Some definitions

1. Thermodynamics

   study of energy transformations (work & heat)

   [as well as devices & materials used to accomplish these trans.]

   • energy - capacity for performing work

2. System

   - device(s) containing a quantity of matter being analyzed.
     (quantity of matter or a region of space)
   - defined by a control volume
     or a control boundary

3. Surrounding

   - everything that is not part of the defined system
   • isolated system - no mass, Q or W crosses boundary
   • closed system - no mass crosses boundary; Q & W can (control mass)
   • open system - mass crosses boundary (as well as Q & W) (control volume)

4. * MACRO scopic point of view

   - deals w/ agregate or average effects

5. MICRO scopic point of view

   - deals w/ individual effects; each atom or particle.

6. Phase - quantity of matter that is chemically/structurally homogeneous throughout

   GAS (vapor); LIQUID; SOLID   common phases

7. Property (substance, phase, system)

any characteristic that can be observed or measured.

EXTENSIVE Property – depends on size or mass

i.e. volume, mass, weight

INTENSIVE Property – independent of size or mass

i.e. temperature, density, pressure

Rule of Thumb:

if property for part ≠ property for whole ⟹ EXTENSIVE

if property for part = property for whole ⟹ INTENSIVE

an EXTENSIVE PROPERTY can be made intensive by ÷ by mass, volume or # moles.

8. Notation

M & S v

UPPER CASE	V	property, extensive	volume	m^3
v lower case	$v = \frac{V}{m}$	property/unit mass intensive	specific volume	m^3/kg
$\overline{\text{lower case}}$	$\bar{v} = \frac{V}{n}$	property/unit mole	molal specific volume	$m^3/kmol$

density? $\rho = \frac{kg}{m^3} = \frac{m}{V} = \frac{1}{v}$

9. State (of a system)

condition of system as described by its properties.

[Thermo – E transformations – involve changing state, passing through intermediate states] i.e me moving across room

10. PROCESS – a sequence of states

11. Equilibrium: Mech, Chem, Thermal equilibria — Thermodynamic. Mechanical E. ↔ balanced forces

system in equil when contents cannot change condition of their own accord. Change only brought about by outside forces.

12. Quasi Equilibrium process – process where deviation from equilibrium is infinitesimal.

13. Types of Processes
ISO → constant

Iso thermal ? const T
Iso baric ? const P
Iso choric ? const V
Isentropic ? const S

14. Cycle - series of processes where the final and initial states are the same
[end where you started - although things may have changed in the middle]

UNITS

SI & English

SI neatly packaged, usually powers of 10
English a bit more challenging

Let's first deal w/ # of atoms

1. MOLE
a mole = 6.02×10^{23} (atoms, molecules, etc)

1 kmole = 10^3 mole

if C has molecular mass 12

1 kmole C has mass = 12 kg

g-mole - the wt of 1 mole of a substance in grams

lb-mole - the amount of a substance such that the mass is equal to the # of molecular mass

1 lb-mole C has mass = 12 lb-mass (lbm)

n = # moles

$n M = m$ $\quad$ kmoles $\cdot \frac{kg}{kmole} \Rightarrow kg$

lb-moles $\cdot \frac{lbm}{lb\text{-}moles} \Rightarrow lbm$

M = molecular mass (sometimes called molecular weight)
it's an English thing

shown w/o units, BUT

units are $\frac{kg}{kmole}$, $\frac{g}{mole}$, or $\frac{lbm}{lb\text{-}mole}$

use whichever units fit the problem.

2. FORCE (weight)

Newton's 2nd

$$\boxed{F = ma}$$

$$F = (kg)\left(\frac{m}{s^2}\right) = \boxed{\frac{kg\, m}{s^2} = N \quad \text{newton}}$$

weight is force exerted by a mass due to the gravitational acceleration (on earth)

$$F = mg$$

$g = 9.80665 \frac{m}{s^2}$ (but depends on elevation & location)
$= 32.174 \frac{ft}{s^2}$

BUT in English,
1 lbm weighs $\boxed{1\, lbf \quad (lbf = \text{pound-force})}$

so we must introduce a fudge factor ☒

$$F = \frac{m\, a}{☒}$$

$$1\ lbf = \frac{1\ lbm \times 32.174 \frac{ft}{s^2}}{☒}$$

$$☒ = \frac{(1\ lbm)(32.174 \frac{ft}{s^2})}{1\ lbf} = \boxed{32.174 \frac{lbm\ ft}{lbf\ s^2} = g_c}$$

↑ conversion constant [fixed]

in English Newton's 2nd becomes

$$\boxed{F = \frac{ma}{g_c}}$$

3. Energy - capacity for performing work)

$W = F \cdot d$ (more on work in chapt 4)

$N \cdot m = J = \frac{kg\,m}{s^2} \cdot m = \boxed{\frac{kg\,m^2}{s^2} = J}$

$lbf \cdot ft = ft\text{-}lbf$

or $\boxed{1\ Btu = 778.17\ ft\text{-}lbf}$

4. Pressure

$P = \frac{F}{A} = \frac{N}{m^2} = \frac{kg\frac{m}{s^2}}{m^2} = \boxed{\frac{kg}{m\,s^2} = Pa}$

$1\ bar = 10^5\ Pa = 100\ kPa \qquad k, kilo = 10^3$

in english

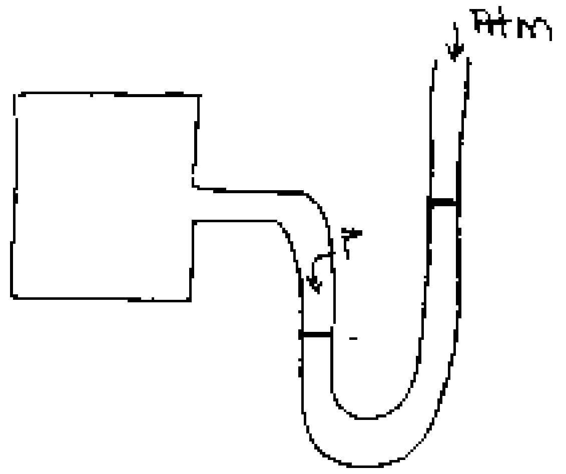
$P = \frac{F}{A} = \frac{lbf}{ft^2} \Rightarrow \frac{lbf}{in^2}$ or psi

$1\ atm = 101325\ Pa = 14.696\ \frac{lbf}{in^2}$

you may have seen psia & psig

psia $\frac{lbf}{in^2}$ absolute

psig $\frac{lbf}{in^2}$ guage



Pressure on guage measured relative to atmospheric pressure.

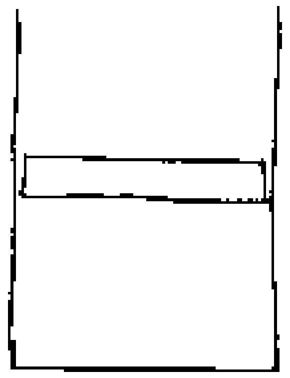
$\Delta P = \frac{\text{weight of stuff}}{\text{Crossectional Area}}$

$= \frac{mg}{A} = \frac{\rho V g}{A} = \frac{\rho A L g}{A}$

$\boxed{\Delta P = \rho L g}$

pictorially

5. Pressure & Pistons



piston is a device that allows volume changes with constant pressure

What is Pressure?

$$P = P_o + P_{piston}$$

P_o → atm Press

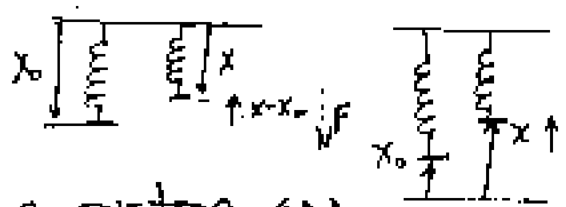
P_{piston} → $\frac{F_{piston}}{A_{piston}} = \frac{m_{piston}\, g}{A}$

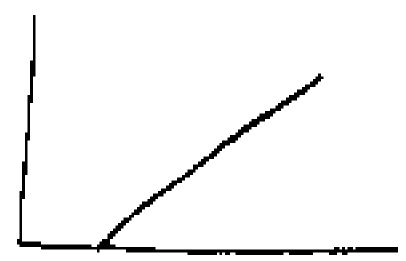
$$\therefore P = P_o + \frac{m_{pist}\, g}{A}$$

and for small piston movements ($< \sim 0.25$ miles) g is const & P is const

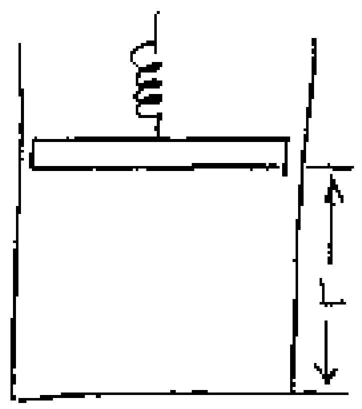
6. Pressure & Linear springs

$$F_{spring} = -kx \quad \text{or} \quad k(x - x_o) = kx - \underbrace{kx_o}_{const} \Rightarrow F = kx - const$$





lets look @ a piston arr.



$F_{spring} = kL$

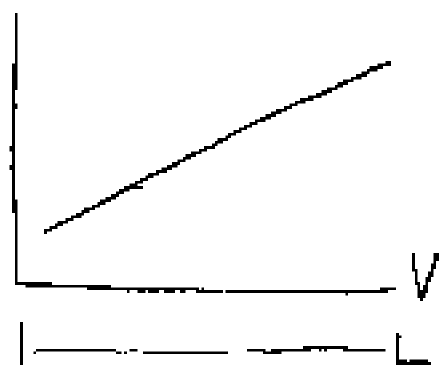
and $V = LA \Rightarrow L = \frac{V}{A}$

$$P_{spring} = \frac{F_{spr}}{A} = \frac{kL}{A} = \frac{k\frac{V}{A}}{A} = \frac{k}{A^2}V$$

act $P_{spring} = \frac{k}{A^2}V - \frac{k}{A^2}V_o$

$P_{spring} \propto L$

$P_{spring} \propto V$



$$P = P_o + P_{piston} + P_{spring}$$

7. Temperature

0^{th} law of Thermo.   3 bodies [A] (B) △C

If $T_A = T_B$
and $T_C = T_B$
Then $T_A = T_C$

in words
If 2 bodies are each in thermal equilibrium with a third body, they are in thermal equilibrium with each other.

Temperature scales

		mp H_2O	VPt H_2O	abs 0
Fahrenheit	F	32 F	212 F	-459.67 F
Celsius	°C	0°C	100°C	-273.15°C
Kelvin	K	273.15 K	373.15K	0 K
Rankine	R	491.67 R	671.67R	0 R

K does not have °

R & F sometimes have °, but not in this book

Conversions

$$K = °C + 273.15$$

$$R = F + 459.67$$

$$F = \frac{9}{5}°C + 32$$

$$C = \frac{5}{9}(F - 32)$$

$F = f(C)$

$F = mC + b$

$m = \frac{\Delta F}{\Delta C} = \frac{212-32}{100-0} = \frac{180}{100} = \frac{9}{5}$

$F = \frac{9}{5}C + b$

$b = F - \frac{9}{5}C$
$= 212 - \frac{9}{5}(100)$
$= 212 - 180 = 32$

$F = \frac{9}{5}C + b$

check $b = F - \frac{9}{5}C$
$= 32 - \frac{9}{5}(0) = 32$

* SAMPLE PROBLEMS
2.2
2.13
2.16

Definition

g mole (n)

a mole is 6.02×10^{23} — it is a number

1 Kmole = 10^3 moles = 6.02×10^{26}

Molecular Mass (sometimes referred to as molecular wt.)

no units are given.

ie. $M(c) = 12$ — found in table A.8 pg 752

but units are understood to be $\frac{g}{mole} \cdot \frac{10^3}{10^3}$ or $\frac{kg}{kmole}$

$n \text{ (moles)} \cdot M \left(\frac{g}{mole}\right) = (g)\ m$

$n \text{ (kmol)} \cdot M \left(\frac{kg}{kmol}\right) = (kg)\ m$

in this class we will use kg & kmoles

H_2O has molecular mass = 18

∴ 25 kmoles has mass

$n \cdot M = m$

$25 \text{ kmol} \cdot \frac{18 \text{ kg}}{\text{kmol}} = 450 \text{ kg}$

IN ENGLISH UNITS

lb mole – is the unit for n (best defined by M)

M has same numerical value as w/ SI

BUT units are $\frac{lbm}{lb\text{-}mol}$

$n \cdot M = m$

∴ lb-mole is actually

2.2 lbmole = 1 kmole

Last time.

we defined phase – a quantity of matter that is homogeneous throughout.

property (any characteristic that can be observed or measured)
intensive, extensive

state (condition of system as described by its properties)

A pure substance

a substance that is chemically homogeneous with a fixed chemical composition

gases – compressible
fluid (flow under stress)
molecules rarely exert forces on each other

solids – incompressible
rigid
strong intermolecular forces
dense

liquids – relatively incompressible
fluid
dense
properties determined by intermolecular forces

boiling point – at given pressure
temp above which liquid is no longer present
(all vapor)

freezing point – at given pressure
temp below which no liquid is present
(all solid)

Both BP & FP are pressure dependent

* we'll also give these states new names.