Aerospace Thermodynamics

AE 210
Summer, 2017

Instructor: Professor Sejin Kwon (3721, trumpet@kaist.ac.kr, Rm#4307, ME Bldg)
Hours: 9:00~12:00am Monday thru Friday during July, 2017, Rm#2320, ME Bldg
Textbook: Cengel, Y. A. and Boles, M. A. Thermodynamics, An Engineering Approach, 7^{th} Ed. McGraw-Hill.
Teaching Assistant: TBA
Course Website: http://klms.kaist.ac.kr

What is Education 3.0?

Over the last two decades, we saw a revolution in how we exchange information and knowledge. Teaching, however, relatively remained unaffected by this revolution in the way we disseminate information. Education 3.0 is an experiment that began four years ago at KAIST. Lecture are recorded and posted on the course website. Presentation files used in the lecture are available on the course website along with the lecture videos. Students can view the lecture at their time of choice. At the end of each lecture, there are assignments. Students are grouped into small discussion teams. During the class hours, discussion teams solve the assignments. When the discussion is over, the teams should present their results in front of the class.

Course description

Thermodynamics is a science of energy. As every process in nature involves energy, thermodynamics is behind every phenomenon that is worth of our attention. Particularly, we are interested in energy transformation and power generation in the flight of the aerospace systems. The reason we recognize the feat of Wright brothers is because they carried out the first "powered" flight. Powered flight requires transformation of energy in numerous subsystem of the flight vehicle. In order to analyze and predict the flight, we need to understand the principles that govern the energy transformation.

Thermodynamics is also one of the fundamental areas of science in a sense that it constitutes one of the pillars of our understanding of the nature. Thermodynamics has been understood as an independent branch of physical science until advances were made in molecular physics in the early 20th century and links were laid between classical physics and thermodynamics. Even after it was understood that thermodynamic processes could be described by molecular physics, macroscopic thermodynamic laws have been still used to provide quantitative relationships between physical properties that are relevant to natural processes, whether they are mechanical, electrical, or biological.

In traditional engineering, thermodynamics is most widely used in applications that involve power generation and heat transfer. Jet engines, rockets, and space propulsion systems in particular are a few examples where thermodynamic knowledge is essential in design, performance prediction and testing. Applications of thermodynamics nowadays go exceed the natural sciences. Concepts of thermodynamics, such as entropy and conservation of energy, have been effectively used to analyze social phenomena and biological processes. Recent awareness of environmental issues also draws attention to thermodynamics, because power generation is the single most important source of environmental pollution. This lecture explains the laws of thermodynamics and properties of substances that transport them.

The laws and concepts of thermodynamics will be applied to rockets. In order to obtain propulsive power of rockets, energy transformation processes are extensively used. Firstly, the chemical energy stored in propellant (fuel) is released by a combustion process. The heat energy is then transformed to kinetic energy. Propulsion force is eventually obtained as a reaction force when high speed propellant is exhausted at the rocket nozzle.

Contents

Introduction and Basic Concepts (Chap. 1): Lecture 1

Brief history of thermodynamics will be covered at the beginning. The origin and foundation of thermodynamics, and its establishment as an independent area of science will be presented. To help understanding, some engineering applications will be given. Specific issues include; (1) definitions and concepts, physical properties of energy carrier substances; (2) principles of thermodynamics as law of nature and thermodynamic efficiency; (3) heat engines, aerospace propulsion systems. Definitions and explanations of open and closed systems, form of energy, thermodynamic equilibrium, process, cycle, temperature and pressure, zeroth law of thermodynamics will be presented.

Energy, Energy Transfer, and General Energy Analysis (Chap. 2): Lecture 2

Concept of energy and define its various forms. Internal energy, heat and work transfer.

Properties of Pure substance (Chap. 3): Lecture 3 and 4

Substance as energy carrier; phase, state and properties of pure substance; property diagram; properties of water, ideal gases and real gases; internal energy, enthalpy and specific heats of liquid and solids

Energy Analysis of Closed System (Chap. 4): Lecture 5

First law of thermodynamics for a closed system is introduced. Heat transfer and various forms of work are described. Balance of energy is established.

Mass and Energy Analysis of Control Volume (Chap. 5): Lecture 6, 7, and 8

First law of thermodynamics for closed systems and its applications of the law in the analysis of engines, turbines, etc. will be covered.

Midterm Examination

Second law of thermodynamics (Chap. 6): Lecture 9, 10, and 11

Concepts of heat engines, efficiency of energy transformation, and quality of energy will be introduced. Perpetual motion machines will be discussed in light of the second law.

Entropy (Chap. 7): Lecture 12 and 13

Law of entropy increase, entropy change in the property diagram of substances, and isentropic processes are explained. Method to calculate entropy changes of ideal gases, liquids, and solids will be presented.

Gas power cycles (Chap. 9): Lectures 14, 15, and 16

Principles and thermodynamic analysis of Otto, Diesel and jet propulsion cycles will be discussed.

Thermodynamic property relations (Chap. 12): Lectures 17 and 18

Mathematical relationships among the thermodynamic properties are derived. Maxwell relation, Clapeyron relation*, and general equations of internal energy, enthalpy, and entropy are presented. Applications in Joule-Thompson effect* and evaluation of real gas properties will be discussed.

Gas mixtures (Chap.13): Lecture 19

Properties of gas mixtures and relationship among them are covered.

Final Examination

Miscellaneous

Grade will be evaluated from four examinations with equal importance. Exams will evaluate how you follow the subject and will be given without prior announcement.