LAB MANUAL IS ON D2L.

↳ Industry people use different units for viscosity

Most commonly used units for dynamic viscosity

$$\text{Poise} = \frac{\text{dyne} \cdot s}{cm^2} = \frac{g}{cm \cdot s} = 0.1\ Pa \cdot s$$

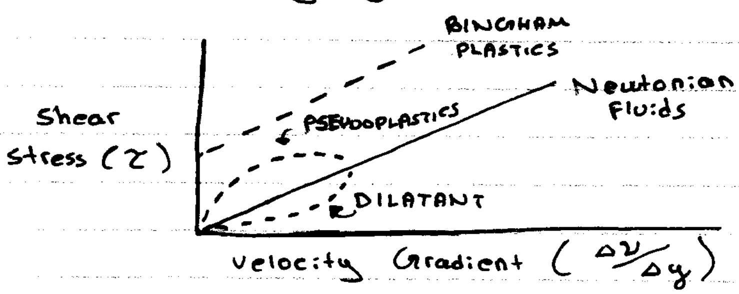
$$\text{Centipoise} = \frac{\text{Poise}}{100} = 0.001\ Pa \cdot s$$

Similarly, for kinematic viscosity, people in industry use the unit "stroke"

$$1\ \text{stroke} = 1\ \frac{cm^2}{s} = 1 \times 10^{-4}\ \frac{m^2}{s}$$

$$1\ \text{centistroke} = 1/100\ \text{stroke}$$

Behavior of various fluids – relationship between velocity gradient and shear stress



In this course, we only study Newtonian fluids

- Viscosity of liquids decreases with increase in temperature
- Viscosity of gases increases with increase in temperature

(Although this course does not deal with change in temperature, it is important to understand the effect of temperature on viscosity)

A measure of how greatly the viscosity of a fluid changes with temperature is given by the viscosity index. (VI)

$$VI = \frac{L - U}{L - H} \times 100$$

L = Kinematic viscosity at 40°c of a standard oil of zero VI having the same viscosity at 100°c as the test oil.

U = Kinematic viscosity at 40°c of the test oil.

H = Kinematic viscosity at 40°c of a standard oil of 100 VI having the same viscosity at 100°c as the test oil.

Society of Automotive Engineers (SAE) have developed these standards for viscosity grades.

Questions from Chapter 2 then can be answered on the basis of what we did in class.

2.1 to 2.5, 2.9, 2.14 to 2.17

Chapter 3 - Pressure Measurement

Absolute pressure and gage pressure
(gauge in North America)

When making calculations involving pressure in a fluid, you must make the measurement relative to some reference pressure.

Normally, the reference pressure is that of the atmosphere, and the resulting measured pressure is called "gage pressure"

Pressure measured relative to perfect vacuum is called "absolute pressure"

A simple equation relates these two pressure measuring systems

$$P_{abs} = P_{gage} + P_{atm}$$

where, P_{abs} = absolute pressure
P_{gage} = gage pressure
P_{atm} = atmospheric pressure

The magnitude of atmospheric pressure varies from location to location.

The range of normal atmospheric pressure varies from 95 kPa to 105 kPa
(In US units, 13.8 psia to 15.3 psia
where psia = pounds per square inch absolute)

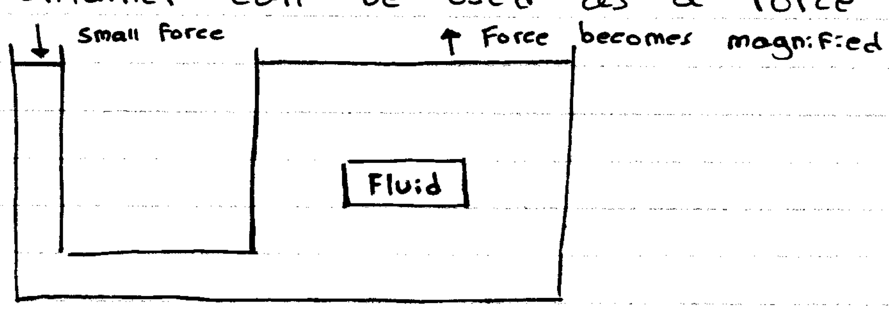
When atmospheric pressure is not given, in this course it is assumed to be 101 kPa.
(You need to remember this)

The change in pressure in a homogeneous liquid at rest
$\Delta P = \gamma h$ (need to remember)
where ΔP = change in pressure
h = depth or change in elevation
γ = specific weight of liquid

Applicability of this relationship
1. Homogeneous liquid at rest
2. Points at the same horizontal level, have same pressure.
3. Pressure varies linearly with depth

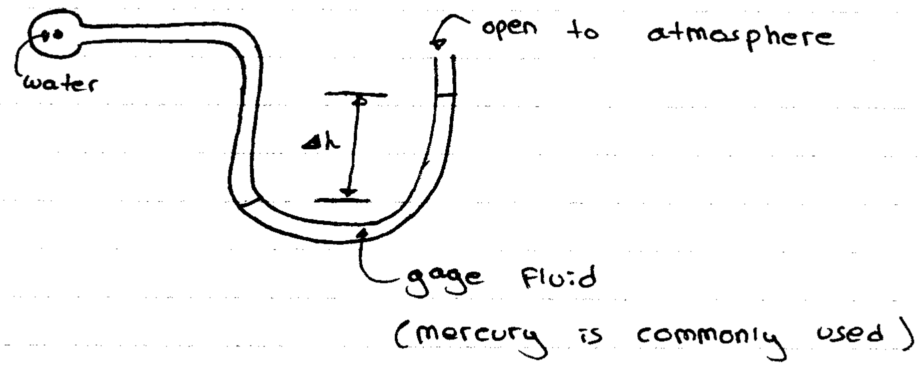
So, the change in pressure depends only on the change in elevation (or depth) and the type of fluid, but not on the size of the container.
(this is called Pascal's paradox)

It became very useful because the geometry of a container can be used as a force magnifier



<u>Manometers</u> - use the relationship between a change in pressure and change in elevation in a static fluid to measure pressure.

Most common is u-tube manometer



Under the action of pressure to be measured, the gage fluid is displaced from its normal location or position

The equation $\Delta P = \gamma h$ can be used to write an expression for the change in pressure that occurs throughout the manometer.

The expressions can be combined and solved algebraically to determine the unknown pressure.

The procedure to determine unknown pressure:

1. Start from one end of the manometer and express the pressure there in symbolic form (e.g. P_A refers to pressure at point A) If one end is open to atmosphere, there is zero gage pressure.
2. Add terms representing changes in pressure using $\Delta P = \gamma h$, proceeding from the starting point and including each column of each fluid separately (obviously γ for each fluid is different)

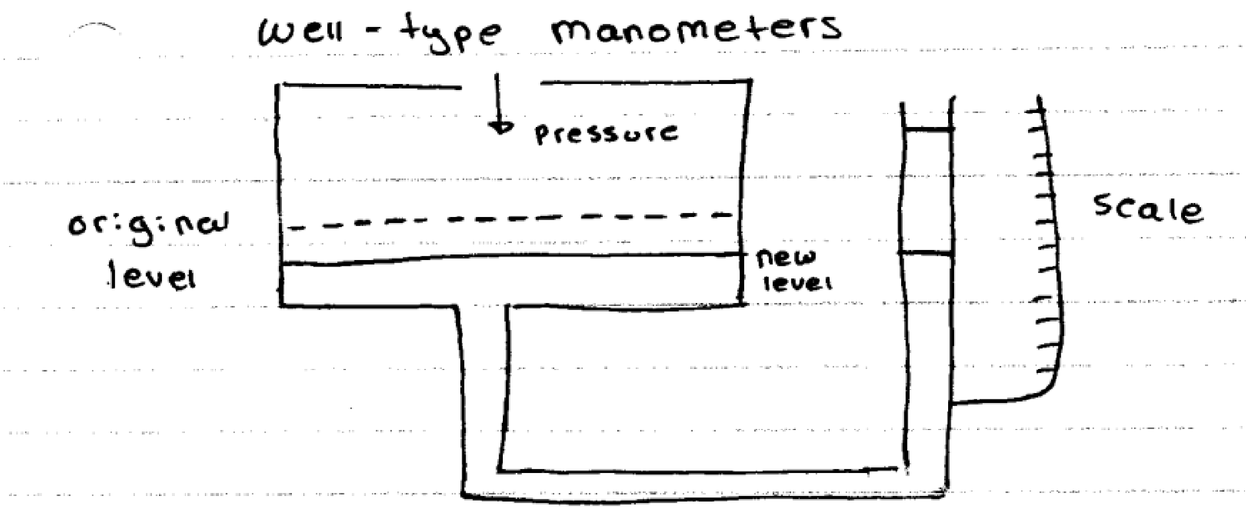
3. Whenever the movement from one point to another is .....

4. Continue this process until other end is reached. The result is an expression for the pressure at the end point. Equate this expression to the symbol for the pressure at the .... point, giving a complete equation for the ....

5. Solve the equation algebraically for the desired pressure of a given point or the difference in pressure between the points of interest.

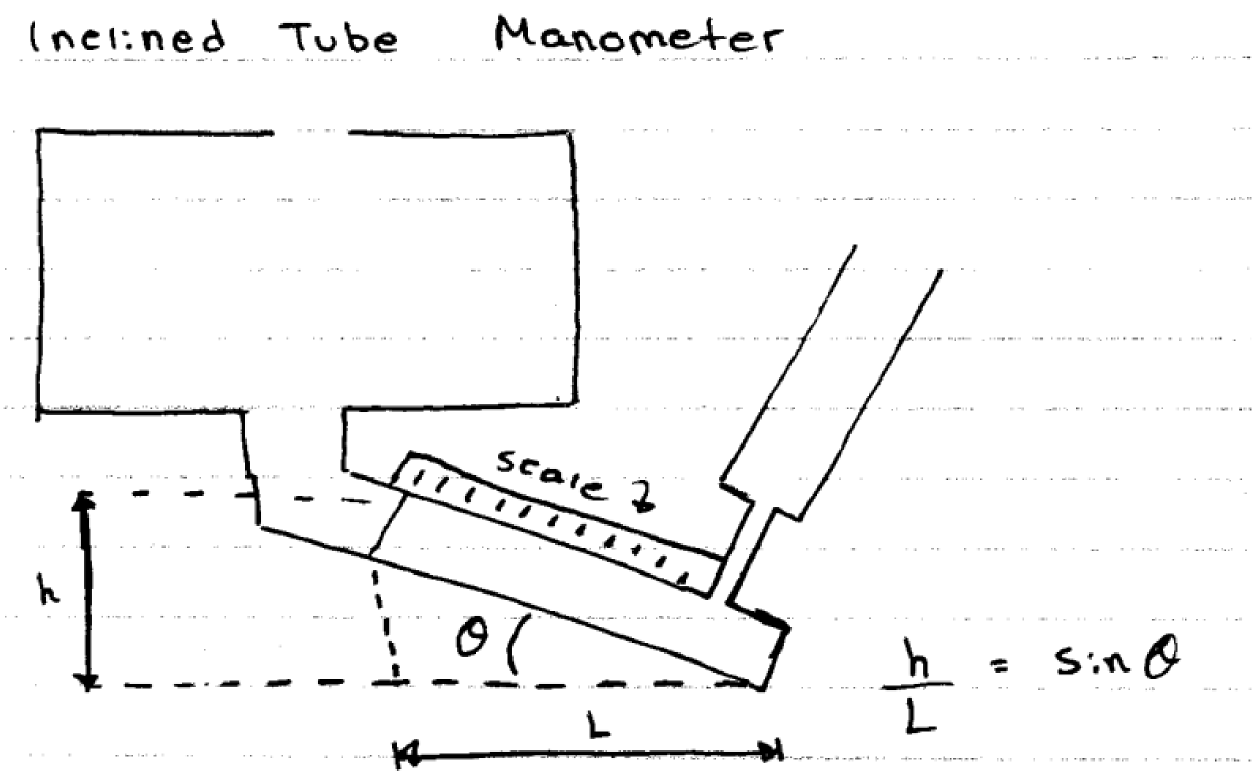
6. Obtain a known delta and obtain a numerical value for unknown pressure.

Other Geometries for Manometers:



This is more accurate than U-tube.

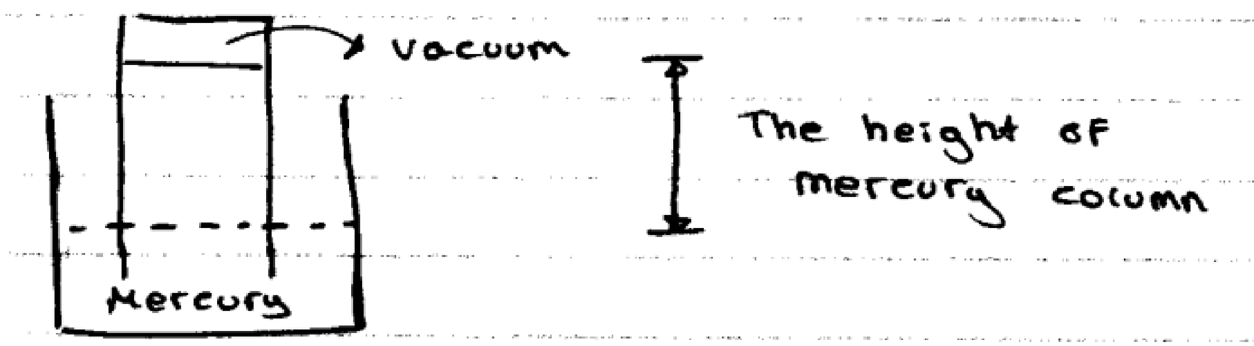
Another idea to get accurate measurement by using an inclined tube manometer.



Because of the inclined scale, we get little more magnification.

Barometer – for measuring atmospheric pressure.

Usually, a tube filled with mercury inverted in a container.



The height of mercury column gives the atmospheric pressure.

In academic setting, we say atmospheric pressure is $101.5\ kPa$ or $14.7\ psia$, but practising engineers express it in terms of height of a fluid column like so many meters of water or so many mm of mercury.

So, $1.0\ inch$ of water $= 0.0361\ psi$
$1.0\ inch$ of water $= 299.1\ Pa$
$1.0\ inch$ of mercury $= 0.491\ psi$
$1.0\ mm$ of mercury $= 0.01939\ psi$ (or $= 133.3\ Pa$)

Pressure gages and transducers:

In many practical situations, we need to get a visual indication of pressure – so we use pressure gages.

In many practical situations, we need to know pressure at some remote location, and in their case we use transducers.

Transducers – when a sensed pressure is used to cause electrical signals that can be transmitted to a remote location for reading.

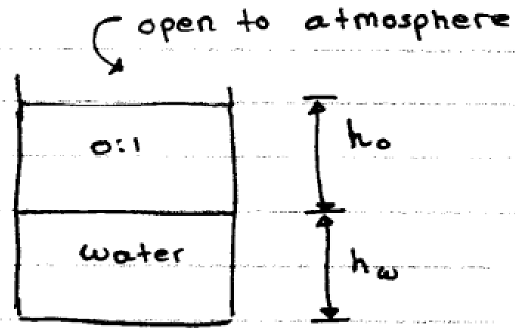
Problem 3.49

s.g. of oil = 0.86

depth of oil = h_o = 6.90 m

Gage at bottom reads 123.3 kPa

Calculate water depth h_w



$0 + \gamma_o h_o + \gamma_w h_w = P_{bottom}$ only h_w is unknown

$$h_w = \frac{P_{bottom} - \gamma_o h_o}{\gamma_w} = \frac{125.3 - (0.86)(9.81)(6.90)}{(9.81)}$$

$$= 6.84 \text{ m}$$

(make sure you understand why 9.81 appeared)

From Chapter 3 you should be able to answer question 3-1 to 3-13 by reading notes.

Practise Problems 3.50, 3.65, 3.67 (he will put solutions on D2L)

Chapter 4 – Forces due to static fluids

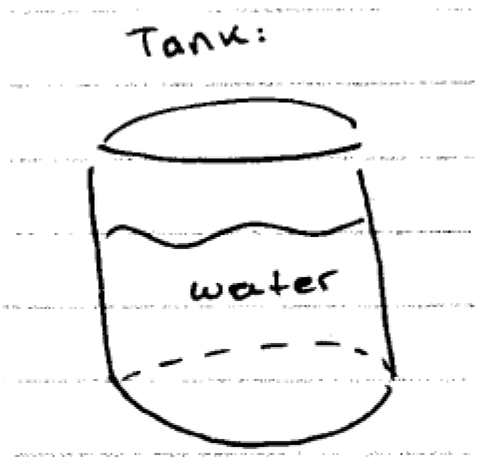
Consider a storage tank filled with a liquid, an aquarium, a dam, a fluid powered cylinder, etc.

In each case, the fluid exerts a force on the surface of interest that acts perpendicular to the surface.

Consider the basic definition of pressure: $P = \frac{F}{A}$
and the corresponding form: $F = P \cdot A$

But we can apply these equations directly only when the pressure is uniform over the entire area of interest.

If we look at a tank:



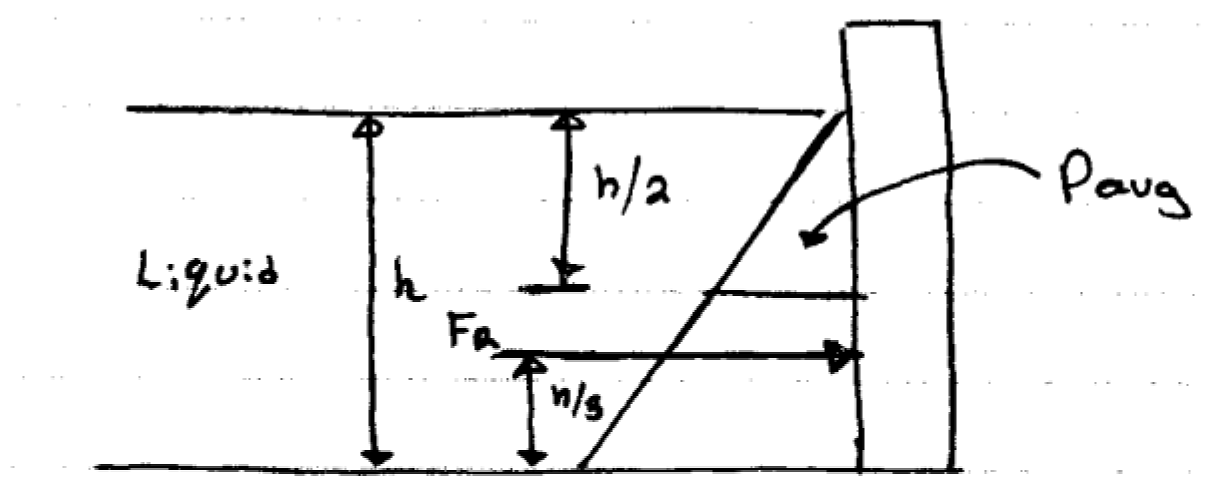
The pressure at the bottom of the tank is uniform because the depth of the water is the same at all points of the bottom.

If we look at the wall of this tank, the depth is different at different points ass we go down from the surface to the bottom.

We know the pressure depends on the depth, so on the wall, we have uniform pressure.

The definition $P = \frac{F}{A}$ is always valid, but we have to be careful in writing it when the pressure is not uniform.

Schematically,



So, the average pressure, P_{avg} is reached at half height $\frac{h}{2}$.

But, you should know that the resultant force F_R acts at the centre of pressure, $\frac{h}{3}$ from the bottom.

The total resultant force can be calculated from the equation: $F_R = P_{avg} \cdot A$

A is the total area of the wall.

P_{avg} is the average pressure, and is represented by the following equation: $P_{avg} = \gamma \frac{h}{2}$

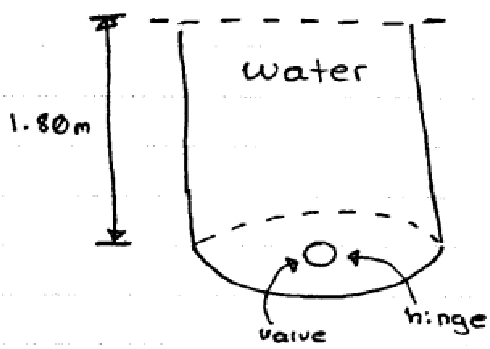
γ is the specific weight of the liquid.

So, we have $F_R = \gamma \frac{h}{2} \cdot A$

The resultant force acts perpendicular to the wall at the centroid of the pressure distribution triangle, one third of the distance (of height) from the bottom of wall.

Problem 4.10

How much force is required to open the valve?



(diameter given as 9.5 cm for the valve)

Force on the valve

$F = P \cdot A$

$$A = \frac{\pi (0.095)^2}{4}$$

$$A = 7.088 \times 10^{-3}\ m^2$$

$$P = \gamma_w h = 9.81\ kN/m^3 \times 1.80\ m = 17.66\ kN/m^2$$

need to remember

So, $F = (17.66 \times 10^3)(7.088 \times 10^{-3}) = 125\ N$

This force acts at the centre of the valve.

diameter/2

$$\Sigma M_{hinge} = 0 = (125\ N)(47.5\ mm) - F_o(65\ mm)$$

$$F_o = \frac{5946}{65}\ N\frac{mm}{mm} = 91.5\ N \text{ opening force.}$$

(such a problem will not be in exam)