Ch. 1 Fluid Mechanics & Hydraulics

omework: Tonight, place a smooth plate under a tap & describe what you see. You will be called on in class to describe it.

1) Fluids: Mechanics → behavior at rest (STATICS) or in motion (dynamics)

liquids — more later → (generally incomp.)

- Takes shape with sides & bottom
- Top @ uniform level
- liquid pours out (viscous)

↑ Focus of this course

gases (compressible)

- expand to completely fill space
- Gas escapes container

2) Units & Dimensional analysis

Generally use SI. However US std still is used (e.g. psi)

m - sec - kg vs. ft - sec - slug

You are assumed to know dimensional analysis techniques. When in doubt, work it out. And check units!

UNITS

3) A) $\boxed{\text{Force} = m \cdot a}$

$$= kg \frac{m}{sec^2} = \boxed{\text{Newton}} \; ; \; g = 9.81 \; m/sec^2$$

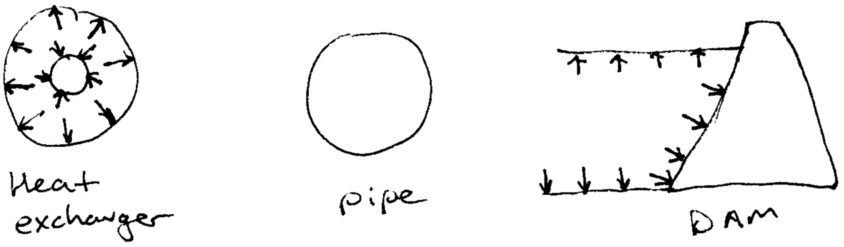
Hint: sometimes preferable to use $\boxed{\frac{N \, sec^2}{m}}$ vs. $\boxed{kg}$

B) $\boxed{\text{Pressure} = \frac{F}{A}} = \frac{\frac{kg \cdot m}{s^2}}{m^2} = \frac{N}{m^2} = \boxed{Pa}$

Theory: Pascal's laws

I) Pressure is uniform in all directions

II) In a fluid contained by boundaries, pressure acts perpendicular to surface



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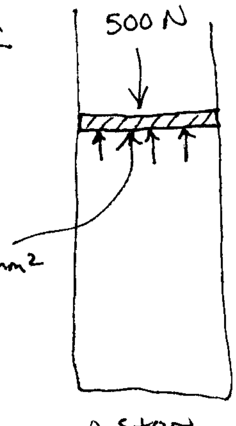
ex



Find the liquid pressure?

By Law II, pressure is uniform & perpend.

$$p = \frac{F}{A} = \frac{500 \, N}{2500 \, mm^2} = 0.2 \; N/mm^2$$

$$\left(0.2 \frac{N}{mm^2}\right)\left[\frac{10^3 \, mm}{m}\right]^2 = 0.2 \times 10^6 \frac{N}{m^2} = \underline{0.2 \; MPa}$$

Common pressures kPa to MPa

4) compressibility :

ΔV when subjected to a change in pressure Δp

Bulk modulus = $E = \frac{-\Delta p}{\frac{\Delta V}{V}}$ UNITS? Pressure $\left(\frac{N}{m^2}\right)$

liquids → very large E } large pressure change to induce ΔV

gases → small E

Table 1.4

	E (MPa)	E (psi)
ethyl alcohol	896	130,000
Benzene	1060	154,000
water	2180	316,000
glycerine	4510	654,000
Hg	24,750	3.6×10^6

Ex Δp to impart 1% change in water volume?

1% ; $\frac{\Delta V}{V} = -0.01$; $\Delta p = (E)\left[\frac{\Delta V}{V}\right] = [-0.01][2180]$

$\Delta p = 21.8$ MPa (= 3160 psi)

Hint: Atmospheric pressure is about 1/200 of this

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5) Density $\rho = \frac{m}{V} = \frac{kg}{m^3}$

spec. wt. $\gamma = \frac{wt}{V} = \frac{N}{m^3} = \rho \cdot g \left[\frac{kg \cdot g}{m^3}\right]$

Spec. gravity (normalized) $\frac{\rho}{\rho_{w,4°C}}$ $\left[1000 \frac{kg}{m^3}\right]$; $\frac{\gamma}{\gamma_{w,4°C}}$ $\left[9.81 \frac{kN}{m^3}\right]$

Ex Problem

Your Professor recently produced some Belgian Whitbier. The initial extract (a dissolved sugar/malt solution) had S.G. = 1.045. After fermentation (extract → alcohol) had $SG_F = 1.010$. What was the final Alcohol (EtOH) conc?

Assume: Ignore T effects

$SG_\ell = \text{CONST.} = 1.045$

DATA: $SG_{EtOH} = 0.787$ (App. B, pg. 554)

$$SG_F = \frac{SG_\ell V_\ell + SG_{EtOH} V_{EtOH}}{(V_\ell + V_{EtOH}) = V_T} \quad ; \quad \text{for } V_T = 1\,L$$

$$V_\ell = V_T - V_{EtOH}$$

Re-arranging: (Substitute $V_T - V_{EtOH} = V_\ell$

$$\frac{V_{EtOH}}{V_T}\left[SG_\ell - SG_{EtOH}\right] = SG_\ell - SG_F$$

$$\frac{V_{EtOH}}{V_T} = \frac{SG_\ell - SG_F}{SG_\ell - SG_{EtOH}} = \frac{1.045 - 1.010}{1.045 - 0.787} = 0.136 = \underline{\underline{14\%}}$$

b) Surface Tension

Ex. Needle floating

↳ NOT due to buoyancy → submerge & it sinks

↳ add detergent → sinks

Forces at liquid interfaces

Def: work req'd to bring molecules to surface per unit area

$$\boxed{\frac{\text{work}}{\text{area}} = \frac{F \cdot l}{l^2}} = \frac{N \cdot \cancel{m}}{m^{\cancel{2}}} = \frac{N}{m}$$

Resultant: $\frac{\text{Force}}{m} = \boxed{\frac{N}{m}}$