MA3010 Thermodynamics and Heat Transfer OBTL July 26 2021

Thermodynamics & Heat Transfer (Nanyang Technological University)

Teaching, Learning and Pedagogy Division

Reg. No. 200604393R

Academic Year	2021/2022	**Semester**	1
Course Coordinator	Assistant Professor Hou Han Wei		
Course Code	MA3010		
Course Title	Thermodynamics & Heat Transfer		
Pre-requisites	MA2003 Introduction to Thermo-fluids		
No of AUs	3		
Contact Hours	Lectures: 26 hours Tutorials: 13 hours		
Proposal Date	July 2019		

Course Aims

This is a core mechanical engineering course covering the basic concepts and principles of thermodynamics and heat transfer.

You will be 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 basic concepts of heat transfer and how to describe and analyse systems, in which heat transfer by conduction, convection and radiation takes place. You will develop necessary skills and abilities to analyse and solve realistic engineering problems using basic concepts of thermodynamics and heat transfer.

Intended Learning Outcomes (ILO)

Upon successful completion of the course, you will be able to

1) set up basic thermodynamic systems and their interactions with the surroundings for analysis,
2) perform energy balances (1st Law analysis) for closed systems and steady state control volumes,
3) evaluate the thermodynamic properties for ideal gases, water/steam and major refrigerants,
4) identify and explain processes using the 2nd Law of thermodynamics and the concept of maximum efficiency of thermodynamic cycles,
5) use the entropy concept to analyse closed systems and steady state control volumes undergoing reversible and irreversible processes,
6) differentiate between thermodynamics and heat transfer,
7) differentiate between conduction, convection and radiation modes of heat transfer,
8) describe the main principles of conduction heat transfer (steady and unsteady cases),
9) describe the main principles of convection heat transfer (forced and free/natural cases),
10) describe the main principles of radiation heat transfer, and make appropriate assumptions when applying the thermodynamic and heat transfer laws to real-world and

engineering problems.

Course Content

	Topic	Hours
1	**Second Law of Thermodynamics and Entropy** Irreversible and reversible processes. Statements of the Second law and corollaries. Thermodynamic temperature scale. Carnot cycle and maximum performance of cycles. Clausius inequality. Entropy. Entropy change for pure substances. Entropy balance for closed systems. Entropy rate balance for control volumes. Isentropic and polytrophic processes. Isentropic efficiencies of devices. Reversible steady flow processes.	7
2	**Non-reacting Gas Mixtures and Psychrometrics** Description of mixture composition. Properties of ideal and real gas mixtures. Principles of psychrometrics. Conservation of mass and energy for psychrometric systems. Air conditioning processes.	6
3	**Conduction heat transfer** Concepts of heat flow. Fourier's Law; one dimensional heat conduction. Steady conduction: the concept of thermal resistance; thermal energy generation. Unsteady heat flow concept (the lumped capacitance method).	4
4	**Convection heat transfer** Forced convection: external convection (flows over bodies) and internal convection (duct flow). Free convection over flat plate, cylinder and sphere.	6
5	**Radiation** Blackbody radiation. Properties of surfaces, view factor concept.	3

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team/Individual	Assessment rubrics
1. Continuous Assessment 1 (CA1): Quiz	1-6	EAB SLO a,b,c,d	15%	Individual	
2. Continuous Assessment 2 (CA2): Quiz	7-8	EAB SLO a,b,c,d	15%	Individual	
3. Continuous Assessment 3	1-10	EAB SLO a,b,c	10%	Individual	

(CA3):Weekly online Quizzes					
4. Final Examination (2.5 hours; Closed book)	1-10	EAB SLO a,b,c,d	60%	Individual	
Total			100%		

Formative feedback

The outcome of the quiz will be released after the quiz to provide feedback and correct any mistakes/misapplication of concepts made by the class.

The answers for the weekly online quiz (on NTU Blackboard) will be provided upon submission to reinforce key concepts of the lecture materials.

Youare encouraged to participate actively in tutorials and present your solutions and approaches to the tutorial questions. The instructor will comment on your solutions and clarify doubts on key concepts.

Feedback is welcome during the course and you can 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	Lectures provide important background concepts, and numerous worked and practical examples will also be included to assist you in your learning.
Tutorial	You will learn to apply key concepts to solve engineering problems. You are encouraged to present your solutions for class discussions.

Reading and References

Textbook

1. 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)

2. Cengel, Y.A. and Ghajar, A.J., Heat and Mass Transfer: Fundamentals and Applications, 5th

Edition (SI Units), McGraw Hill, 2015

Course Policies and Student Responsibilities

As a student of the course, you are required to abide by both the University Code of Conduct and the Student Code of Conduct. The Codes provide information on the responsibilities of all NTU students, as well as examples of misconduct and details about how students can report suspected misconduct. The university also has the Student Mental Health Policy. The Policy states the University's commitment to providing a supportive environment for the holistic development of students, including the improvement of mental health and wellbeing. These policies and codes concerning students can be found in the following link.
http://www.ntu.edu.sg/CampusLife/StudentLife/Pages/StudentConduct.aspx

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
Dr Hou Han Wei	N3-02c-86	6790 4950	hwhou@ntu.edu.sg
Aw Kuan Thai	N.A	9297 5109	ktaw@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Review of first law of thermodynamics Review of thermodynamic properties, property diagrams and property tables	Understand the law of conservation of energy (ILO 1, 2) Review on definition of thermodynamic properties and systems, understand how to interpret	Access recorded lecture sequence Textbook (Cengel, Y.A., Boles, M.A. and Kanoglu, M.) Chapter 1 to 6

	Heat engines, refrigerators and heat pumps Reversible and irreversible processes Clausius inequality and Kelvin-Plack statement Carnot cycle, Carnot principles Thermodynamic temperature scale	property diagrams and property tables (ILO 3) Understand the working principles of heat engines, refrigerators and heat pumps (ILO 1, 2, 4) Understand and differentiate between reversible and irreversible processes (ILO 4) Understand the concepts behind the Clausius inequality and Kelvin-Plack statement (ILO 4) Understand the processes of the Carnot cycle, relate the Carnot principles to the 2nd law of thermodynamics. (ILO 4) Understand the basis for the thermodynamic temperature scale (ILO 4)	
2	Entropy definition Entropy change for reversible, irreversible processes	Understand the concept of entropy (ILO 5) Understand how entropy changes for different processes (ILO 4 ,5)	Access recorded lecture sequence Textbook (Cengel, Y.A., Boles, M.A. and Kanoglu, M.) Chapter 7
3	Tds relations	Understand the Tds equation and its	Access recorded lecture sequence

	Entropy change of liquids and solids Entropy change for ideal gases	different forms (ILO 4, 5) Understand the application of Tds equations to the different states of matters and their entropy changes (ILO 4, 5)	Textbook (Cengel, Y.A., Boles, M.A. and Kanoglu, M.) Chapter 7
4	Entropy balance for steady flow control volumes Reversible steady flow work Isentropic efficiencies of steady flow devices	Understand how entropy changes during different processes for flow systems (ILO 3, 4, 5) Understand and identify reversible steady flow work (ILO 4, 5) Understand the concept of isentropic efficiency (ILO 4, 5)	Access recorded lecture sequence Textbook (Cengel, Y.A., Boles, M.A. and Kanoglu, M.) Chapter 7
5	Composition of gas mixtures, properties of ideal gas mixtures Energy balance for ideal gas mixtures	Understand gas mixtures and their properties (ILO 3) Understand how the properties of gas mixtures changes via different processes (ILO 2, 3)	Access recorded lecture sequence Textbook (Cengel, Y.A., Boles, M.A. and Kanoglu, M.) Chapter 13
6	Dry and atmospheric air Specific and relative humidity Dew-point, adiabatic saturation and wet bulb temperatures Psychrometric chart	Overview on atmospheric air (ILO 3) Understand the different definitions and vapour states for atmospheric air (ILO 2, 3) Understand how to interpret the psychrometric chart (ILO 2, 3)	Access recorded lecture sequence Textbook (Cengel, Y.A., Boles, M.A. and Kanoglu, M.) Chapter 14

7	Air-conditioning processes Introduction to heat transfer Heat transfer mechanisms and simultaneous heat transfer modes	Understand the various air-conditioning processes and identify the paths on a psychrometric chart (ILO 2,3) Understand the fundamental principles of heat transfer (ILO 6) Obtain a broad overview of different heat transfer mechanisms (ILO 7)	Access recorded lecture sequence Textbook (Cengel, Y.A., Boles, M.A. and Kanoglu, M.) Chapter 14 Textbook (Cengel, Y.A. and Ghajar, A.J.) Chapter 1
8	Fourier's Law Heat conduction equations and one-dimensional heat conduction Steady-state heat conduction and concept of thermal resistance Thermal resistance network Heat conduction with thermal energy generation	Understand the fundamentals of heat transfer (ILO 8) Understand multi-dimensional and time dependence of heat transfer (ILO 8) Understand the concept of thermal resistance and its limitations (ILO 8) Understand and evaluate the total thermal resistance of a system (ILO 8) Understand and evaluate heat conduction when there is thermal energy generation involved (ILO 8)	Access recorded lecture sequence Textbook (Cengel, Y.A. and Ghajar, A.J.) Chapter 2
9	Transient conduction: Lumped capacitance model	Understand conditions at which lumped system analysis are	Access recorded lecture (NTULearn) Textbook (Cengel,

	Fundamentals of convection: Classification of fluid flow, dimensional less groups and their significance	applicable. (ILO 8) Understand physical mechanism of convection. Derivation of differential equations based on mass, momentum and energy balance. (ILO 9)	Y.A. and Ghajar, A.J.) Chapter 4 and 6
10	External forced convection: Flow over flat plate, cylinder and sphere	Distinguish laminar and turbulent flow. Understand various approaches to analyse local and averaged convection coefficients. (ILO 9)	Access recorded lecture (NTULearn) Textbook (Cengel, Y.A. and Ghajar, A.J.) Chapter 7
11	Internal forced convection Radiation	Understand different flow regimes in internal flow. Analyse heat convention problems with constant heat flux or surface temperature conditions. (ILO 9) Fundamentals of thermal radiation. Properties of surfaces. (ILO 10)	Access recorded lecture (NTULearn) Textbook (Cengel, Y.A. and Ghajar, A.J.) Chapter 8 and 12
12	Radiation	Blackbody radiation. View factor concept. (ILO 10)	Access recorded lecture (NTULearn) Textbook (Cengel, Y.A. and Ghajar, A.J.) Chapter 13
13	Radiation and Revision	View factor concept worked examples. (ILO 10)	Access recorded lecture (NTULearn) Textbook (Cengel, Y.A. and Ghajar, A.J.) Chapter 13

Appendix 1

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

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*