnakke and Sonntag (Chapter 8)

STUDY THEME 8: REAL GASES

After completing this section, the student must:

1. Know and be able to analyse the behaviour of real gases.
2. Know when to use real gas analysis. He/she must also be aware of the limitations of the different models and when not to apply a particular model.
3. The principle of enthalpy deviations in real gases and be able to solve engineering problems using the first law of thermodynamics and the theory of enthalpy deviations.
4. The principle of entropy deviations in real gases and the application of the theory to engineering problems in which the second law of thermodynamics is used.