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Labs start week of Jan. 16th/17 (next week)
Lab rooms CB0043 and CB0016

Labs are due 1 week after lab @ 4pm.
w/ Title page, Group # included, date submitted, date conducted.
Discussion max 1-page.

- Course outline is emailed to you
- You need to complete the labs to pass the course
- Fluid mechanics / hydraulic engineering

↳ Though, from the formal engineering point of view, fluid mechanics is a fairly new subject, but ancient civilizations used those principles.
  - Egyptians
  - Roman
  - Inca, Mayan (South America)
  - China, India

↳ Why do you need to learn fluid mechanics?
  - water supply + distribution
  - irrigation
  - drainage
  - town planning
  - pumping water
  - mechanical systems (engines, machines)
  - aerodynamics (air flow) - designing cars, planes

Units - SI and U.S. customary units
In Canada, we study in SI units.
It is good to be familiar with U.S. units, but for exam problems, only SI units are used.

SI units

Length - meter (m)
Time - seconds (s)
Mass - Kilogram (kg)
Force - Newton (N) = $kg \cdot N / m$

SI unit prefixes

Giga	G	=	10^9
mega	M	=	10^6
kilo	k	=	10^3
milli	m	=	10^{-3}
micro	μ	=	10^{-6}

↖ greek letter mu

US system of units

Length - Foot (Ft)
Time - Seconds (s)
Force - pound (lb)
mass - slug or $\frac{lb \cdot s^2}{Ft}$

Basic definitions of the terms

Fluids → Liquids, → Gases (this course is mostly about liquids)

Gases - compressible → analysis is difficult, usually studied at higher levels

Liquids - almost incompressible - easier to analyze.

Weight and mass:
mass is the property of a body of Fluid that is a measure of its inertia or resistance to change in motion. It is also a measure of the quantity of Fluid.

Weight is the amount that a body weighs, that is, the Force with which the Fluid is attracted towards earth by gravitation.

mass = quantity of substance
weight = Force = object influenced by gravity
weight = Force = mass × acceleration

$\omega = m \cdot g$

where, ω = weight

m = mass

g = gravity (acceleration due to gravity) (9.81 m/s^2) (32.2 ft/s^2 in US units)

Unit of mass = kg

Unit of weight = N = ($kg \cdot m/s^2$)

Temperature:

Expressed in either - Fahreinheit (F) or Centigrade or Celcius (C)

$$T_c = \frac{(T_F - 32)}{1.8}$$

(we will not deal with temperature change in this course).

Water Freezes at 0°C (32°F)

Water boils at 100°C (212°F)

Absolute temperature

SI units Kelvin (K) is the unit of absolute temperature,

$K = 273.15 + C$

US units Renkn (R) is the unit of absolute temperature

$R = 460 + F$

(Remember -40°C = -40°F)

Pressure - Amount of Force per unit amount

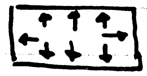
$P = F/A$

Two important principles

1 - pressure acts in all directions on a small volume of fluid.

2 - In a container pressure acts perpendicular to the boundary

PIPE FLOW



AIR DUCT

Unit of pressure is force per unit area
=> $\frac{N}{m^2}$ (newton per meter squared)

In practice $\frac{N}{m^2}$ is rarely used.

In practice (outside university)

1 bar = 10^5 pa (Pa for pascal)
1 Pa = 1 N/m^2
kPa = Kilopascal
MPa = Megapascal

In U.S. customary units for pressure in psi (pounds per square inch)

Generally, 1 atmospheric pressure = 14.7 psi

In S.I. units 1 atmospheric pressure ≅ 100 kPa

Compressibility refers to the change in volume (V) of a substance that is subjected to a pressure.
↳ used qualitatively to write compressibility

$$E = \frac{-\Delta P}{\left(\frac{\Delta V}{V}\right)}$$

Δ - greek letter delta (δ is also delta)
ΔP means $P_2 - P_1$
ΔV means $V_2 - V_1$

The negative sign is there to account for the fact that increasing pressure means decreasing volume, and if we want to keep the value of compressibility as positive, we put a negative sign.

(many textbooks use symbol β for compressibility)
greek letter Beta

Density - $\rho = \frac{m}{V}$ $\frac{Kg}{m^3}$ in SI units

ρ is Greek letter Rho, m is mass, V is volume

Specific weight - is the amount of weight per unit volume.

$$\gamma = w/v \qquad N/m^3 \text{ in SI units}$$

γ is Greek letter gamma, (Γ is also gamma)

Specific gravity - is the ratio of the density of a substance to the density of water at 4°c

(remember water has maximum density at 4°c It is 1000 kg/m³)

specific gravity → $$sg = \frac{\gamma_s}{\gamma_{water @ 4°c}} = \frac{\rho_s}{\rho_w \text{ at } 4°c}$$

γ_s = the specific weight of substance under consideration

ρ_s = the density of the substance under consideration

Properties of Fluids vary with temperature, but in this course we do not deal with temperature.

(Petroleum industry uses slightly different definition of specific gravity. They use water at 60°F instead of water at 4°c)

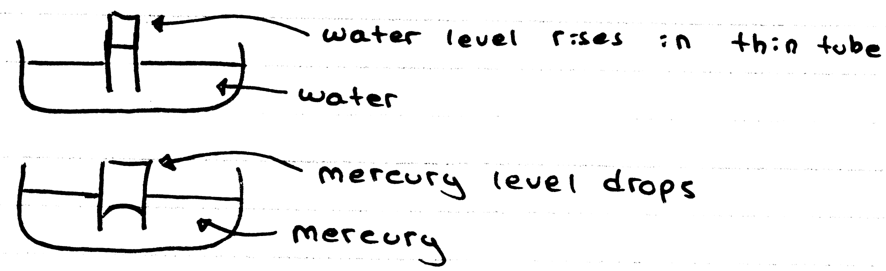
Surface Tension - helps spiders walk on water. The Force of surface tension balances the spiders weight, helping it to walk on water.

When water molecules stick to each other, it is cohesion.

When they stick to other substance (like glass walls)
↳ it is adhesion

Surface tension decreases with temperature.

Compatibility (?)



Problems From Chapter 1

→ Problem 1.43 (it is in U.S. units, so not for exam, but it is good to be familiar with US units)

$$P = F/A = \frac{2500 \text{ lb}}{[\pi(3.00 \text{ in})^2/4]}$$

(You have to remember things like the area of a circle $= \frac{\pi D^2}{4} = \pi r^2$)

D and d are used to represent diameter
r and/or R are used to represent radius.

So, here, $P = 354 \text{ lb/in}^2 = 354$ psi

→ Problem 1.57 - Pressure change required for 1% decrease in volume of ethyl alcohol

$$\Delta P = -E\left(\frac{\Delta V}{V}\right)$$

(You should be familiar with the tables in appendices of the textbook)

From one of these tables

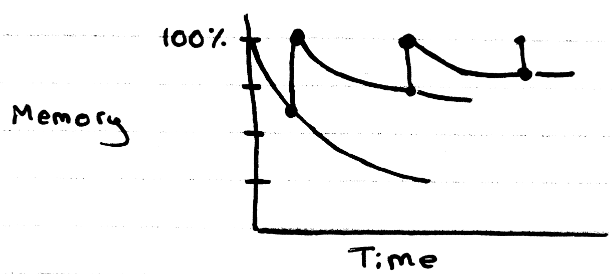
E = 130,000 psi for Ethyl alcohol
(in North America we write 130,000.00
in Europe they write . for comma)

(From previous):
So ΔP = 1300

Same problem in SI units
E = 896 MPa (From the tables)

So, ΔP = - 896 MPa (-0.01)
= 8.96 MPa

Practise problems from chapter 1
1.21, 1.45, 1.59, 1.76, 1.88
(I will put solutions on D2L in few days
For practise problems from chapters)



4 repititions needed to master new material for most people.

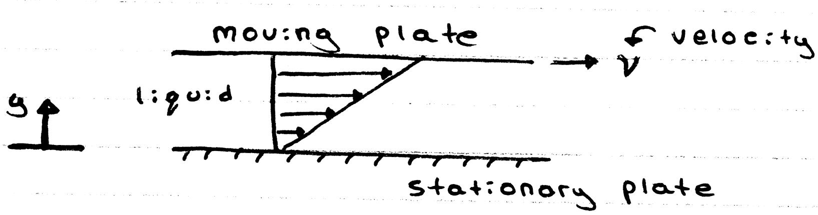
Chapter 2 - Viscosity of Fluids
The ease with which a fluid pours is an indication of its viscosity.

As fluid moves, a shear stress is developed in it, the magnitude of which depends on its viscosity.

Shear stress is denoted by the Greek letter τ (tau)

We know stress is force per unit area

So, the τ can be defined as the force required to slide one unit area layer of a liquid over another layer.

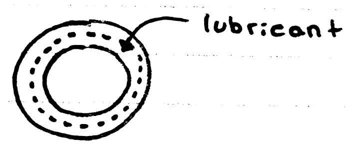


no-slip condition ⟶ Fluid sticks to the surface it is touching

(in reality, we do not have two parallel plates and fluid in-between)

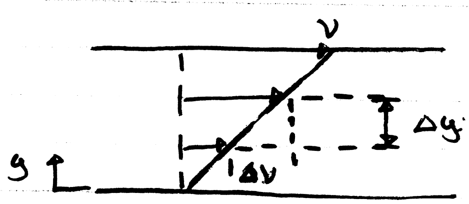
In Engineering, one of the most useful tools is modeling.

We usually have



one is rotating
other is stationary

So, open up and it becomes like two Parallel plates
So, a rotating shaft supported by a stationary sleeve with a lubricant inbetween is the same as two parallel plates - one moving and the other stationary.



Shear stress $\tau = \eta \left(\frac{\Delta v}{\Delta y} \right)$

η (Greek letter eta) is called "Dynamic Viscosity"

Units for μ are $\frac{N \cdot s}{m^2}$, $Pa \cdot s$, $\frac{kg}{ms}$

So, viscosity or μ is a constant of proportionality between shear stress and velocity gradient ($\Delta v / \Delta y$)

In U.S. units - dynamic viscosity is

$\frac{lb \cdot s}{ft^2}$ or $\frac{slug}{ft \cdot s}$

Chemical engineering literature mostly uses the term kinematic viscosity (Greek letter Nu)

$$\nu = \mu / \rho \qquad m^2/s \qquad \left(\frac{\text{dynamic viscosity}}{\text{density}} \right)$$