Course Introduction

Larry Caretto
Mechanical Engineering 370
Thermodynamics

August 24, 2010

California State University Northridge

Today's Class

- First class day items: roll, outline, etc.
- Class goals and learning objectives
- Assessment quiz
- Discussion of dimensions and units
  - Physical quantities have dimensions
  - Several units measure same dimension
  - Use SI system of units (meter, kilogram, ...
  - Also use engineering units (feet, pounds ...

California State University Northridge 2

Basic Information

- Larry Caretto, Jacaranda (Engineering) 3333, lcaretto@csun.edu, 818.677.6448 (temporary)
- Office hours Tuesday and Thursday 10 to 10:45 am; also by email or appointment
- Web: http://www.csun.edu/~lcaretto/me370
- Yunus A. Çengel and Michael A. Boles, *Thermodynamics, an Engineering Approach*, (seventh edition) McGraw-Hill, 2011.
  - Bring text to class for use of tables
- Class email list, me370-c@csun.edu uses CSUN email addresses

California State University Northridge 3

…each day brings further evidence that the ways we use energy strengthen our adversaries and threaten our planet.

We will harness the sun and the winds and the soil to fuel our cars and run our factories.

Barak Obama, January 20, 2009

California State University Northridge

Course Learning Objectives

- Understand the and be able to formulate and solve problems using thermodynamic properties: pressure, temperature, specific volume, internal energy, enthalpy, entropy, and quality
- determine thermodynamic properties of real substances
- calculate thermodynamic properties of ideal gases

California State University Northridge 5

More Learning Objectives

- Understand the meaning of heat and work and the notion that these energy terms are not properties
- Formulate and solve energy balance problems in engineering systems, including those with fixed mass and those with steady and unsteady flows

California State University Northridge 6

Still More Learning Objectives

- Understand the engineering significance of the second law of thermodynamics: maximum work and maximum efficiency in reversible processes
- Formulate and solve problems with first law to find maximum work using the property entropy
- Solve problems using the concept of isentropic efficiency as an empirical correction to maximum work

California State University Northridge 7

Learning Objectives Concluded

- Formulate and solve problems that require the use of the energy balance from the first law and the principle of maximum work from the second law
- Apply the first and second law to the analysis of engine and refrigeration cycles, using common idealizations for such cycles

California State University Northridge 8

Class Operation

- Thursday: lecture on new topic
  - Assigned reading and suggested homework on new material in outline
- Tuesday: group problem solving on this week's topic
- Thursday: Thirty-minute quiz on old topic prior to lecture on new topic
- First quiz is Thursday, September 2
  - See sample quiz on-line

California State University Northridge 9

Quizzes

- Twelve during the semester
- Based on group work and homework
- See sample of first quiz on line
  - http://www.csun.edu/~lcaretto/me370
    - Use link to Homework, Quizzes and Examinations
- Count ten highest quiz grades for final
  - No makeup quizzes; final quiz grade based only on quizzes taken if fewer than ten
- First four closed book; remainder use sheet of equations from web site

California State University Northridge 10

Grading

- Quiz grades 45%
- Midterm October 14 20%
- Final Exam 35%
  - Tuesday, December 14, 10:15 am
- Plus/minus grading will be used
- Grading criteria in course outline
- No make-up quizzes or exams
  - Quiz grade details on previous slide
  - Missed midterm grade from other grades

California State University Northridge 11

See the Course Outline

- Download from web site for your section
- Contains lecture and quiz schedule
- Also read information on following items
  - Class participation and courtesy
  - Collaboration versus plagiarism: students found cheating receive F grade in course
- Students are responsible for changes to outline announced in class

California State University Northridge 12

Galileo Galilei

(1564-1642)

You cannot teach people anything; you can only help them find it within themselves.

http://space.about.com/od/astronomyhistory/a/galileoquotes.htm

Northridge 13

Goals for this Course

- My goal is to help all students find within themselves sufficient knowledge of thermodynamics so that they will all get an A grade in the course
- What is your goal for this course?
- What will you do to achieve that goal?

Northridge 14

How to get your A

- Spend six to ten hours per week outside class studying for the course
- Prepare for lecture and be ready to ask questions
  - – Read the assigned reading before class
  - – Download, print, and review the lecture presentations before class
    - Use these as notes so that you can follow the lecture; write additional notes on these presentations

Northridge 15

How to Get your A, Part II

- Study with fellow students and try to answer each other's questions
- Do the homework as well as you can before reviewing the on-line solutions
- Contact me by email or during office hours to ask questions
- Develop a good working relation with other members of your self-study group

Northridge 16

What I will do to help

- Arrive at class a few minutes early to answer any questions you may have
- Give lectures that stress application of basics to problem solving
- Return quizzes and exams promptly so that you can learn from your errors
- Be available for questions via email, office hours or phone/appointment
  - – Send entire class emails as appropriate

Northridge 17

Preliminary Assessment

- Designed to help instruction
- One set of questions on student background
- Second set of questions is ungraded quiz
- Take about 10 minutes for this assessment
- Hand yours in when finished
  - – Will call time when most students are done

Northridge 18

Dimensions and Units

- Any physical quantity has a unique dimension: e.g., mass, length, time, …
- Several units may be available for any dimension
  - Length is measured in meters, feet, miles, fathoms, furlongs, yards, light-years, etc.
  - You cannot measure length in units with the dimension of mass

Systems of Units

- Arbitrary units for fundamental dimensions, e.g. mass, length, time, electric charge and temperature.
- Units for other physical quantities from the physical relations to quantities with fundamental units
  - Velocity dimensions are length/time.
  - Acceleration dimensions are length/time^2,
  - Force dimension of (mass)(length)/(time)^2

More Dimensions

- Pressure = force per unit area
  = (force) / (length)^2
  = (mass) (length) / [(time)^2(length)^2]
  = (mass) / [(time)^2(length)]
- Common dimensions for energy terms are (mass)(length)^2/(time)^2
  - Work = force times distance
    = (force)(length)
    = (mass)(length)^2/(time)^2
  - Kinetic energy = mV^2/2
    = (mass)(velocity)^2
    = (mass)(length)^2/(time)^2

Still More Dimensions

- Another energy term
  - Potential energy = mgh = (mass)(acceleration)(length) = (mass)(length)^2/(time)^2
- Power = (energy)/(time)
  = (mass) (length)^2 /(time)^3
- Will see thermodynamic work is PdV
  - This is like Fdx where P = F/A and dV = Adx (A is area)
  - PdV dimensions are (length)^3(force)/(area) which also is (mass)(length)^2/(time)^2

SI Units

- Basic definitions for fundamental units
  - Mass: kilogram (kg) = international prototype
  - Time: second (s) = time for 9 192 631 770 periods of radiation from Cs^{133}
  - Length: meter (m) = length light travels in 1/299 792 458 of a second
  - Temperature: kelvin (K) = 1/273.16 of the triple point of water
  - Current: ampere (A) defined in terms of induced force

Other Units

- Light intensity and molar units
- Other quantities have derived units based on their physical definitions
  - Velocity and acceleration are m/s and m/s^2
  - Force is kg·m/s^2
    - 1 newton (N) = 1 kg·m/s^2
  - Energy units energy are kg(m/s)^2 = N·m
    - 1 joule (J) = 1 N·m = 1 kg·m^2/s^2

Still More Units

- Power: (energy)/(time) = joules/second
  - 1 watt (W) = 1 J/s = 1 N·m/s = 1 kg·m²/s³
- Pressure: (force)/(area) = newtons per square meter
  - 1 pascal (Pa) = 1 N/m² = 1 kg/(m·s²)
- Note that Isaac Newton has a capital N, 1 newton of force does not, unless it is abbreviated as 1 N (true for all units named after individuals)

California State University Northridge 25

Prefixes

pico, p	nano, n	micro, μ	milli, m
10^{-12}	10^{-9}	10^{-6}	10^{-3}
tera, T	giga, G	mega, M	kilo, k
10^{12}	10^{9}	10^{6}	10^{3}

California State University Northridge 26

Engineering Units

- Basic time unit, second, same as SI
- The foot = 0.3048 m (exactly) is the basic unit of length
- Pound is confusing because it is used to represent two dimensions
  - Mass: pound-mass (lb_m = 0.453592 kg)
  - Force: pound force (lb_f = 32.174 lb_m·ft/s²)
    - What is SI equivalent for pound force?

1 lb_f = 4.4482 N

California State University Northridge 27

More Engineering Units

- foot-pound is work (energy unit)
- British thermal unit (Btu = 778.16 ft-lb_f)
- Horsepower as power unit
  - 1 hp·hr = 2,545 Btu = 1.98x10⁶ ft·lb_f
  - 1 kW·hr = 3,412 Btu
- The metric unit, calorie = 1/252 Btu
- The food calorie is a kilocalorie often spelled with a capital C, Calorie

California State University Northridge 28

Calculating Units

- What is kinetic energy of a 100 lb_m mass moving at 10 ft/s
- $mV^2/2 = (100\ lb_m)(10\ ft/s)^2/2 = 5000\ lb_m \cdot ft \cdot s^{-2}$
- Unit conversion

$$KE = \frac{(100\ lb_m)}{2}\left(\frac{10\ ft}{s}\right)^2 \frac{lb_f \cdot s^2}{32.174\ lb_m \cdot ft} = 165.4\ ft \cdot lb_f$$

- Note algebraic cancellation with unit conversion factors = 1 $\frac{lb_f \cdot s^2}{32.174\ lb_m \cdot ft} = 1$

California State University Northridge 29

Units quiz

- What is the change in potential energy when a mass of 20 lb_m is raised a distance of 15 ft?
- Do you need more data to answer this question?
- What is g? Use 5 ft/s² for this problem

$$\Delta PE = (20\ lb_m)\frac{5\ ft}{s^2}(15\ ft)\frac{lb_f \cdot s^2}{32.174\ lb_m \cdot ft} = 46.62\ ft \cdot lb_f$$

California State University Northridge 30

Typical Thermodynamic Units

Quantity	SI units	Engr units
Energy	kJ or MJ	ft-lb_f or Btu
Specific energy	kJ/kg	Btu/lb_m
Pressure	kPa = kN/m^2	psia = lb_f/in^2(abs)
Atmosphere	101.325 kPa	14.696 psia
Temperature	K = °C + 273.15	R = °F + 459.67
Power	W, kW, MW	hp, Btu/hr

Thermodynamics Problems

- Use pressure in kPa and energy in kJ and volume in m^3 for consistent units
  - 1 kPa·m^3 = 1 kJ
  - 1 MPa = 1000 kPa, 1 m^3 = 10^6 cm^3 = 10^3 L
- Engineering units, with pressure in psia and volume in ft^3 give PdV work in units of psia·ft^3
  - Multiply psia·ft^3 by 144 in^2/ft^2 to get ft·lb_f or divide by 5.40395 psia·ft^3/Btu to get Btu

Kinetic and Potential Energy

- Watch these units
- Look at energy per unit mass (KE/m = $V^2/2$ and PE/m = $g\Delta z$)
- A velocity of 1 m/s has a KE/m of 1 m^2/s^2 = 1 J/kg = 0.001 kJ/kg
- A velocity of 1 ft/s has KE/m of 1 ft^2/s^2 = 0.031081 ft·lb_f/lb_m = 3.9942x10^{-5} Btu/lb_m
- Similar conversions for PE/m

How Much Energy is a Joule

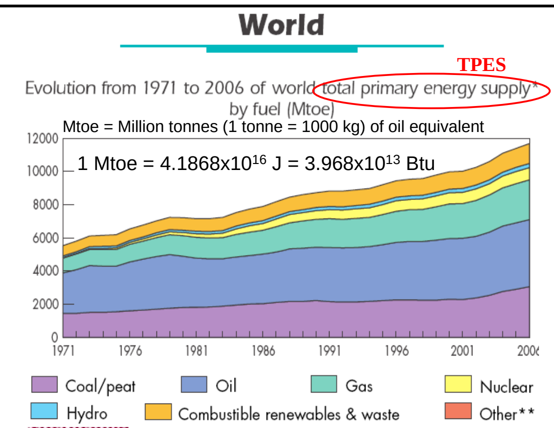
- 1 W = 1 J/s
- Electrical energy measured in kWh

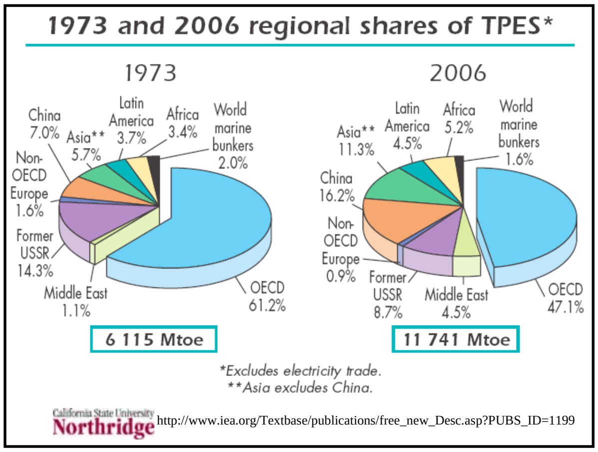
$$1\text{ kWh} = \left(1\ \cancel{\text{kW}}\ \cancel{\text{h}}\right)\frac{1000\text{ J}}{\cancel{\text{kW}}\ \cancel{\text{s}}}\frac{3{,}600\ \cancel{\text{s}}}{1\ \cancel{\text{h}}} = 3.6\text{x}10^{6}\text{ J} = 3.6\text{ MJ}$$

- 1 J of electrical energy costs \$3x10^{-8}
- 1 J of natural gas costs \$1x10^{-8}
- World energy use ≈ 450x10^{18} J/yr
- US energy use about 25% of world use

What does 1J Cost?

- Average San Fernando Valley home utility bills in 2008 (without fees and tax)
  - Electricity: \$32x10^{-9} per joule
  - Natural gas: \$11x10^{-9} per joule
- What about gasoline at \$3 per gallon?
  - With taxes in the three dollars (usual case): \$26x10^{-9} per joule
  - Without California taxes of \$0.585 per gallon: \$21x10^{-9} per joule




1973 and 2006 regional shares of TPES*
1973
2006
China 7.0%
Asia** 5.7%
Latin America 3.7%
Africa 3.4%
World marine bunkers 2.0%
Non-OECD Europe 1.6%
Former USSR 14.3%
Middle East 1.1%
OECD 61.2%
6 115 Mtoe
Asia** 11.3%
Latin America 4.5%
Africa 5.2%
World marine bunkers 1.6%
China 16.2%
Non-OECD Europe 0.9%
Former USSR 8.7%
Middle East 4.5%
OECD 47.1%
11 741 Mtoe
*Excludes electricity trade.
**Asia excludes China.
California State University Northridge
http://www.iea.org/Textbase/publications/free_new_Desc.asp?PUBS_ID=1199