



Fundamentals of Thermodynamics

1.0 Course Faculty Information

Name: Prof. Dr. M. Enamul Hossain
NSRIC Chair Professor in Sustainable Energy
NSRIC Inc., Toronto, Ontario, Canada

2.0 Course Information

Course Codes	
Class Days	Follow posting in NSRIC LMS system
Class Time	Follow posting in NSRIC LMS system
Course Credit Hours	2 + 2
Class Location	NSRIC online platform
prerequisites and/or co-requisites	n/a
Level /A, E, H, I, K12, M, P, S, T, U, V, W	M

Note: The below classification of courses is related to any areas of knowledge:

A: Advanced level academic level courses; **C:** Canadian immigration and training courses; **E:** Executive courses; **H:** Higher-level courses (i.e., graduate courses); **I:** Intermediate courses (i.e., university preparatory courses – Grade XII+); **K12:** Foundational, and lower-level courses; **M:** Mid-level courses (i.e., undergraduate courses); **P:** Professional courses; **S:** Short/seminar courses; **T:** Training courses; **U:** Tutorial Courses; **V:** Vocational training courses; and **W:** Workshop courses.

3.0 Professor Information

Name	Prof. Dr. M. Enamul Hossain
Title	NSRIC Chair Professor in Sustainable Energy
Contact Information	enamulh@nsric.ca ; dr.mehossain@gmail.com
Office Location	NSRIC online platform
Office Hours	10: 30 am – 11:30 am EST (Monday) by email appointment

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4.0 Target Audiences

- University graduates, early career engineers, scientists, and professional engineers.
- Diploma and vocational training student.
- Science and engineering undergraduate-level student.
- Any student who is interested in thermal engineering.
- Any student who is interested in automobile engineering.

5.0 Course Modules Descriptions

Module I

This course introduces students to the fundamental concepts of pure substances, phases, P-V T-V and P-V-T diagrams, classification of matters, equation of state, compressibility factor, dimensions and units, thermodynamic system and the surrounding, intensive property, extensive property, state, equilibrium, process, and the zeroth law of thermodynamics. The course also covers the basics of the thermodynamic cycles. This module explains each concept in detail and with examples and illustrations. This approach will make the students interested in enrolling in the course.

This module is a foundation, resource guide and an excellent source for science and engineering students, early career professionals, and executives who want to learn concepts, design, and dimensions through enough practice of the theories and examples. This module is designed for individuals and students who need to understand the basics of thermodynamics. The course contains a total of six lectures, and each lecture comprises 20 to 35 PowerPoint presentation slides and pdf documents. The course is also designed with two quizzes and two assignments. Students are strongly advised to complete the “Fundamentals of Thermodynamics (Module I – IV)” course by Prof. M. Enamul Hossain at NSRIC Platform to understand this course content.

Keywords: pure substances, phases, T-V diagram, P-V diagram, P-V-T diagram, classification of matters, mixture, homogeneous, heterogeneous, primary or fundamental dimensions, secondary or derived dimensions, dimensions and units, thermodynamic system and the surrounding, open system, closed system, isolated system, rigid/adiabatic system, intensive property, extensive property, state, equilibrium, and process, thermodynamic cycle, process, non-equilibrium process, quasi-equilibrium process, steady flow process, isobaric process, isochoric process, isentropic process, isothermal process, microscopic view, macroscopic view, reference points, path & point functions, work, heat, and energy transfer.

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Module II

This course covers the fundamental concepts of heat, work, and energy. In addition, the module discusses kinetic energy, potential energy, macroscopic and microscopic energies, temperature, internal energy, heat, conduction, convection, radiation, electromagnetic energy, linear and volume thermal expansion. The first law of thermodynamics is introduced and used to analyze entropy and enthalpy. For flash point calculation and experimental test (i.e., Pensky Marten apparatus), a test procedure is introduced in addition to the mathematical modelling which is covered in Module IV. The Clausius inequality and Mollier diagram are also illustrated in this module. This course explains each concept in detail and with examples and illustrations. This approach will make the students interested in enrolling in the course.

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Keywords: Energy, kinetic energy, potential energy, macroscopic and microscopic energies, flash point, ignition point, fire point, Pensky Marten apparatus, first law of thermodynamics, temperature, internal energy, heat, entropy, enthalpy, conduction, convection, radiation, electromagnetic energy, particularly infrared photons, linear thermal expansion, volume thermal expansion, Clausius inequality, and Mollier diagram.

Module III

This course covers the limitations of first law and the fundamental concepts of second law of thermodynamics, reversible and irreversible processes, Gibbs free energy, Gibbs energy equation, heat capacity, exothermic and endothermic reactions, Kelvin–Planck statement, Clausius statement, perpetual motion machine (PMM), PMM2, perpetual-motion machine of the second kind (PMM2). Further, the different aspects of the second law of thermodynamics are discussed. Module III introduces the concepts of the different thermodynamic cycles such as ideal cycle, Carnot cycle, power cycles, heat pump cycles, Otto cycle, diesel cycle, Brayton cycle, Atkinson cycle, dual cycle, Rankine cycle, heat engines, and Ericsson cycle. A details of Carnot cycle and the derivations of efficiency are illustrated. This course explains each concept in detail and with examples and illustrations. This approach will make the students interested in enrolling in the course.

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This module is a foundation, resource guide and an excellent source for science and engineering students, early career professionals, and executives who want to learn concepts, design, and dimensions through enough practice of the theories and examples. This module is designed for individuals and students who need to understand the basics of thermodynamics where the second law of thermodynamics is the main focus. The course contains a total of six lectures, and each lecture comprises 20 to 35 PowerPoint presentation slides and pdf documents. The course is also designed with two quizzes and two assignments. Students are strongly advised to complete the “Fundamentals of Thermodynamics (Module I – IV)” course by Prof. M. Enamul Hossain at NSRIC Platform to understand this course content.

Keywords: Entropy, enthalpy, limitations of the first law, the second law of thermodynamics, Rudolf Clausius, Lord Kelvin, reversible and irreversible processes, Gibbs free energy, Gibbs energy equation, heat capacity, exothermic and endothermic reactions, Kelvin–Planck statement, Clausius statement, perpetual motion machine, PMM2, PMM, perpetual-motion machine of the second kind, thermodynamic cycles, power cycles, heat pump cycles, ideal cycle, Carnot cycle, Otto cycle, spark ignition, diesel cycle, Brayton cycle, gas turbine, Rankine cycle, heat engines, Atkinson cycle, dual cycle, Ericsson cycle, and Carnot cycle efficiency.

Module IV

This course covers the fundamental concepts of Otto cycle, diesel cycle, Brayton cycle, gas turbine, Rankine cycle, heat engines, Atkinson cycle, dual cycle, and Ericsson cycle. The thermal efficiencies of Otto cycle and diesel cycle are derived to calculate the compression ratio of an Otto cycle and Diesel cycle. The cut-off ratio is also illustrated in this module. Further, the module covers the steam turbine cycle, William John Macquorn Rankine cycle, turbine engine, refrigeration system, T-S diagram, and vapor compression refrigeration cycle. The different components such as compressor, condenser, metering devices, expansion valve, throttle valve and evaporator are discussed. The coefficient of performance for both refrigeration and air conditioning are presented too. The module also covered the mathematical modelling of flash point by employing the lower flammability limit (LFL), combustion theory and Clapeyron equation. Finally, it covers the conservation laws such as conservation of momentum, angular momentum, and conservation of energy. This course explains each concept in detail with workout examples and illustrations. This approach will make the students interested in enrolling in the course.

This module is a foundation, resource guide and an excellent source for science and engineering students, early career professionals, and executives who want to learn concepts, design, and dimensions through enough practice of the theories and examples. This module is designed for individuals and students who need to understand the basics of thermodynamics where thermodynamic cycles are the main focus. The course contains a total of six lectures,

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and each lecture comprises 20 to 35 PowerPoint presentation slides and pdf documents. The course is also designed with two quizzes, two assignments and one final exam. Students are strongly advised to complete the “Fundamentals of Thermodynamics (Module I – IV)” course by Prof. M. Enamul Hossain at NSRIC Platform to understand this course content.

Keywords: Otto cycle, diesel cycle, Brayton cycle, gas turbine, Rankine cycle, heat engines, Atkinson cycle, dual cycle, Ericsson cycle, different cycle's efficiencies, thermal efficiency for Otto cycle, compression ratio of an Otto cycle, exhaust stroke, power stroke, ignition phase, compression stroke, thermal efficiency for Diesel cycle, automobile engines, cut-off ratio, compression ratio, steam turbine cycle, William John Macquorn Rankine, turbine engine, refrigeration system, T-S diagram, vapor compression refrigeration cycle, compressor, condenser, metering devices, expansion valve, throttle valve, evaporator, coefficient of performance, heat pump, air conditioning, cooling cycle, condensing coil, expansion valve, evaporator coil, refrigerant, lower flammability limit (LFL), combustion theory and flames, boiling point, Clapeyron equation, conservation laws, conservation of momentum, angular momentum and energy.

6.0 Course Learning Outcomes

Students who complete this course can achieve the following course learning outcomes (CLOs):

Module I

- CLO1: Ability to identify the concepts of pure substances and thermodynamic properties.
- CLO2: Ability to draw and apply the theories on PV, TV and PVT diagrams for different substances.
- CLO3: Ability to evaluate the concepts of different systems and processes, intensive and extensive properties.
- CLO4: Ability to understand the concepts of microscopic and macroscopic views, path, and point functions.

Module II

- CLO5: Apply the concept of the first law of thermodynamics for a system.
- CLO6: Measure the concepts of heat, work, and energy.
- CLO7: Analyze the concept of entropy and its applications.

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CLO8: Analyze the concept of enthalpy and its applications.

CLO9: Examine the concept of flash point and calculation through the experimental test (i.e., Pensky Marten apparatus).

Module III

CLO10: Ability to identify the concept of the second law of thermodynamics for a system.

CLO11: Apply the thermodynamic concepts to analyze the different cycles such as ideal and Carnot cycles.

CLO12: Apply the concept of Gibbs free energy toward deriving the Gibbs energy equation.

CLO13: Ability to understand the concepts of the Kelvin–Planck statement, Clausius statement, perpetual motion machine and the perpetual-motion machine of the second kind.

CLO14: Apply the concept of thermodynamic efficiency for different cycles.

Module IV

CLO15: Calculate the thermodynamic efficiencies of Otto and Diesel cycles.

CLO16: Calculate the cut-off ratio and compression ratio.

CLO 17: Analyze the refrigeration cycle and air conditioning system.

CLO 18: Identify the mathematical models for flash point calculation.

CLO19: List and discuss the different conservation laws.

7.0 How the course supports the attainment of the student outcomes

Student Learning Outcomes (1-6)						
1	2	3	4	5	6	7
Moderate	Moderate	Moderate	Low	Moderate	Moderate	Excellent

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8.0 Course Materials

Online course materials

- Online presentation documents in pdf form.
- Audio/visual recording of lectures (Optional).
- Online tutorial and meeting with students upon request.
- Workout examples for hands-on experience.
- Assignments and MCQs in the form of evaluation at the NSRIC online MLS system
- Reading materials, if any, in pdf form

Textbook and resources (If any)

- 1) Fundamental of Thermodynamics, CIAUC Borgnakke and Richard E. Sonntag, Wiley, 8th Ed., 2014
- 2) Thermodynamics, An Engineering Approach, Cengel and Boles. McGraw-Hill.
- 3) Fundamentals of Engineering Thermodynamics, Moran and Shapiro, (Wiley and Sons)
- 4) Principles of Engineering Thermodynamics, Moran, Shapiro, Boettner and Bailey (Wiley and Sons)

9.0 Academic Integrity

Students are encouraged to have a look at the NSRIC's statement of academic integrity at NSRIC website. It is noted that by signing this syllabus, you will acknowledge that you have understood that any detected plagiarism should be reported.

10. Assessment for Grade

This course is a professional course not an academic course (i.e., K12, and university level courses). Therefore, there will not be any assessment based on individual and team performance as shown in Table 1. However, the course contains four quizzes and assignments to make the assessment. Students will receive a "**Certificate of completion**" after successful completion of the course.

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Table 1: NSRIC grading system.

Type of Assessment	Grade %
Participation/Engagement/Performance	10%
Assignments (For Module IV – 40%)	60%
Quizzes (For Module IV – 20%)	30%
Research Project	0%
Midterm Exam I	0%
Midterm Exam II	0%
Final Exam (Module IV – 30%)	0%
Total	100%

Important Note:

- i) The below classified courses (i.e., academic courses) will only be evaluated based on the grade system shown in Table 2. A grade and certificate will be issued for the student(s) and participant(s).

A: Advanced level academic level courses; **H:** Higher-level courses (i.e., graduate courses); **I:** Intermediate courses (i.e., university preparatory courses – Grade XII+); **K12:** Foundational, and lower-level courses; **M:** Mid-level courses (i.e., undergraduate courses).

- ii) The below-classified courses will **not** be evaluated based on the grading system shown in Table 2. A certificate will be issued for the student(s) and participant(s).

E: Executive courses; **P:** Professional courses; **S:** Short/seminar courses; **T:** Training courses; **U:** Tutorial Courses; **V:** Vocational training courses; and **W:** Workshop courses.

Participation/Engagement/Performance

Your participation in every aspect of the course is important for the learning process. Your engagement in every discussion in the course, and due delivery of all practices will be fruitful. These efforts from your side will reflect your performance in the course delivery and your commitments. This performance is the reflection of your dream grade!!

At the end of the term, below Table 2 will be used for translating your marks into a “Latter Grade” based on the NSRIC grading policy.

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Table 2: NSRIC grading system.

Marks	Letter Grade	Points	Description
≥ 93	A+	4.00	Outstanding
≥ 90	A	3.75	
≥ 87	A-	3.50	Excellent
≥ 84	B+	3.25	Very good
≥ 81	B	3.0	
≥ 78	B-	2.75	Moderately Good
≥ 75	C+	2.50	Good
≥ 72	C	2.25	
≥ 69	C-	2.0	Moderately Good
≥ 66	D+	1.75	Pass
≥ 63	D	1.50	
≥ 60	D-	1.25	Poor Pass
< 60	F	0	Failing

11.0 Advice and additional requirements

I advise you to:

- Please contact me if you need any help.
- Students are expected to attend all scheduled online lecture classes.
- Students are expected to study from the course materials and/or textbooks which will help to easily read and understand.
- Students are encouraged to write their own notes during lectures/presentations (pdf PowerPoint presentations, and additional materials if any).
- Students are encouraged to attend online platform classes on time because late-attendee disrupts the flow of the class for both the instructor and the other students.

Additional information (During Online Course offering Period)

- The PowerPoint course materials and video lectures will be available on the NSRIC Platform.
- There will be scheduled discussion/tutorial sessions based on the request at the class scheduled time. All students must attend this session (Need the student's email request).
- There will be an office hour for students on Monday from 10:30 am – 11:30 am EST (Toronto, Canada time). Students need to send an email request so that a Zoom meeting can be arranged. In addition, any time students can set up an online

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appointment (i.e., phone, zoom, and/or other mode of communication) based on the availability of the course instructor. However, students should request an email to set up this type of meeting.

12.0 Course Topics

- Properties of the pure substances
- Fundamental concepts and definitions including flash point calculation.
- 1st Law of Thermodynamics
- 2nd Law of Thermodynamics
- Flash point calculations
- Steam/gas power cycles
- Refrigeration, and air conditioning system
- Conservation laws

Requirements/Instructions

Students are advised to register for all drilling engineering modules courses to become a master in the subject area.

13. Bundled Courses Program Description

The objectives of thermodynamics are to improve the efficiency of a process for the transformation between energy and work, to study energy conversion in different forms and to study the entropy and enthalpy of a system. The bundled courses program begins with an overview of the fundamentals of thermodynamic concepts step-by-step with specific workout examples. A complete discussion is presented on different concepts as highlighted in the section below.

Thermodynamics concerns energy, entropy, and the behavior of almost all physical systems one way or another. It treats in the first instance large systems in thermal equilibrium, or moving slowly from one equilibrium state to another, and then more general methods are developed. The basic principles of thermodynamics are presented in this program. The bundled courses program covers concepts of pure substance, total energy, internal energy, entropy, enthalpy, specific heat, heat transfer, work, flash calculations, reversible and irreversible processes. The first law of thermodynamics for open and closed system, second law of thermodynamics, and entropy are applied in thermodynamic analyses directed towards understanding the performances of engineering systems. The second law of thermodynamics is used to evaluate the direction in which real processes occur. The concept of entropy as a property is introduced and used to evaluate irreversibilities in real processes and to quantify the efficiency of devices. Power and refrigeration cycles are introduced and the first and second laws are used to perform engineering analysis of the cycles. The different cycles such as steam

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power cycles, gas power cycles, refrigeration, and air conditioning system are also covered in this program.

This program is a foundation, resource guide and an excellent source for science and engineering students, early career professionals, and executives who want to learn concepts, design, and dimensions through enough practice of the theories and examples. The different modules are designed for individuals and students who need to understand the basics of thermodynamics where thermodynamic cycles are the main focus. Each bundled course contains a total of six lectures, and each lecture comprises 20 to 35 PowerPoint presentation slides and pdf documents. The courses are also designed with two quizzes, two assignments and one final exam in Module IV. Students are strongly advised to complete the “Fundamentals of Thermodynamics (Module I – IV)” course by Prof. M. Enamul Hossain at NSRIC Platform to understand this course content.

14.0 Course Contents and Schedule

Lec. No.	Module	Topics	Remarks
Module I			
01	Introduction	A brief overview of thermodynamics	
02	Pure substance	Properties of pure substances I	Quiz 1
03	Pure substance	Properties of pure substances II	Assignment 1
04	Them. concept	Fundamental concepts on thermodynamics I	
05	Them. concept	Fundamental concepts on thermodynamics II	Quiz 2
06	Them. concept	Fundamental concepts on thermodynamics III	Assignment 2
Module II			
07	Them. concept	Fundamental concepts on thermodynamics IV	
08	Them. concept	A summary and problem session on fundamental concepts V	Quiz 3
09	First Law	1 st Law of thermodynamics I	Assignment 3
10	First Law	1 st Law of thermodynamics II	
11	First Law	1 st Law of thermodynamics III	Quiz 4
12	First Law	1 st Law of thermodynamics IV	Assignment 4
Module III			
13	First Law	A summary and problem session on the 1 st law V	
14	Second Law	2 nd Law of thermodynamics I	Quiz 5
15	Second Law	2 nd Law of thermodynamics II	Assignment 5
16	Second Law	2 nd Law of thermodynamics III	
17	Second Law	A summary and problem session on 2 nd law IV	Quiz 6
18	Cycles	Thermodynamic cycles I	Assignment 6

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Course Contents and Schedule Cont.

Lec. No.	Module	Topics	Remarks
Module IV			
19	Cycles	Thermodynamic cycles II	
20	Cycles	Thermodynamic cycles III	Quiz 7
21	Refrigeration	Refrigeration, and air conditioning system I	Assignment 7
22	Air Condition	Refrigeration, and air conditioning system II	
23	Flash point	Flash point calculations	Quiz 8
24	Consn. Laws	Conservation Laws and Summary	Assignment 8
25	Final Exam – Online after completion of the course requirements		

Prepared by Prof. M. Enamul Hossain, NSRIC Chair Professor in Sustainable Energy, Dept. of Petroleum Engineering, OE Division, NSRIC Inc., Toronto, ON, Canada.

Subtitle

A comprehensive discussion on fundamentals of thermodynamics to understand the thermodynamic properties and their applications to science and engineering.

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