AREN 2110
Introduction Overview

THERMODYNAMICS IS THE SCIENCE OF ENERGY. Although everyone has some kind of understanding of energy (**what is yours??**), by the end of the class, you will have learned a <u>precise definition of energy</u>, including its <u>forms</u> and <u>how to quantify</u> it.

The scientific basis of thermodynamics is physics, and its principles are important in chemistry and biology as well. However, many of the concepts and principles of thermodynamics were actually discovered by engineers based on the observations they made as they built and studied practical devices for doing work, transferring heat, and transforming material.

Two approaches to learning thermodynamics:

<u>MACROSCOPIC</u> **(classical thermodynamics)** based on the **AVERAGE or AGGREGATE** behavior or properties of systems which are comprised of many individual particles or molecules. Systems characteristics are **estimated from measurements** such as temperature, pressure, density, mass, volume, etc. assuming that they represent all the component molecules.

<u>MICROSCOPIC</u> **(statistical thermodynamics)** based on mathematical characterization of the DISTRIBUTED behavior or properties of individual molecules **using statistical parameters** (average, median, variance) to describe.

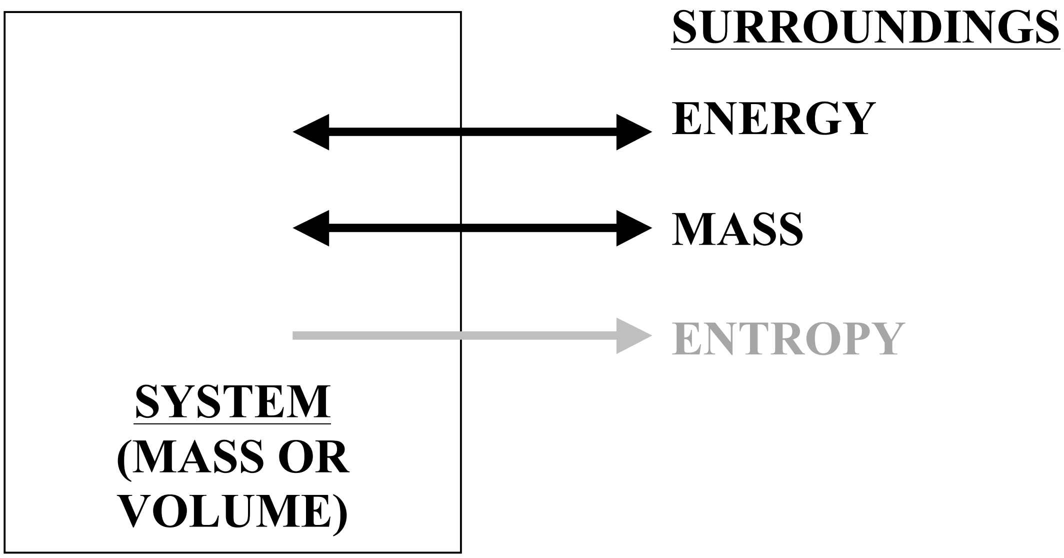
In AREN 2110 you will learn classical thermodynamics.

AREN 2110 is divided into three major components.

1. **Thermodynamic properties of matter**, measuring properties, and associating measureable properties to derived energy properties.
2. **Conservation of Energy (1st Law of Thermodynamics).** Informally: You cannot get more energy out of a system than you put in plus what is stored.
3. **Entropy and the 2nd Law of Thermodynamics**. Certain processes that meet the conditions of the 1st Law are in fact impossible. In any real process, you actually lose something of the quality of energy as it is transferred or transformed.

Throughout the course there will be engineering applications of these three theoretical components, often focused on civil and architectural engineering interests.

1. Concepts and Definitions



a. Forms of **Energy**
b. Systems
c. **Processes** and **paths**
d. Interactions between **system and surroundings**
e. **State** of the system
f. Thermodynamic **Properties** and Relation to States

2. Details

a. Dimensions and **units**
b. **Unit homogeneity**
c. **Measured** properties (laboratory)
d. **Derived** properties (formulas and tables)

FORMS OF ENERGY

MOTION
  Mechanical WORK (force x distance)
  Kinetic energy (velocity squared)

HEAT

POSITION IN GRAVITY FIELD
  Potential energy (mgh)
CHEMICAL BONDS
  Reactions
MAGNETIC
ELECTRIC
NUCLEAR/ATOMIC
SURFACE TENSION

DIMENSIONS

SI (System International) in AREN 2110

Primary dimensions	SI Unit
Length (L)	meter (m)
Mass (m)	kilogram (kg)
Time (t)	second (s)
Temperature (T)	degrees Kelvin (K)
Electric current (I)	ampere (I)
Amount of matter (N)	Mole (mol)
Secondary (derived) dimensions	SI unit
Force (F)	Newton (N) = $kg*m/s^2$
Energy (E)*	Joule (J) = N*m
Power	Watt (w) = J/s
Pressure (P)	Pascal (Pa) = N/m^2
Volume (V)	cubic meter (m^3)
Velocity, (*V*)	meter per second (m/s)

* the term energy includes units for all the types of energy given above

DIMENSIONAL HOMOGENEITY: units of additive terms in formulas must be the same.

EXAMPLE of 1st law for one kind of system:

Work (J) = potential energy + kinetic energy = PE + KE

PE = mgh with units $kg*(m/s^2)*m = N*m = J$ ✔

KE = $mV^2/2$ with units $kg*m^2/s^2 = N*m = J$ ✔

EXAMPLE of 1st law for another system

Work (J) = pressure*change in volume = $P*(V_2-V_1)$

Unit of P are N/m^2

Units of V are m^3

$(N/m^2)*m^3 = N*m = J$ ✔

EXAMPLE, Ideal Gas Law, find unit of gas constant, Ru

P*(V/N) = Ru*T

(V/N) has units of m^3/kmol

P has units of kN/m^2

T has unit of K

Ru has units of P*(V/N)/T or $(kN/m^2)*(m^3/kmol)/K$ = kN-m/(kmol*K) = kJ/(kmol*K)

Given 1 kilomole of ideal gas at 273K and 1 atmosphere pressure = 101.325 kPa occupies 22.4 m^3

Ru = 101.325*22.4/273 = 8.314 kJ/(kmol*K)

Comments on graph of US energy consumption

1 Btu = 1.055 kJ

1 quad = 10^{15} BTU ~ 10^{15} kJ

1 kwh = 1 kJ/s * 3600 s/h = 3600 kJ

1 terawatt hour = 10^{12} wh = 10^{9} kwh

Note that "efficiency" of US energy use is ~ 38% (35.2 quad/91.4 quad)

You will learn why given current ways of producing mechanical (vehicle) and electrical energy, we can't get all, or even most of, the lost energy back even with improvements to technology.