NANYANG TECHNOLOGICAL UNIVERSITY

Teaching, Learning and Pedagogy Division

Reg. No. 200604393R

COURSE OUTLINE TEMPLATE FOR STUDENTS AT NTU

Academic Year	AY2017/18	**Semester**	both
Course Coordinator	Prof Ng Yin Kwee (Semester 1) Prof Fei Duan (Semester 2)		
Course Code	MA2007		
Course Title	Thermodynamics		
Pre-requisites	MA2003 Introduction to Thermo-fluids		
No of AUs	3		
Contact Hours	Lectures: 26 Hours Tutorials: 13 Hours		
Proposal Date	26 December 2017		

Course Aims

This is a core mechanical engineering course covering the basic concepts and principles of thermodynamics and its major applications. You are taught how to use second law to describe irreversible processes. You will be introduced to ideal gas mixtures and their applications in the analyses of psychrometry. You will learn to evaluate closed systems and steady-flow open systems of basic thermodynamic devices and processes on the basis of the first and second law of thermodynamics, analyse thermodynamic cycles and apply them to power and refrigeration systems. You will learn how to describe and analyse combustion systems. You will develop necessary skills and abilities to analyse and solve realistic engineering problems using thermodynamic principles.

Intended Learning Outcomes (ILO)

By the end of the course, you should be able to:

1. Evaluate the thermodynamic properties including internal energy, enthalpy, entropy and the others for ideal gases, water/ steam and major refrigerant.
2. Further understand basic thermodynamic systems and their interactions with the surroundings for analysis.
3. Employ the second law of thermodynamics in the closed systems and steady state control volumes based on the energy balances (the first law analysis).
4. Interpret the concept of maximum thermal efficiency or coefficient of performance of the thermodynamic cycles correctly.
5. Use the entropy concept to analyse closed systems and steady state control volumes undergoing reversible and irreversible processes.
6. Explain the working principle of vapour power plants and gas power systems and analyse them on the basis of thermodynamic cycles.
7. Analyse refrigeration and heat pump systems based on their working principles
8. Evaluate the properties of ideal gas mixtures and apply thermodynamic laws to air conditioning processes involving mixing and air-water vapour mixtures.
9. Balance chemical reaction equations in combustion, evaluate the enthalpy of formation of substances and use it to analyse energy balance for reacting systems.

10. Identify the thermodynamics processes and their relevance to industrial problems and analyse evolving complex thermodynamics problems.
11. Make appropriate assumptions when applying the thermodynamics laws to real-world and engineering problems.

Course Content

(1) Second Law of Thermodynamics and Entropy (2 hours)

- Review of thermodynamic properties, systems and first law of thermodynamics
- Introduction to second law of thermodynamics
- Thermal energy reservoirs
- Heat engines
- Refrigerators and heat pumps
- Statements of the second law
- Reversible and irreversible processes
- Carnot cycle
- Carnot principles
- Thermodynamic temperature scale
- Carnot heat engines, refrigerators and heat pumps

(2) Entropy (7 hours)

- Clausius inequality and entropy
- Increase of entropy principle
- Isentropic processes
- Property diagrams Involving entropy
- What is entropy?
- The Tds relations
- Entropy change of liquids and solids
- Entropy change of ideal gases
- Entropy balance for steady flow control volumes
- Reversible steady flow work
- Minimizing the compressor work
- Isentropic efficiencies of steady flow devices
- Entropy balance

(3) Refrigeration and Heat Pump Systems (4 hours)

- Characteristics of refrigerators and heat pumps
- Schematics of Carnot vapour compression
- Ideal vapor-compression refrigeration cycle
- Principal irreversibilities and losses
- Actual vapour-compression refrigeration cycle
- Other vapour refrigeration cycles
- Refrigerants and environment
- Absorption refrigeration vs vapour compression cycle
- Heat pump systems
- Refrigerants
- Heat pumps
- Gas refrigeration systems

(4) Analyses of Thermodynamic Cycles (7 hours)

a. Gas power systems
    - Power cycles

- Carnot cycle
- Air standard assumptions and gas power cycles
- Reciprocating IC engines, Otto, Diesel and Dual cycles
- Air standard Brayton cycle
- Brayton cycle with regeneration, reheat and intercooling
- Jet propulsion cycle

b. Vapour power systems

- Vapour power systems
- Rankine cycle
- Superheat and reheat
- Regenerative cycles
- Cogeneration
- Combined gas-vapour power cycle

(5) Non-reacting Gas Mixtures and Psychometrics (3 hours)

- Composition of gas mixtures
- Properties of Ideal gas mixtures
- Principles of psychrometrics
- Conservation of mass and energy for psychrometric systems
- Applications

(6) Reacting Mixtures and Combustion (3 hours)

- Fuels and Combustion, A/F ratio, products of combustion
- Enthalpy of formation and enthalpy of combustion
- First-law (energy) analysis reaction systems
- Introduction to other combustion and reacting system topics

Assessment (includes both continuous and summative assessment)

Component	**Course LO Tested**	**Related Programme LO or Graduate Attributes**	**Weighting**	**Team/Individual**	**Assessment rubrics**
Final Examination (Closed Book;2.5hrs)	1 - 11	SLO a, b, c, d, g, l	60%	Individual	
Continuous Assessment 1 (CA1): Take-home Quiz	1 – 3	SLO a, b, c, d	10%	Individual	
Continuous Assessment 2 (CA2): Quiz	1 – 5 7	SLO a, b, c, d, g	15%	Individual	
Continuous	6 ,10,11	SLO a, b, c, d, g, k	15%	Individual	

Assessment 3 (CA3): Quiz					
Total			100%		

* EAB SLO stands for the Engineering Accreditation Board Student Learning Outcomes. The list is below:

a) **Engineering knowledge:** Apply the knowledge of mathematics, natural science, engineering fundamentals, and an engineering specialisation to the solution of complex engineering problems

b) **Problem Analysis:** Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

c) **Design/development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.

d) **Investigation:** Conduct investigations of complex problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions

e) **Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.

f) **The engineer and Society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

g) **Environment and Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for the sustainable development.

h) **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

i) **Individual and Team Work:** Function effectively as an individual, and as a member or leader in diverse teams and in multidisciplinary settings.

j) **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

k) **Project Management and Finance:** Demonstrate knowledge and understanding of the engineering and management principles and economic decision-making, and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

l) **Life-long Learning:** Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

Formative feedback

• The outcome of the quiz will be released through NTULearn (on grades) and discussed after the quiz to provide feedback and correct any mistakes/misapplication of concepts made by you.

• You are encouraged to participate actively in tutorial class. This will help clarify your doubts.

• Feedback will be welcome through the course, where you could write in to the lecturers for constructive suggestions.

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Lecture	All concepts, involved in the course, are explained; examples of practical problems solving are provided.
Tutorial	Students are to learn how to employ the concepts they learned for solving problems individually and discuss the solutions presented during the tutorial sessions.

Reading and References

Yunus A. Cengel, Michael A. Boles. THERMODYNAMICS: An Engineering Approach, 6th Edition, McGraw-Hill, NY, 2007, ISBN 978-007-125771-8.
(7th (2011) or 8th Edition (2015) in SI Units are also acceptable)

Course Policies and Student Responsibilities

1) General

You are expected to complete all assigned pre-class readings and activities, attend and participate in every tutorial session. You are expected to take responsibility to follow up with course notes and course related announcements.

2) Quizzes

Note that it is compulsory for you to take the quizzes for this course. In the case of absence due to medical reasons, you must submit a medical certificate to the School not later than 1 week after that quiz, failing which you would be considered to be absent and given 0 mark for that component of the CA. The original medical certificate with the appropriate Leave of Absence form should be endorsed by respective tutor and submitted to the MAE Undergraduate Office with a scanned version emailed to the Course Coordinator and the tutor concerned

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Eddie Ng YK	N3.2-02-70	6790 4455	mykng@ntu.edu.sg
Chan Siew Hwa	N3.2-02-12	6790 4862	mshchan@ntu.edu.sg
Fei Duan	N3.2-02-84	6790 5510	FeiDuan@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Review of thermodynamic properties, systems and first law of thermodynamics Introduction to second law of thermodynamics Thermal energy reservoirs Heat engines Refrigerators and heat pumps Statements of the second law Reversible and irreversible processes Carnot cycle Carnot principles Thermodynamic temperature scale Carnot heat engines, refrigerators and heat pumps	1 - 3	Access recorded lecture sequence NTULearn/ LAMS
2	Clausius inequality and entropy Increase of entropy principle Isentropic processes	3 - 5	Access recorded lecture sequence NTULearn/ LAMS
	Tutorial #1 in Classroom	1 – 3	Attend tutorial
3	Property diagrams Involving entropy What is entropy? The Tds relations Entropy change of liquids and solids Entropy change of ideal gases	3 – 5	Access recorded lecture sequence NTULearn/ LAMS
	Tutorial #2 in Classroom	1– 5	Attend tutorial
4	Entropy balance for steady flow control volumes Reversible steady flow work Minimizing the compressor work Isentropic efficiencies of steady flow devices	3 - 5	Access recorded lecture sequence NTULearn/ LAMS
	Tutorial #3 in Classroom	1 – 5	Attend tutorial

5	Entropy balance Characteristics of refrigerators and heat pumps Schematics of Carnot vapour compression	3- 5	Access recorded lecture sequence NTULearn/ LAMS
	Tutorial #4 in Classroom	1 - 5	Attend tutorial
6	Ideal vapor-compression refrigeration cycle Principal irreversibilities and losses Actual vapour-compression refrigeration cycle Other vapour refrigeration cycles Refrigerants and environment Absorption refrigeration vs vapour compression cycle	7	Access recorded lecture sequence NTULearn/ LAMS
	Tutorial #5 in Classroom	1 - 5	Attend tutorial
7	Heat pump systems Refrigerants Heat pumps Gas refrigeration systems Power cycles. Carnot cycle. Air standard assumptions and gas power cycles.	7 6, 10-11	Access recorded lecture sequence NTULearn/ LAMS
	Tutorial #6 in Classroom	7	Tutorial + Quiz
8	Reciprocating IC engines, Otto, Diesel and cycles. Air standard Brayton cycle. Brayton cycle with regeneration, intercooling.	6 – 10 - 11	Access recorded lecture sequence NTULearn/ LAMS
	Tutorial #7 in Classroom	7	Attend tutorial
9	Jet propulsion cycle. Vapour Power Systems. Rankine Cycle.	6, 10 -11	Access recorded lecture sequence NTULearn/ LAMS
	Tutorial #8 in Classroom	6, 10 -11	Attend tutorial
10	Superheat and reheat. Regenerative cycles. Cogeneration. Combined gas-vapour power cycle.	6, 10 -11	Access recorded lecture sequence NTULearn/ LAMS
	Tutorial #9 in Classroom	6, 10 -11	Attend tutorial
11	Composition of gas mixtures. Properties of Ideal gas mixtures. Principles of psychrometrics.	8, 10-11	Access recorded lecture sequence NTULearn/ LAMS
	Tutorial #10 in Classroom	6, 10 -11	Attend tutorial
12	Conservation of mass and energy for psychrometric systems. Applications. Fuels and Combustion, A/F ratio, products of combustion.	6, 9 -11	Access recorded lecture sequence NTULearn/ LAMS
	Tutorial #11 in Classroom	8, 10 -11	Attend tutorial

13	Enthalpy of formation and enthalpy of combustion. First-law (energy) analysis reaction systems. Introduction to other combustion and reacting system topics.	9 -11	Access recorded lecture sequence NTULearn/ LAMS
	Tutorial #12 in Classroom	9 -11	Attend tutorial