Unit Systems

Unit systems:

International system (SI)
British Gravitational system (BG)

Basic dimensions:

FLT system: force, length, and time
[N], [m], [s] in SI
[lb], [ft], [s] in BG
MLT system: mass, length, and time
[kg], [m], [s] in SI
[slug], [ft], [s] in BG

Unit conversion: Tables 1.3 and 1.4
on the web: http://www.onlineconversion.com/

Fluid Mass and Weight

$$w = m\,g$$

Relation with volume:

$$w = \gamma\, V$$

specific weight

$$m = \rho\, V$$

density

Specific gravity:

$$SG = \frac{\rho}{\rho_{\mathrm{H_2O@4°C}}}$$

Eq (1.7)

Fluid Pressure

Atmospheric pressure: exerted by air at sea level

by convention: 101 [kPa] or 14.7 [psi] or 1 [atm]

Absolute pressure: relative to absolute zero pressure (perfect vacuum)

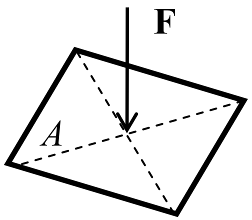
Gage pressure : relative to atmospheric pressure

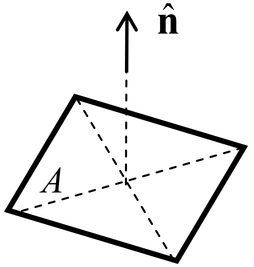
Pressure inside fluids at rest is the normal stress:
perpendicular to the object surface

$$p = \frac{F}{A}$$

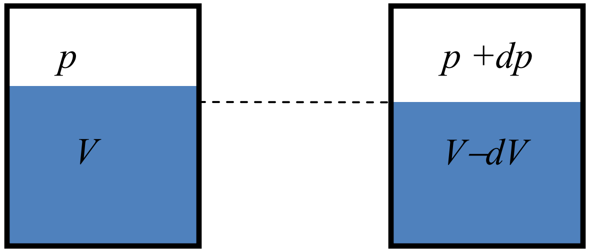
[N/m^2]

FL^{-2}





Fluid Compressibility



Bulk modulus:

$$E_V = \frac{-dp}{dV/V} \qquad \text{Eq (1.12)}$$

$$E_V = \rho \frac{dp}{d\rho} \qquad \text{Eq (1.13)}$$

Liquids:

E_V is large: liquids can be considered as *incompressible* for most practical engineering applications.

e.g.: water changes only 1% volume at 60ºF with a high pressure of 3120 psi (> 200 times atmospheric pressure).

Fluid Compressibility

Gases:

E_V is small: gases are *compressible*; for most practical engineering applications gases can be considered as ideal gases.

$$p = \rho RT$$ Eq (1.8)

Isothermal compression/expansion

$$\frac{p}{\rho} = \text{constant}$$ Eq (1.14)

Adiabatic/isentropic compression/expansion

$$\frac{p}{\rho^k} = \text{constant}$$ Eq (1.15)

Fluid Compressibility

Gases:

Bulk modulus:

$E_V = p$ (isothermal) Eq (1.16)

$E_V = kp$ (adiabatic) Eq (1.17)

$$k = \frac{c_p}{c_V}$$

Gases can often be treated as *incompressible* if the *changes* in pressure are small.

Fluid Compressibility

Gases:

Speed of sound:

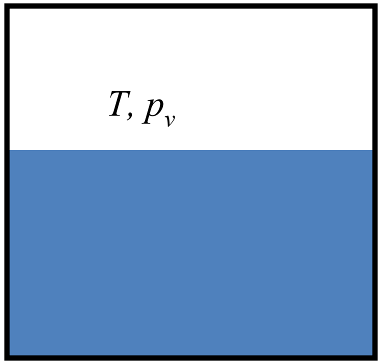
$$c = \sqrt{\frac{E_V}{\rho}}$$ [m/s] LT^{-1} Eq (1.19)

valid in gases, liquids, and solids

Speed of sound in ideal gas:

$$c = \sqrt{kRT}$$ Eq (1.20)

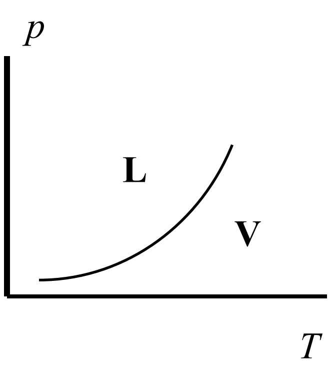
Liquid –Vapor/Gas



At T, there is a maximum pressure where evaporation stops. It is at the equilibrium between liquid and vapor phase. The pressure is called the vapor pressure: p_v

p_v is the pressure where pure liquid boils at T, e.g., for water:

p_v = 14.7 psi (1 atm) at t = 212ºF (100ºC)
p_v = 0.089 psi (0.006 atm) at t = 32ºF (0ºC)



Antoine equation

$$\ln p_v = A - \frac{B}{t + C}$$

Liquid –Vapor/Gas

Surface tension

$$\sigma = \frac{F}{\ell} \qquad \left[\frac{\text{N}}{\text{m}}\right]$$

F: Force working on the surface
ℓ : the perimeter of the surface

$$\sigma = \frac{dW}{dA}$$

FL^{-1}

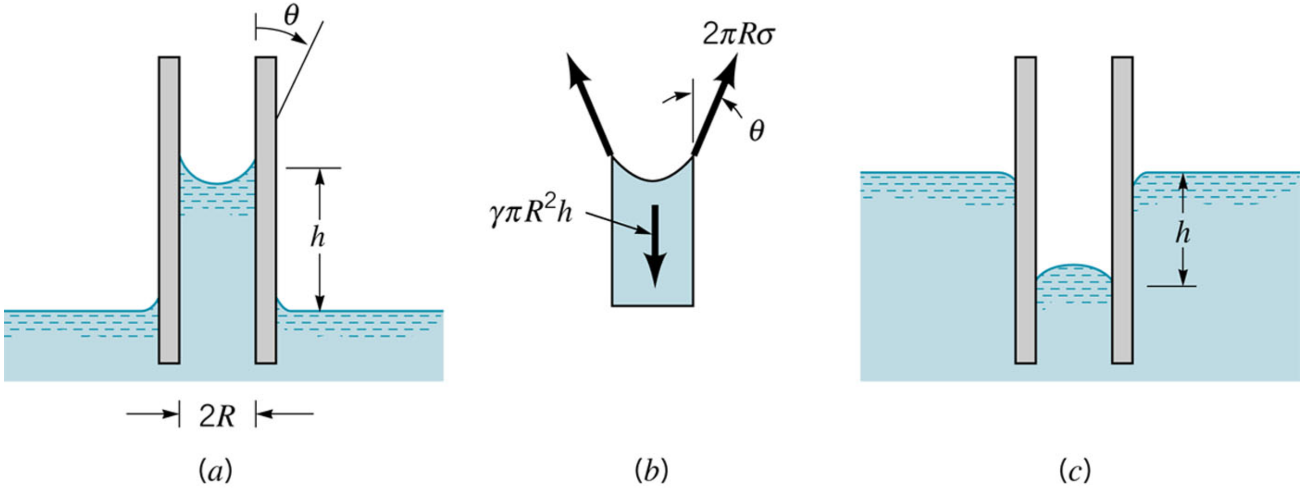
How much work (W) needed to extend the surface area (A).

Examples: water drop, soap bubble

Liquid-vapor:	surface tension vanishes at critical point
Liquid-gas:	surface tension vanishes if miscible
Liquid-liquid:	interfacial tension
Liquid-solid:	angle of contact θ

Liquid –Vapor/Gas –Solid

Capillarity



$$\gamma\left(\pi R^2 h\right) = \sigma\left(2\pi R\right)\cos\theta$$

$$h = \frac{2\sigma\cos\theta}{\gamma R}$$ Eq (1.22)