# Boston University FALL, 2019
## ENERGY and THERMODYNAMICS (ME 304 A1)

### COURSE SYLLABUS

***OVERALL COURSE OBJECTIVE***

**"...The fact of the matter is that everything we see in the world around us operates according to a very small number of basic principles, or laws. There are Newton's three laws that describe the motion of material objects, *the three laws of Thermodynamics* (emphasis is the instructor's) that describe things related to heat, the four of Maxwell's equations that describe electricity and magnetism, the single principle of general relativity that describes gravity and a few more laws... maybe fifteen in all..." (ref.: "Meditations at 10,000 Feet", Mr. James Trefil, Scribner's Publishers)**

Thermodynamics is one of the most basic of physical sciences and almost defines the field of Mechanical Engineering. Certainly there are many areas of study that make up the full gamut of an Engineer's education. However, the subject of thermodynamics brings to the fore front some of the most basic of nature's physical laws: the First, Second, Third and even the Zeroth Laws of Thermodynamics. A truly educated individual should consider the understanding of the essence of these basic laws to be necessary if one is to be truly considered educated. However, the need to understand the essence and the application of these laws in engineering practice becomes an absolute necessity for the well educated engineer.

***SPECIFIC COURSE OBJECTIVES***

Traditionally the student's first venture in Thermodynamics is often considered the most difficult for students. The reason, speaking from my experience as a continuous student of the subject, is the introduction of very simple appearing concepts and definitions, but ones that have immense significance to the continuous understanding of how the Universe or Nature is structured and "goes about its business". These concepts are often "simplified" in non-engineering courses as to require a virtual re-learning of seemingly familiar terms when they are presented in their correct meaning to solve engineering problems. For example, energy, heat, work, temperature, and pressure are all common terms. However, in Thermodynamics they take-on more significance in order to describe the ways the Universe is put together and how it responds to the engineer's intent to alter it to the benefit of humanity. Thermodynamics give the rules-of-the-game of how Nature's energy can be transformed from heat to work to internal energy and back again. Knowing these rules the engineer is well prepared to transform one form into another with hopefully some positive result.

Once the student has had a taste of the 'language' of Thermodynamics and a better sense of the true meaning of such common terms, the student will now begin to utilize these concepts in real-world applications: heat engines, chemical fuel combustion, piston-cylinder cycles, HVAC cycles, and refrigeration cycles. By applying the basics of thermodynamics to such real-world problems the student starts to gain more and more incite as to how to apply the basic principles to even more difficult problems- by "seeing" them as extensions to the better-known applications. This is due certainly because the language is becoming more familiar but also because the problems that will be solved more resemble real-world applications.

This course will strengthen your understanding of the First and Second Laws but by looking at all of the most common power cycles or heat engines. We will also look at how thermodynamics can define not only how efficient these power cycles are but also look at the limitations imposed by the First and Second laws on a cycle's efficiency.

This course will introduce the student to the thermodynamics of non-reacting mixtures as well as introduce concepts of combustion and chemical kinetics from the point of view of how the Mechanical Engineer might apply such knowledge.

This course will explore the real meaning of "...the entropy of the Universe always increases..." and apply this to the concept of Available Energy and Second Law System Efficiencies.

In general, this second course will be successful if after the end of the course, in a short 10 weeks, you can take an unfamiliar thermodynamic process diagram, with real world mechanical elements and fully understand via the application of the thermodynamic principles that you have learned in this class.

***TEACHING METHODOLOGY***

The presentation of the course material is straight forward: FIRST-present the concept, the theories and principles, THEN: work many examples. Thermodynamics, like most engineering subjects is mastered through the application to meaningful examples-the types of problems that would be encountered in real engineering experience. I shall try to instruct the student by example and not necessarily by words. For the student's part HOMEWORK will be mandatory and will be submitted for review and a grade. This is not meant to be a form of corporal punishment but rather the only way that the student can best understand the material **AND the only way that I can keep tract of your understanding of what has been presented. Ultimately, the homework helps students not to be left behind**.

The textbook is an excellent source of well-structured instruction. The Instructor may pick sections of the textbook that may not be in the exact order that the author's have presented their subjects. This is done to keep the learning of the new language of thermodynamics as useful as possible by tying the related principles to the application where it is used the most often in real-world applications. The Instructor's experience will be used to coordinate this instruction.

The use of worked-examples is so important that it is anticipated that a high portion of each will be spent on the problems that have been assigned or ones that are similar to the problems that have been assigned. The student is encouraged to look through the textbook questions at the end of each chapter and ask that one be reviewed in class.

## Graduate Teaching Fellow

Xiaozhu Liu (xzliu@bu.edu) and Angel Rubio (ajrubio@bu.edu)

Discussion Section: B4 Tue 6:30-7:20 pm; CASB06A
B5 Thu 11:15 am-12:05 pm; PHO 201
B2 Tue 11:15 am-12:05 pm PHO 201
B3 Wed 2:30-3:20 pm CAS 324

***TEXTBOOK:***

**"Fundamentals of Engineering Thermodynamics",9th edition; Moran, Shapiro, Boettner and Bailey (ISBN: 13 987-1-119-39138-8) BUY THE BOOK! It's a "KEEPER". It is in paperback and e-text in the BU Book Store. You may also use the 8th Ed. if it is available as a used book BUT THEN you will need to get the correct problems to solve.**

***SCHEDULE:*** **MONDAY and WEDNESDAY from 4:30 to 6:15 p.m. Rm. 205 EPC**
**CONFERENCE HOURS: AFTER EACH CLASS AND/OR BY PHONE OR E-MAIL AT ANY TIME**
**EXTRA HELP DAY PRIOR TO QUIZES AND FINAL EXAMS WILL BE CONDUCTED AFTER THE REGULAR CLASS HOURS OR ON THE SAT.s BEFORE THE EXAM DATE**

***Instructors:***

**FRANCIS A. Di BELLA, PE; Program Manager; Large Product Development; CONCEPTS NREC; (Office) 781-937-4718; e-mail: fdibella@conceptsnrec.com**

***OTHER ENGINEERING TEXTBOOKS***

**THE TEXTBOOK SELECTED FOR THIS CLASS WILL SERVE YOU WELL AS STUDENTS AND AS PRACTICING ENGINEERS. HOWEVER, MANY TIMES A DIFFERENT AUTHOR SOMETIMES CAN DESCRIBE A CONCEPT BETTER THAN ANOTHER. THE FOLLOWING TEXTS ARE SUGGESTED AS ALTERNATIVE REFERENCES BUT ARE NOT EXPECTED TO BE PURCHASED BY THE STUDENT. I HAVE THESE TEXTS AND CAN LOAN THEM TO THE STUDENT IF NECESSARY.**

**1. "THERMODYNAMICS" by: BLACK AND HARTLEY; WILEY PRESS**
**2. "THERMAL ENGINEERING" by: SOLBERG, CROMER, SPALDING; WILEY PRESS**
**3. "ENGINEERING THERMODYNAMICS: FUNDAMENTALS AND APPLICATIONS" by: HUANG; COLLIER PRESS**
**4. "ENGINEERING THERMODYNAMICS" by: HALL AND IBELE; PRENTISE HALL**
**5. "APPLICATIONS OF THERMODYNAMICS" by: WOOD; ADDISON-WESLEY**
**6. "BASIC THERMODYNAMICS: ELEMENTS OF ENERGY SYSTEMS" by: SKROTZKI; McGRAW-HILL**
**7. "HEAT ENGINES" by: SANDFORTH; DOUBLE DAY AND COMPANY**
**8. "ANALYSIS OF ENGINEERING CYCLES" by: R.W. HAYWOOD; PERGAMAN PRESS**

***IN CONCLUSION:***

**THERE ARE NO STUPID QUESTIONS. VERY OFTEN THE STUDENT AVOIDS ASKING QUESTIONS OUT OF FEAR OF REVEALING SOME WEAKNESS IN A SUBJECT AREA. THERE ARE MORE QUESTIONS IN THERMODYNAMICS THAN ANSWERS SO DO NOT FEAR THAT YOU ARE ALONE IN WONDERING ABOUT THE PRECISE MEANING OF SOME CONCEPT OR TOPIC. OFTEN AN ANSWER TO ONE STUDENT'S QUESTION BRINGS EVERYONE'S UNDERSTANDING OF THE TOPIC AT HAND "UP A NOTCH". YOUR QUESTIONS ARE ALWAYS WELCOMED AS AN IMPORTANT CONTRIBUTION TO THE COURSE AND IN-CLASS INSTRUCTION.**

***GENERAL COURSE OUTLINE:***

**I. REVIEW OF ENGINEERING ANALYSIS METHODOLOGY (Chapter 1)**

**II. DEFINITIONS OF THERMODYNAMIC TERMS) (Chapter 3)**

- **a. Heat (Conduction, convection and radiation heat transfer)**
- **b. Internal Energy**
- **c. Reversible and actual Work**
- **d. Pressure and temperature**
- **e. Specific heat; Cp, Cv and specific heat ratio, k**
- **f. Properties of State: quality, enthalpy, entropy, specific volume**

**III. FIRST LAW OF THERMODYNAMICS (Chapter 2)**

- **a. CLOSED MASS ANALYSIS**
  - **1. constant volume process**
  - **2. constant pressure process**
  - **3. constant temperature process**
  - **4. adiabatic process**
  - **5. polytropic process**
- **b. APPLICATIONS OF CLOSED MASS TO HEAT ENGINES**
  - **1. Diesel cycle**
  - **2. Otto cycle**
  - **3. Dual cycle**

**4. Carnot cycles, Stirling and Ericson cycle**

**c. DEVELOP CONTROL VOLUME EQUATION FOR FIRST LAW FOR COMMON ENGINEERING DEVICES (Chapter 4)**

**IV. SECOND LAW OF THERMODYNAMICS (Chapters 5, 6, and 7)**

**a. Entropy and the second law**

**1. Clausius Inequality**

**2. Clausius and Kelvin statement of second law**

**3. Entropy equation**

**b. CONCEPTS OF AVAILABILITY ENERGY AND SECOND LAW EFFICIENCY**

**V. POWER AND REFRIGERATION CYCLES (Chapters 8, 9 and 10)**

**1. Rankine Cycle**

**2. Advanced Rankine Cycles**

**3. Vapor Compresson Cycle (reversed Rankine or refrigration cycle)**

**4. Alternative refrigeration cycles: Absorption, Reversed Brayton Cycle.**

**VI. NON-REACTING GAS MIXTURES and APPLICATIONS (Chapter 12)**

**1. Psycrometric Chart: Dew Point, Rel. Humidity, Dry and Wet Bulb temp.s**

**2. Air Conditioning and Air-Conditioning Processes**

**VII. CHEMICAL REACTING MIXTURES and APPLICATIONS (Chapter 13)**

**1. Fuel Combustion**

**2. Adiabatic Flame Temperature**

## IN SUMMARY:

### Course Objectives

To deliver a broad and in-depth presentation of modern thermodynamics with sufficient coverage of cycles as a prerequisite for focused study of energy conversion and propulsion.

### Course Prerequisites

1) Differential and integral calculus, multivariate calculus
2) One-semester college physics (calculus based)

### Course Website

learn.bu.edu

### Textbook

Fundamentals of Engineering Thermodynamics by Moran, Shapiro, Boettner, and Bailey, 9th Edition, Wiley

### Class/Laboratory Schedule

Two lectures (1 hour and 45 minutes each) and one discussion (50 minutes) per week. There are two lab exercises for this course. Sign-up sheets will be posted once the labs are scheduled. The experiments will be done in groups, but reports are individual. This class has homework every week. Homework assignments and deadlines will be announced in class, as well as on the course webpage. Homework submitted late will not receive credit.

**Exams**

There will be three exams, including two midterms and one final exam. The exact dates are listed in the syllabus. All exams are closed book, but allowed two-page (8.5" x 11") formula sheet. Calculators are allowed to use during exams but other electronic devices (cell phones, PDAs, laptops, etc.) are prohibited. The only valid reasons for missing an exam are: death in the immediate family, serious illness (documented by a physician), or a conflict with a scheduled Boston University event. If you feel that you have a valid reason for missing an exam, you must petition to the Instructor for permission to take the make-up exam and/or to take the exam in Prof. Duan's Section. This petition must be received **BEFORE** the regularly scheduled exam. Petitions are not always granted! If the petition is granted, a mutually convenient time for the make-up exam will be arranged.

**Collaboration Policy**

Students are allowed (in fact, encouraged) to work together on the homeworks and on the lab worksheets. Working together means truly working together, exchanging ideas, NOT copying. Copying another's work is cheating, as is allowing someone else to copy your work. All exams must be done by each student individually. Anyone caught cheating may be subject to disciplinary action by the Committee on Student Conduct of the College of Engineering. Also, anyone found guilty of cheating will receive a 0 for that particular grade. When in doubt, ask before you collaborate!

**Note on engineering ethics and plagiarism:**

As an engineer, you will be expected by other engineers and the public to conduct yourself in all professional undertakings according to the professional ethics of engineering.

Plagiarism is a violation of all professional ethics codes as well as your College's Code of Student Conduct. Plagiarism is the undisclosed use of another's work as your own, without or even with that person's permission. If without that person's permission, this is the additional crime of intellectual property theft. Unless explicitly stated otherwise, such as "group" lab reports or the special homework assignments. Plagiarizers will be brought to the attention of the proper College Review board.

**Grading Policy**[1]

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|---|---|
| Three exams | 70% |
| Labs | 20% |
| Homework | 10% |

**Lecture and Exam Schedule**[1]

[1] Subject to change due to unforeseen circumstances such as Winter storms, University Holidays, etc.

| Lecture | Date | Topics | Reading | Other |
|---|---|---|---|---|
| | | | | |
| 1 | 09/04 | Introduction to Thermodynamics | 1.1-1.9 | |
| 2 | 09/09 | The 1st Law of Thermodynamics I | 2.1-2.7 | |
| 3 | 09/11 | The 1st Law of Thermodynamics II | 2.1-2.7 | |
| 4 | 09/16 | The 1st Law of Thermodynamics III and Thermodynamic Properties I | 3.1-3.11 | |
| 5 | 09/18 | Thermodynamic Properties of Pure Substances I | 3.1-3.11 | |
| 6 | 09/23 | Thermodynamic Properties of Pure Substances II | 3.1-3.11 | |
| 7 | 09/25 | Properties of solids/liquids & Control Volume Analysis I | 3.1-3.11; 4.1-4.12 | |
| 8 | 09/30 | Control Volume Analysis II - Applications | 4.1-4.12 | |
| | 10/02 | Midterm exam I | | |
| 9 | 10/07 | Control Volume Analysis III - Applications | 4.1-4.12 | "Take Home, Virtual Experiment" Lab 1 |
| 10 | 10/09 | Control Volume Analysis IV_Transient Cases | 4.1-4.12 | Espresso Coffee Pot |
| 11 | 10/14 | Control Volume Analysis V_Transient Cases | 4.1-4.12 | |
| 12 | 10/16 | Second law of thermodynamics | 5.1-5.10 | |
| 13 | 10/21 | Carnot cycle, thermal efficiency | 5.1-5.10 | |
| 14 | 10/23 | Carnot Corrolary and Introduction to Entropy | 5.1-5.10; 6.1-6.13 | |
| 15 | 10/28 | Entropy Calculation | 6.1-6.13 | |
| 16 | 10/30 | Entropy balance | 6.1-6.13 | |
| 17 | 11/04 | Isentropic processes | 6.1-6.13 | Steam Turbine Lab 2 starts |
| 18 | 11/06 | Vapor power system | 8.1-8.3 | |
| 19 | 11/11 | Improving vapor power system Improving & review | 8.4-8.6 | |

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| | 11/13 | **Midterm exam II** | | |
| 20 | 11/18 | Gas Power systems I (Gas Turbine Power Plants I) | 9.1-9.8 | |
| 21 | 11/20 | Gas Power systems II (Gas Turbine Power Plants II) | 9.1-9.8 | |
| 22 | 11/25 | Refrigerator system | 10.1-10.3 | |
| | 11/26 | **Thanksgiving Recess** | | |
| 23 | 11/28 | Refrigerator system | 10.1-10.3 | |
| 24 | 12/02 | | | |
| 25 | 12/04 | Gas Power systems III (Automobile engines I) | 9.1-9.8 | |
| 26 | 12/09 | Gas Power systems IV (Automobile engines II) | 9.1-9.8 | |
| 27 | 12/11 | Final review | | |
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