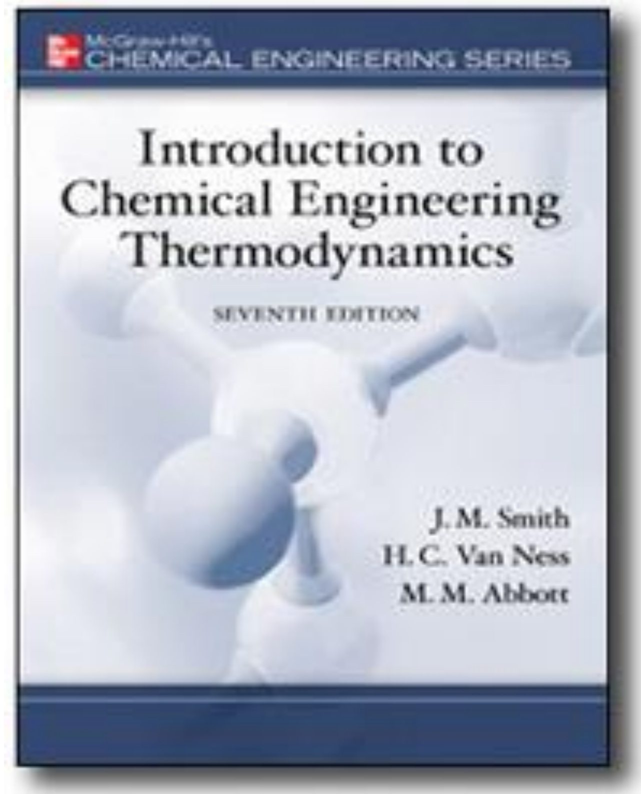
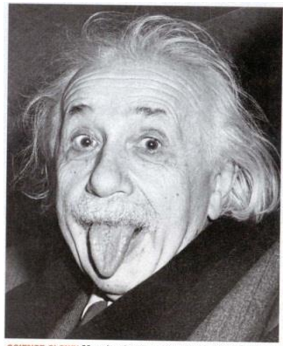
Chapter 1. Introduction



Classical Thermodynamics…

- **Albert Einstein**

"A theory is the more impressive the greater the simplicity of its premises is, the more different kinds of things it relates, and the more extended is its area of applicability. Therefore, the deep impression that classical thermodynamics made upon me. It is the only physical theory of universal content concerning which I am convinced that, within the framework of the applicability of its basic concepts, it will never be overthrown."

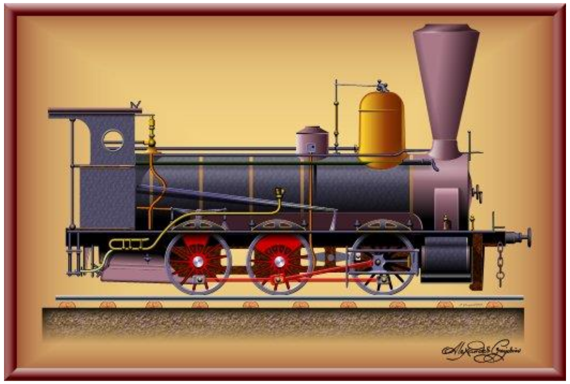


SCIENCE CLOWN Mugging for the press on his 72nd birthday

Introduction

- **Thermodynamics**
  - **Begin in 19th century**
  - **Needed to describe steam engines**
  - **THERMO (HEAT) + DYNAMICS (POWER)**

    = Power Developed from Heat
- **Laws of Thermodynamics**
  - **Cannot be proved**
  - **Validity of laws**
    - Based on the **absence of contrary experience**



Introduction

- **Major problems of chemical engineers**
  - **Calculation of Heat and Work**
  - **Determination of Equilibrium Condition → Thermodynamics**
- **Difference between Thermodynamics and other Topics**
  - **Do not dealing with "RATES" of physical or chemical processes**
  - **Rate depends on driving force and resistance**
- ***Microscopic* interpretation can be useful in the calculation of thermodynamic properties.**
- **Generalized correlation**
  - **Chemical engineer deals many chemical species**
  - **However, many experimental data are often lacking**
- **This Chapter…**
  - **Fundamental dimension of science (length, time, mass, temperature, force, heat, energy, etc)**

Dimensions and Units

- More details are given in 'Introduction to Chemical and Biological Engineering' course.
  - SI Unit vs. American Engineering Unit

Table 1.1: Prefixes for SI Units

Multiple	Prefix	Symbol	Multiple	Prefix	Symbol
10^{-15}	femto	f	10^{2}	hecto	h
10^{-12}	pico	p	10^{3}	kilo	k
10^{-9}	nano	n	10^{6}	mega	M
10^{-6}	micro	μ	10^{9}	giga	G
10^{-3}	milli	m	10^{12}	tera	T
10^{-2}	centi	c	10^{15}	peta	P

Measures of Amount or Size

- **Mass, *m***
- **Number of moles, *n***
- **Total volume, V^t**

- **Specific volume**

$$V \equiv \frac{V^t}{m} \qquad \rho \equiv V^{-1}$$

- **Molar volume**

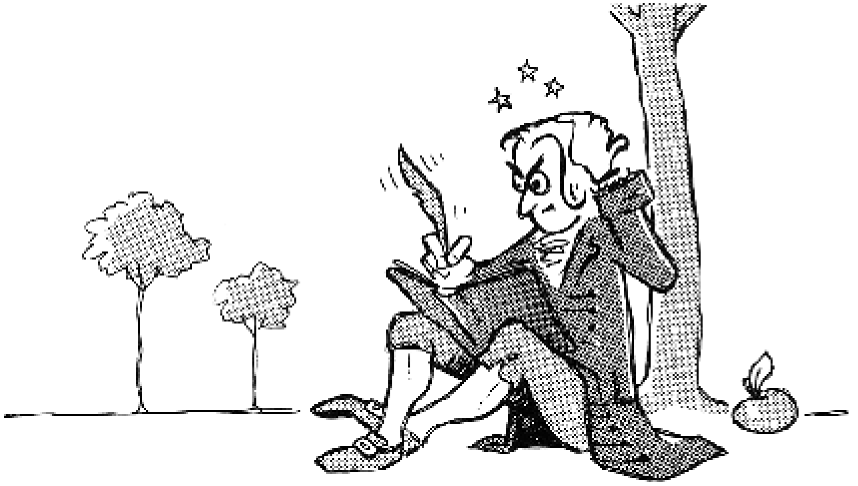
$$V \equiv \frac{V^t}{n} \qquad \rho \equiv V^{-1}$$

Force

- **Newton's Second Law of Motion**

$$F = ma / g_c$$

Definition of force units



1 N = 1 kg · m /s^2

1 dyne = 1 g cm /s^2

1 lb$_f$ = 32.174 lb$_m$ · ft /s^2

Conversion Factor for force

$$g_c = 1\frac{kg \cdot m/s^2}{N} = 1\frac{g \cdot cm/s^2}{dyne} = 32.174\frac{lb_m \cdot ft/s^2}{lb_f}$$

Temperature

- **Temperature**
  - **Degree of "Hotness"**
  - **Measure of kinetic energy possessed by the molecules of given substance**
  - **Conversion**

$$T(K) = T(^oC) + 273.15$$

$$T(^oR) = T(^oF) + 459.67$$

$$T(^oR) = 1.8T(K)$$

$$T(^oF) = 1.8T(^oC) + 32$$

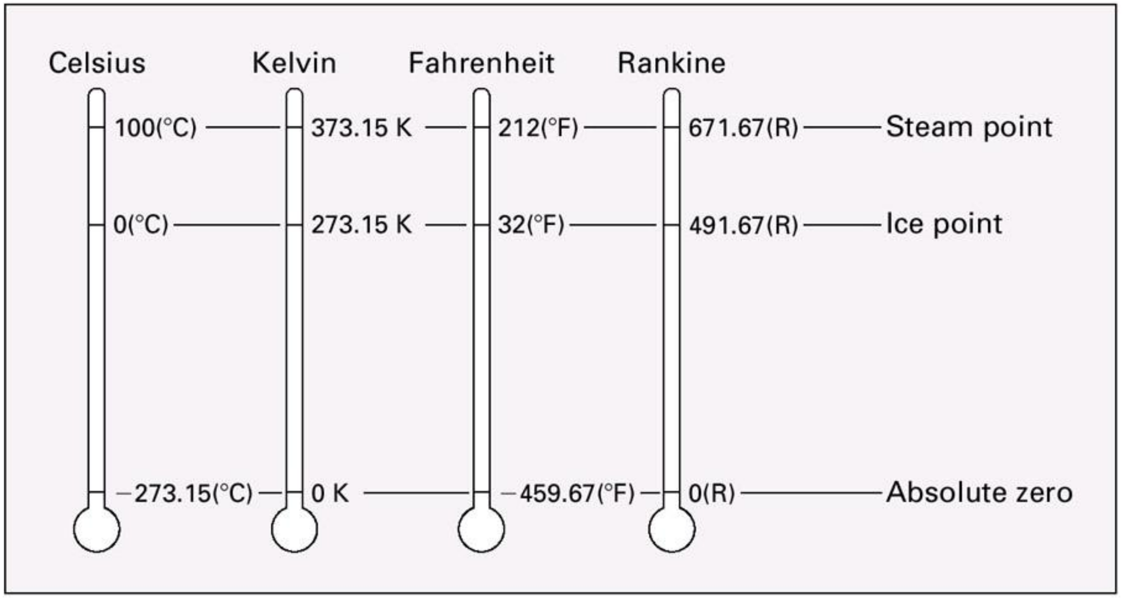


Figure 1.1: Relations among temperature scales.

Temperature

❑ Temperature Measurement

- **Normally measured by liquid-in-glass thermometer**
  - 0 degree Celsius : ice point
  - 100 degree Celsius : boiling point of water
- **At other point, reading of thermometer does not usually coincide because of expansion characteristics of fluids**
- **Kelvin Unit → Based on Ideal Gas as thermometric fluid**

→ Ideal gas temperature scale will be discussed in Chapter.3

Temperature

- **International Temperature Scale of 1990 (*ITS-90*)**
  - **Used for Scientific and Industrial Instruments**
  - **International standard for temperature scale**

Temperature Range	Thermometers	Reference Temperature
0.65 K ~ 5.0 K	Vapour Pressure vs Temperature Relation	-
3.0 K ~ 24.5561 K	Gas Thermometry	-
-259.35 ^{o}C (24.5561 K) ~ 961.78 ^{o}C	Platinum Resistance Thermometer	triple point of hydrogen freezing point of silver
Above 961.78 ^{o}C	Optical Pyrometer or Radiation Pyrometer	Cu, Ag, Au melting points

Pressure

Pressure

- **Normal force exerted by the fluid per unit area of surface**

$$P = \frac{F}{A} = \left(\frac{mg}{g_c A}\right)$$

- **Hydrostatic Pressure : Vertical Column of Fluid**

$$F / A = m\frac{g}{g_c} / A = \rho V \frac{g}{g_c} / A = \rho \frac{g}{g_c} h$$

- **Conversion Factor for Pressure**

1 atm = 1.013 bar

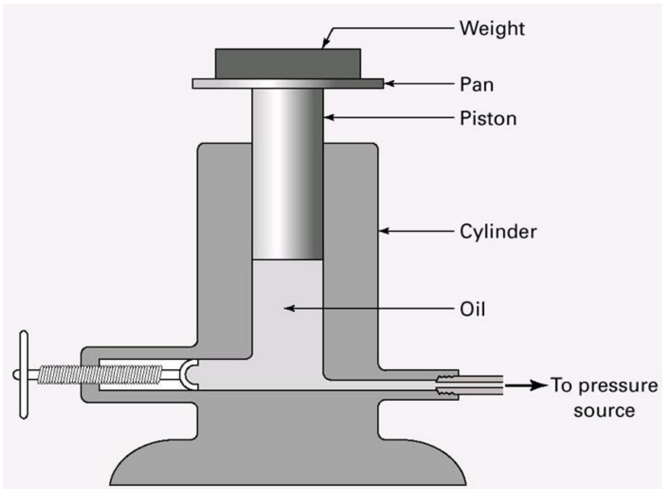
= 1.013×10^5 Pa (N/m^2) = 101.3 kPa

= 760 mm Hg

= 14.7 lb_f/in^2 (psi)

Pressure

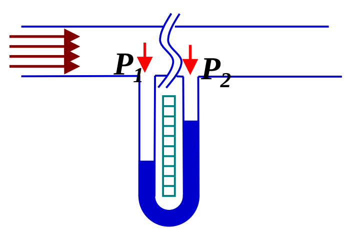
❑ Pressure Calibration → Dead Weight Gauge

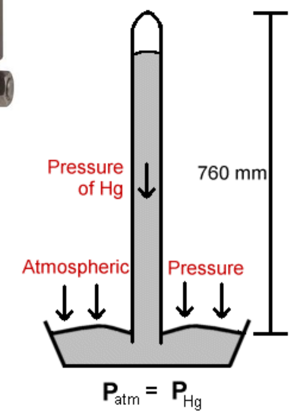


a force is balanced by a fluid pressure acting on a known area

❑ Pressure Measurement

- Bourdon Gauge
- Barometers
- Manometer
- Pressure Transducers





Work

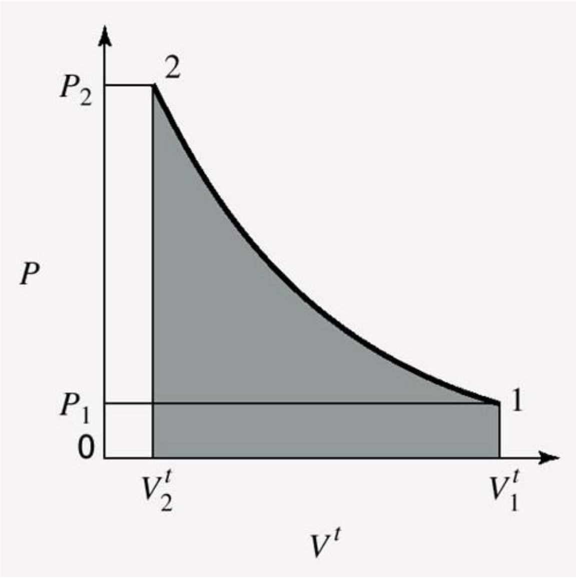
- **Work is performed when force acts through distance**

$$dW = Fdl$$

- **Work accomplished by change in volume of a system**
  - **Work is done when pressure is exerted from surroundings**
  - **Sign convention**
    - Work is done on the system (+) : Volume shrinks (-)
    - Work is done by the system (-) : Volume expands (+)

$$dW = -PAd(V^t / A) = -PdV^t$$

$$W = -\int_{V_1^t}^{V_2^t} PdV^t$$



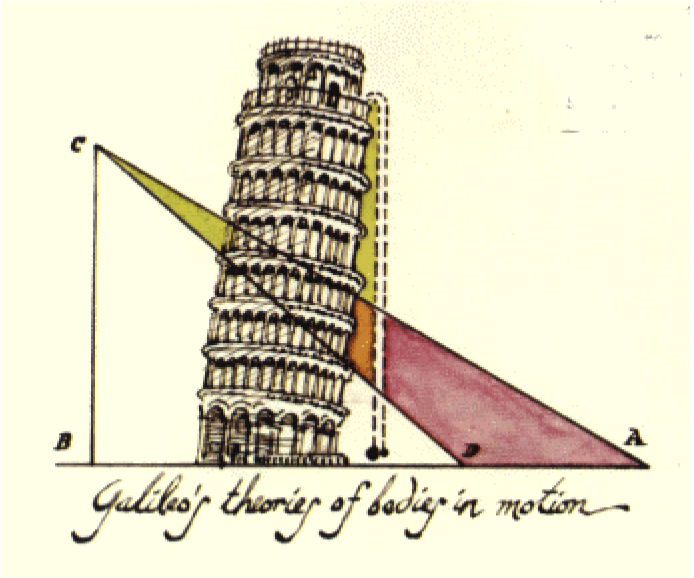
Energy

- **Galileo (1584) and Isaac Newton (1642-1726)**
  - **Established General Principle of Conservation of Energy**
  - **Kinetic Energy**
    - See the derivation in the test (page 10)

$$E_K = \frac{mu^2}{2g_c}$$

  - **Potential Energy**

$$E_P = \frac{mzg}{g_c}$$



Energy

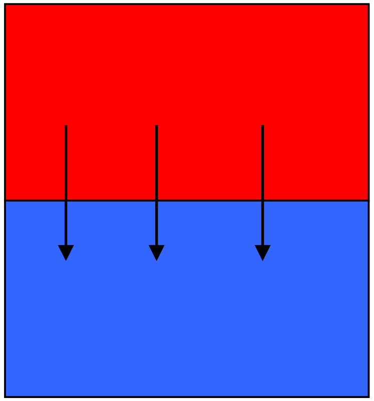
- **Energy Conservation**

$$\Delta E_K + \Delta E_P = 0 \qquad \frac{mu_2^2}{2g_c} - \frac{mu_1^2}{2g_c} + \frac{mz_2 g}{g_c} - \frac{mz_1 g}{g_c} = 0$$

- **Energy conservation for *pure mechanical processes***
- **During the period of development of the law, heat was not generally recognized as a form of energy**
- **In this case, heat was considered an indestructible fluid called *caloric***
  - *Caloric:* a hypothetical fluid of heat
- **Therefore, no connection was made between heat resulting from friction**
- **The law was limited in application to frictionless mechanical processes**
- **How about the energy balance in general case???**
  - Chapter 2

Heat

- When hot body is in contact with cold body, something *flows*
- Only to one direction
  - Hot to cold (O)
  - Cold to hot (X)
- Until Joule's experiment, heat was not considered as a transit of energy
  - No connection with energy
- Unit of Heat
  - Calorie (cal)
  - British Thermal Unit (Btu)
  - Joule (J)



Caloric ?
Heat ?
Energy ?

Unit Conversion

- **Force**
  - $1\ N = 1\ kg \cdot m/s^2$, $1\ dyne = 1\ g\ cm/s^2$
  - $1\ lb_f = 32.174\ lbm \cdot ft/s^2$
- **Pressure**
  - 1 atm

    $= 1.013\ bar = 1.013 \times 10^5\ Pa\ (N/m^2) = 101.3\ kPa$

    $= 760\ mm\ Hg = 14.7\ lb_f/in^2\ (psi)$
- **Energy**
  - $1\ J = 1\ N \cdot m = 10^7\ dyne \cdot cm\ (= 0.23901\ cal = 9.486 \times 10^{-4}\ Btu)$
  - $1\ cal = 4.18\ J$
  - $1\ Btu = 1055\ J$
- **Power**
  - $1\ W = 1\ J/s = 1.341 \times 10^{-3}\ hp$

Homework

- **1.10, 1.13, 1.15, 1.20**
  - **Due: Sept 9, 2015**