

HYDRAULICS 1



Base Units
Properties of Fluids
Unit Pressure

PROPERTIES OF FLUIDS

γ (gamma) - Unit weight; Specific weight

- Weight per unit volume $\gamma = \frac{W}{V} \left(\frac{N}{m^3} \right)$

$\gamma_w = 9810 \frac{N}{m^3}$

ρ (rho) - Unit mass; Mass Density

- Mass per unit volume $\rho = \frac{m}{V} \left(\frac{kg}{m^3} \right)$

$\rho_w = 1000 \frac{kg}{m^3}$

sg - Specific Gravity; Relative Density

$\gamma = \rho g$

$\gamma_{air} = 12 \frac{N}{m^3}$

For solid & liquid:

$sg = \frac{\rho}{\rho_{water}}$

$sg = \frac{\gamma}{\gamma_{water}}$

For gas:

$sg = \frac{\rho}{\rho_{air}}$

$sg = \frac{\gamma}{\gamma_{air}}$

Standard values of sg of common liquids:

freshwater	- 1.0
seawater	- 1.03
oil	- 0.80
mercury	- 13.6

BASE UNITS

International System (SI)

English System

Force (F)

N

lb

Mass (m)

kg

$slug$

Acceleration (a)

m/s^2

ft/s^2

Newton's Second Law:

$F = ma$

$N = kg \left(\frac{m}{s^2} \right)$

$lb = slug \left(\frac{ft}{s^2} \right)$

1. One slug is equivalent to how many kg?

$N = kg \left(\frac{m}{s^2} \right) \rightarrow kg = \frac{N \cdot s^2}{m}$

$lb = slug \left(\frac{ft}{s^2} \right) \rightarrow slug = \frac{lb \cdot s^2}{ft} \times \frac{3.28 ft}{1 m} \times \frac{4.448 N}{1 lb}$

$slug = 14.59 \frac{N \cdot s^2}{m}$

$slug = 14.59 kg$

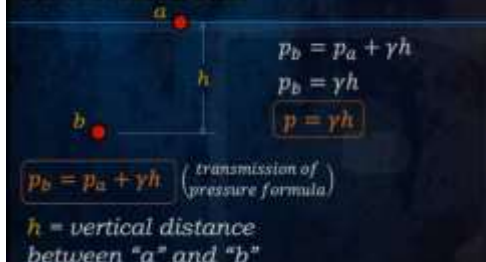
2. What is the mass density of fresh water in slugs per cubic foot?

$$\rho_w = 1000 \frac{\text{kg}}{\text{m}^3} \times \left(\frac{1 \text{ m}}{3.28 \text{ ft}} \right)^3 \times \frac{1 \text{ slug}}{14.59 \text{ kg}}$$

$$\rho_w = 1.94 \frac{\text{slug}}{\text{ft}^3}$$

Gamma of water in English System = 62.4lb per cubic ft.

UNIT PRESSURE



liquid surface

$p_b = p_a + \gamma h$

$p_b = \gamma h$

$p = \gamma h$

$p_b = p_a + \gamma h$ (transmission of pressure formula)

h = vertical distance between "a" and "b"

P = unit pressure

$= \frac{\text{N}}{\text{m}^2}$ (Pa)

= gage pressure (+ or -)

NOTE: If the given pressure is not specified, assume gage pressure.

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

p_{abs} = absolute pressure (+)

p_{atm} = atmospheric pressure = barometric pressure

$1 \text{ atm} = 101.325 \text{ kPa}$

768 mm of Hg

$p = \gamma h$

$p_{atm} = 13.6(9.81)(0.768)$

$p_{atm} = 102.46 \text{ kPa}$

3. A liquid in a $1.13 - \text{m}^3$ container has a mass of 814 kg.
c. What is its gravity force?

$$\rho = \frac{m}{V} = \frac{814}{1.13}$$

$$\rho = 720.35 \frac{\text{kg}}{\text{m}^3}$$

$$\gamma = \rho g$$

$$\gamma = 720.35 (9.81)$$

$$\gamma = 7066.67 \frac{\text{N}}{\text{m}^3}$$


$$\gamma = \frac{W}{V} \rightarrow W = \gamma V$$

$$W = m g$$

$$W = 814(9.81)$$

$$W = 7985.34 \text{ N}$$

UNIT PRESSURE



liquid surface

$p = \gamma h$

$h = \frac{p}{\gamma}$

Pressure Head - height of a column of the fluid that is needed to produce the pressure "p".

UNIT PRESSURE

Convert the pressure head of liquid "A" to the pressure head of liquid "B"



$$\gamma_A h_A = \gamma_B h_B$$

$$sg_A(\gamma_w)h_A = sg_B(\gamma_w)h_B$$

$$h_B = \frac{sg_A}{sg_B}(h_A)$$

4. Evaluate the greatest pressure of water in the tank shown.



$$p_1 = 0 + 35$$

$$p_2 = 9.81(1) + 35$$

$$p_{max} = 35 + 9.81(1.9)$$

$$p_{max} = 53.639 \text{ kPa}$$

Pascal's Law - In a fluid at rest in a closed container, a pressure change in one part is transmitted without loss to every portion of the fluid and to the walls of the container.

5. The pressure gage in a given tank reads 125 mm Hg. Calculate the equivalent height of column of oil.

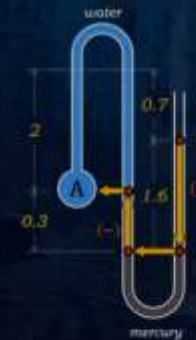


$$h_{oil} = \frac{sg_{Hg}}{sg_{oil}} h_{Hg}$$

$$h_{oil} = \frac{13.6}{0.80} (0.125)$$

$$h_{oil} = 2.125 \text{ m}$$

6. Determine the gage pressure at A in the given open-type manometer.



Σ Pressures:

$$0 + 13.6(9.81)(1.6) - 9.81(0.3) = p_A$$

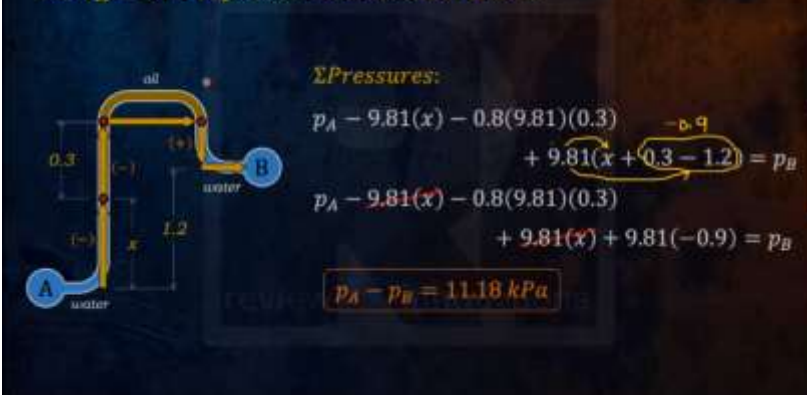
$$p_A = 210.52 \text{ kPa}$$

Σ Pressure Heads:

$$0 + \frac{13.6}{1}(1.6) - 0.3 = \frac{p_A}{\gamma}$$

$$p_A = 210.52 \text{ kPa}$$

7. Assuming oil in the differential-type manometer shown, calculate the difference in pressures between A and B.



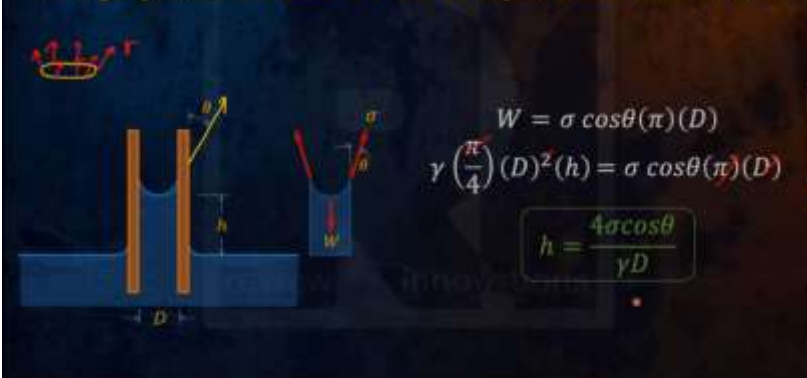
8. Determine the height water will rise due to capillary action in a clean, 6-mm diameter tube. What will be the height if the diameter is reduced to 0.5 mm? The angle of contact with water is 0° and the surface tension is 0.0728 N/m .



If theta is greater > than 90° = depression (downwards)

If liquid is mercury, always depression

8. Determine the height water will rise due to capillary action in a clean, 6-mm diameter tube. What will be the height if the diameter is reduced to 0.5 mm? The angle of contact with water is 0° and the surface tension is 0.0728 N/m .



9. Chlorine gas at 30°C is under a pressure of 481 kPa . Assume a gas constant of $117 \text{ N}\cdot\text{m}/\text{kg}\cdot\text{K}$. Calculate the specific volume.

Solving for "p" of a gas

$$p = \rho RT$$

p = absolute pressure in Pa

ρ = mass density in kg/m^3

T = absolute temperature in Kelvin (K)

$T = ^\circ\text{C} + 273$

R = gas constant $\frac{\text{N}\cdot\text{m}}{\text{kg}\cdot\text{K}}$

$R = 287.4 \frac{\text{N}\cdot\text{m}}{\text{kg}\cdot\text{K}}$ if not given, for air

Solving for "gamma" of a gas

$$p = \gamma RT$$

p = absolute pressure in Pa

γ = specific weight in N/m^3

T = abs. temp in Kelvin (K)

$T = ^\circ\text{C} + 273$

R = gas constant $\frac{\text{m}}{\text{K}}$

$R = 29.3 \frac{\text{m}}{\text{K}}$ if not given, for air

9. Chlorine gas at 30°C is under a pressure of 481 kPa. Assume a gas constant of 117 N-m/kg-K. Calculate the specific volume.

$$p = \rho RT$$

$$(481 + 101.325)(1000) = \rho(117)(30 + 273)$$

$$\rho = 16.426 \frac{\text{kg}}{\text{m}^3}$$

$$\text{sp. vol.} = \frac{1}{\rho} = \frac{1}{16.426}$$

$$\text{sp. vol.} = 0.061 \frac{\text{m}^3}{\text{kg}}$$

6

Density of water is maximum at

- A. 0°C
- ✓ B. 4°C
- C. 100°C
- D. 20°C

Fluid is a substance that

- A. cannot be subjected to shear forces
- B. always expands until it fills any container
- C. has the same shear stress at a point regardless of its motion
- ✓ D. cannot remain at rest under action of any shear force

Property of a fluid by which its own molecules are attracted is called

- A. adhesion
- ✓ B. cohesion
- C. viscosity
- D. surface tension

Property of a fluid by which molecules of different kinds of fluids are attracted to each other is called

- ☒ A. adhesion
- B. cohesion
- C. viscosity
- D. surface tension

Specific weight of sea water is more than that of pure water because it contains

- A. dissolved air
- B. dissolved salt
- C. suspended matter
- ☒ D. all of the above

The normal stress in a fluid will be constant in all directions at a point only if

- A. it is incompressible
- B. it has zero viscosity
- C. it is frictionless
- ☒ D. it is at rest

Free surface of a liquid tends to contract to the smallest possible area due to force of

- ☒ A. surface tension
- B. viscosity
- C. friction
- D. cohesion

A liquid would wet the solid, if adhesion forces as compared to cohesion forces are

- A. less*
- ☒ *B. more*
- C. equal*
- D. less at low temperature and more at high temperature*

Manometer is used to measure

- ☒ *A. pressure in pipes, channels etc*
- B. atmospheric pressure*
- C. very low pressure*
- D. velocity in pipes*

Barometer is used to measure

- A. pressure in pipes, channels etc*
- ☒ *B. atmospheric pressure*
- C. very low pressure*
- D. difference of pressure between two points*

If cohesion between molecules of a fluid is greater than adhesion between fluid and glass, then the free level of fluid in a dipped glass tube will be

- A. higher than the surface of liquid*
- B. the same as the surface of liquid*
- ☒ *C. lower than the surface of liquid*
- D. unpredictable*

When a fluid is subjected to resistance, it undergoes a volumetric change due to

- A. Cohesion*
- B. Strain*
- ☒ *C. Compressibility*
- D. Adhesion*

The rise or depression of liquid in a tube due to surface tension with an increase in size of tube will

- A. increase*
- B. remain unaffected*
- C. may increase or decrease depending on the characteristics of liquid*
- ☒ *D. decrease*

Liquids transmit pressure equally in all the directions. This is according to

- A. Boyle's law*
- B. Archimedes principle*
- ☒ *C. Pascal's law*
- D. Newton's formula*

Mercury is often used in barometer because

- A. it is the best liquid*
- B. the height of barometer will be less*
- C. its vapor pressure is so low that it may be neglected*
- ☒ *D. both (b) and (c)*