CE 1102
FUNDAMENTALS OF CIVIL ENGINEERING

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CE 1102 - Fundamentals of Civil Engineering

- Scope of Civil Engineering
- Fluid mechanics, Hydrostatics
- Hydrodynamics
- Flow classification

Week 1-6

- Introduction to structural engineering
- Building construction & materials
- Highway Engineering

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RESOURCES

- **Module Descriptor- Available in LMS**
- **Lesson Plan- Available in LMS**
- **Suggested list of further readings-Available in LMS**
- **Each week Lecture notes- Will be uploaded to LMS before the each week lecture**
- **Lecture recordings for each week- Will be uploaded to LMS after the each week lecture**
- **Any other specific learning materials will be uploaded to the LMS in each week**

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Learning Outcomes

LO2: Estimate the stability of floating bodies and energy associated in moving fluids

This LO will be covered from Chapter 2, Chapter 3 and Chapter 4

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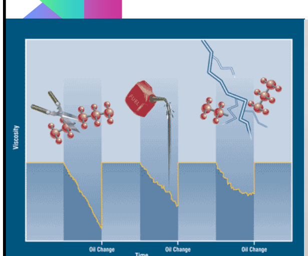
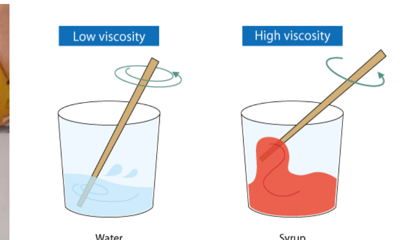
Chapter 2: Fluid mechanics, Hydrostatics
Chapter 2-Part 1- Introduction to Fluid Mechanics and Hydrostatics,
Chapter 2-Part 2- Properties of Fluid
Chapter 2-Part 3-Buoyancy – Stability of Floating Bodies, Metacentre

Chapter 3: Hydrodynamics: Applications of Bernoulli's Equation
Momentum Equation

Chapter 4: Flow classification: Laminar and turbulent flow

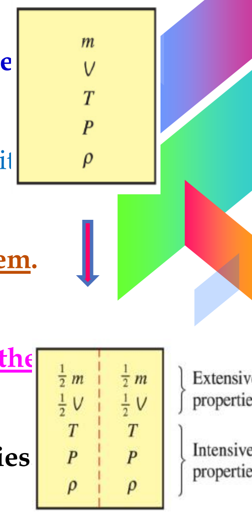
Chapter 2: Part 2- Properties of Fluid





Introduction

- Any characteristic of a system is called a **property. Fluid syste properties include:**
  - Familiar: pressure *P*, *temperature T*, *volume V*, and mass *m*.
  - Less familiar: viscosity, thermal conductivity, modulus of elasticit thermal expansion coefficient, vapor pressure, surface tension.



- ***Intensive properties are independent of the mass of the system.*** Examples: temperature, pressure, and density

- *Extensive properties are those whose value* **depends on the size of the system.** Examples: total mass, total volume, and total momentum

- Extensive properties per unit mass are called **specific properties Examples include –**
  specific volume, $v = V/m$
  specific total energy, $e=E/m$

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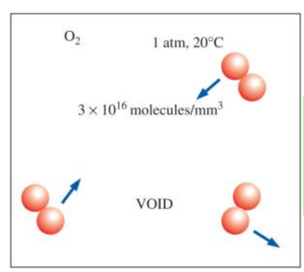
Continuum

- Atoms are widely spaced in the gas phase.
- We can disregard the atomic nature of a substance
- We can view it as continuous, homogeneous matter with no holes, that is, a **continuum.**
- This allows us to treat properties as smoothly varying quantities.
- Continuum is valid as long as the size of the system is large compared to the distance between molecules.



In this subject we limit our consideration to substances that can be modelled as a continuum.

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Density and Specific Gravity

❖Density is defined as the **mass per unit volume** *$\rho = m/V$ and has units of kg/m^3*

❖ Specific volume is defined as $\upsilon = 1/\rho = V/m$.

❖For a gas, density depends on temperature and pressure.

❖**Specific gravity (or relative density) is defined as** the ratio of the density of a substance to the density of some standard substance at a specified temperature (usually water at 4°C),

i.e. $SG = \rho / \rho_{H20}$. *SG is dimensionless.*

❖The **specific weight is defined as the weight** per unit volume, i.e., $\gamma_s = \rho g$ *where g is the* gravitational acceleration. γ_s *has units of N/m^3.*

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Substance	SG
Water	1.0
Blood (at 37°C)	1.06
Seawater	1.025
Gasoline	0.68
Ethyl alcohol	0.790
Mercury	13.6
Balsa wood	0.17
Dense oak wood	0.93
Gold	19.3
Bones	1.7–2.0
Ice (at 0° C)	0.916
Air	0.001204

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FURTHER READINGS AT HOME

Density of Ideal Gases

Vapour Pressure and Cavitation

Energy and Specific Heats

Coefficient of Compressibility

Coefficient of Volume Expansion

Section 2.2/2.3/2.4/2.5

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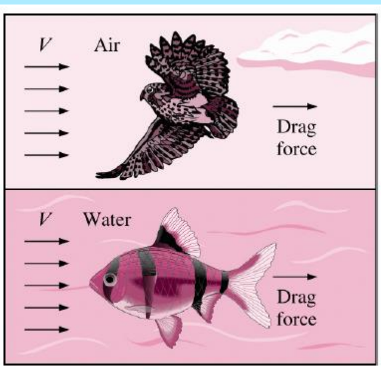
Viscosity

Viscosity is a property that represents the internal resistance of a fluid to motion.



- Units are **stokes or m²/s**
- 1 stoke = 0.0001 m^2/s

The force a flowing fluid exerts on a body in the flow direction is called the drag force, and the magnitude of this force depends, in part, on viscosity.

The World Bog Snorkelling Championships take place every year in a dense peat bog near Llanwrtyd Wells, in Wales.

http://inventorspot.com/files/images/July%201st%20-%20Weird%20Sports5.jpg

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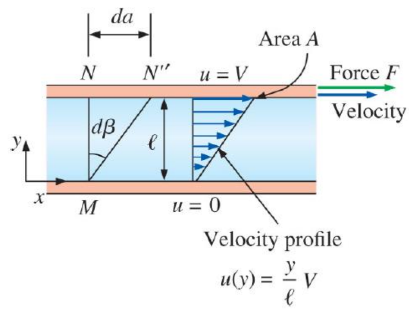
Viscosity

❖To obtain a relation for viscosity, consider a fluid layer between two very large parallel plates separated by distance ℓ

❖A parallel force F is applied to the top plate
❖Definition of shear stress is

$$\tau = F/A$$

(on upper fluid layer)



❖Using the no-slip condition,
$u(0) = 0$ and $u(\ell) = V$
the velocity profile and gradient are $u(y)= yV/\ell$
and $du/dy=V/\ell$

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Viscosity

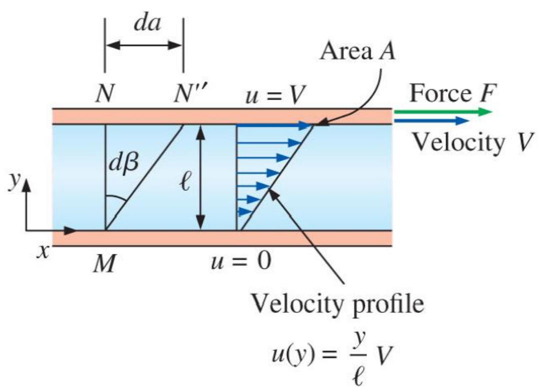
- Shear stress for Newtonian fluid:

$$\tau = \mu \, (du/dy)$$

- μ is the **dynamic viscosity and has** units of *kg/(m·s), Pa·s, or **poise.***

- The shear force:

$$F = \tau A = \mu A \, (du/dy)$$



•The force needed to move the top plate at constant velocity, V, is

$$\boxed{F = \mu A \frac{V}{\ell}}$$

THIS IS THE BEHAVIOUR OF LAMINAR FLOW

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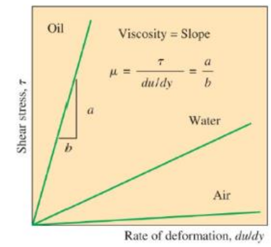
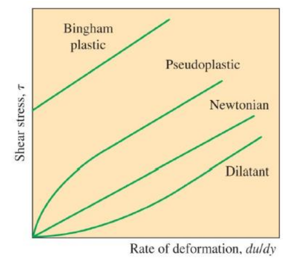
Viscosity

Newtonian fluid - where the rate of deformation is proportional to the shear stress,
eg. water, air, gasoline, oil

Non-Newtonian fluid – above condition is not met, relationship is not linear
eg. blood, liquid plastics

the slope of a curve at a point is the apparent viscosity of the fluid at that point





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FURTHER READINGS AT HOME

Surface tension

Capillary effect

Section 2.7

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Pressure

Pressure- Chapter 3-3.1- Cengel and Cimbala

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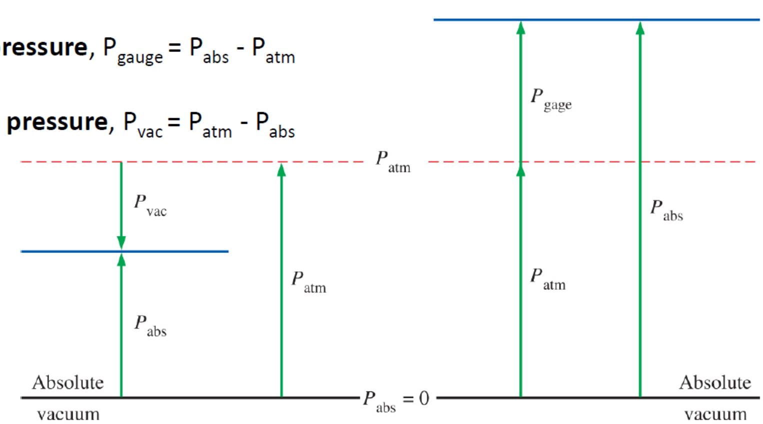
Pressure

❖**Pressure is defined as a** ***normal force exerted by a fluid per unit area***
❖Units of pressure are N/m^2, called a **pascal (Pa)**
❖Other units include *bar, atm, psi*
❖The actual pressure at a given point is called **absolute pressure**

Gauge pressure, $P_{gauge} = P_{abs} - P_{atm}$

Vacuum pressure, $P_{vac} = P_{atm} - P_{abs}$



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Pressure Measurement

Pressure measurement at a point within a fluid mass is generally indicated as either absolute or gauge pressure.

Gauge pressure

- Measured relative to the local atmospheric pressure
- Can be positive or negative.
- A negative gauge pressure is also known as vacuum pressure.
- a gage pressure of zero corresponds to a pressure that is equal to the local atmospheric pressure.

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Pressure Measurement

Absolute pressure

- Measured relative to a perfect vacuum (absolute zero pressure), which is the lowest possible pressure.
- Therefore, an absolute pressure will always be positive.
- A simple equation relating the two pressure measuring system can be written as:

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

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Pressure Measurement

Atmospheric pressure

- Refers to the prevailing pressure in the air around us.
- It varies somewhat with changing weather conditions, and it decreases with increasing altitude.
- At sea level, average atmospheric pressure is 101.3 kPa (abs), 14.7 psi (abs), or 1 atmosphere (1 bar = 1×10^5 Pa).
- This is commonly referred to as 'standard atmospheric pressure'.

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Pressure at a Point

▪Pressure at any point in a fluid is the same in all directions
▪Pressure has a magnitude, but not a specific direction, thus it is a scalar Quantity Now, let's consider the wedge below.

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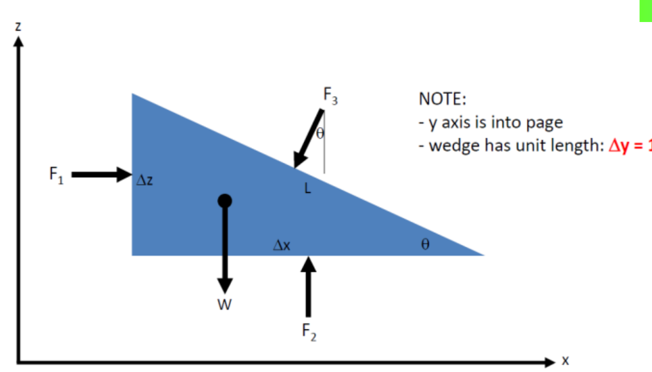

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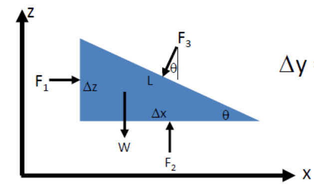
Pressure at a point

1st year Static problem



$\Delta y = 1$

$F_1 = P_1A_1 = P_1\Delta y\Delta z = P_1\Delta z$
$F_2 = P_2A_2 = P_2\Delta x\Delta y = P_2\Delta x$
$F_3 = P_3A_3 = P_3L\Delta y = P_3L$

The wedge is static, so

$\Sigma F_x = 0 \rightarrow P_1\Delta z - P_3L\sin\theta = 0$ (1)
$\Sigma F_z = 0 \rightarrow P_2\Delta x - P_3L\cos\theta - mg = 0$ (2)

NOTE

$L\cos\theta = \Delta x$
$L\sin\theta = \Delta z$

(1) $\rightarrow P_1\Delta z - P_3\Delta z = 0 \rightarrow P_1 = P_3$
(2) $\rightarrow P_2\Delta x - P_3\Delta x - 1/2\rho g\Delta x\Delta z = 0$

$m = \rho V = \rho\ (1/2\ \Delta x\Delta y\Delta z)$

as $\Delta z \rightarrow 0$ (i.e. as wedge gets smaller)
$P_2\Delta x - P_3\Delta x = 0 \rightarrow P_2 = P_3$

$\boxed{\text{Therefore, } P_1 = P_2 = P_3 = P}$

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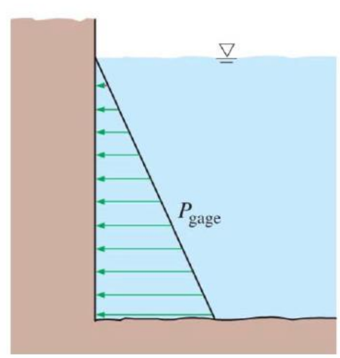
Variation of Pressure with Depth

- For a constant density fluid, the pressure difference between two points is proportional to the vertical distance between the points
- Pressure in a fluid increases linearly with depth



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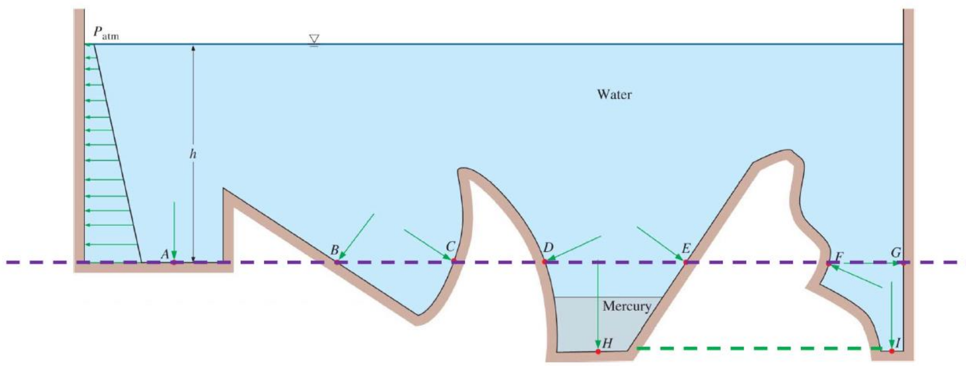
Variation of Pressure with Depth

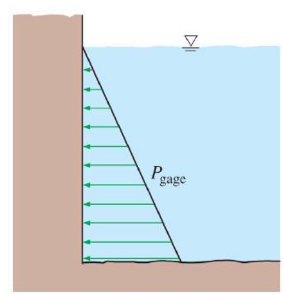
❖ Pressure in a fluid at rest is independent of the shape of the container

❖ Pressure is the same at all points on a horizontal plane in a given fluid

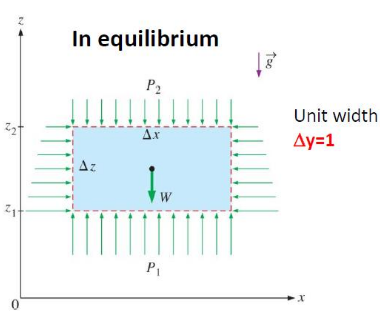


Variation of Pressure with Depth

❑In the presence of a gravitational field, pressure increases with depth because more fluid rests on deeper layers



❑To obtain a relation for the variation of pressure with depth, consider the rectangular element shown below.



– Force balance in the z-direction gives

$$\sum F_z = ma_z = 0$$

$$P_1\cancel{\Delta x} - P_2\cancel{\Delta x} - \rho g\cancel{\Delta x}\Delta z = 0$$

Dividing by Δx ***and rearranging gives***

$$\boxed{\Delta P = P_2 - P_1 = -\rho g \Delta z}$$

Note

Pressure *p at any depth h below the free surface* is given by the equation:

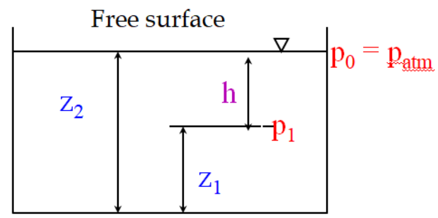
$p = \gamma h + p_0$

Where $p_0 = p_{atm}$

$p_1 = \gamma h + p_{atm}$ (abs)

or in terms of gauge pressure ($P_{atm} = 0$),:

$\mathbf{p_1 = \gamma h = \rho g h}$



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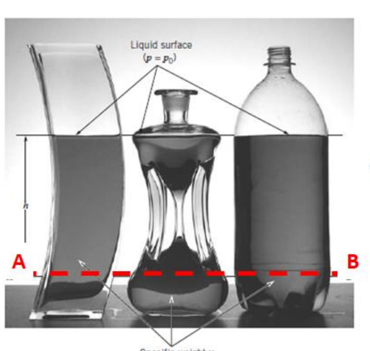
The pressure in a **homogeneous, incompressible fluid at rest** depends on the depth of the fluid relative to some reference plane, and it is *not influenced* by the *size or shape of the tank or container in which the fluid is held.*



Fluid pressure in containers of arbitrary shape.

The pressure is the same at all points along the line *AB even though the containers may have* the very irregular shapes.

The actual value of the pressure along *AB depends* only on the depth, *h, the surface pressure, p_0 and the specific weight, γ, of the liquid in* the container.

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The required equality of pressures at equal elevations throughout a system is important for the operation of hydraulic jacks (see Figure), *lifts, and presses, as well as hydraulic controls on* aircraft and other types of heavy machinery.

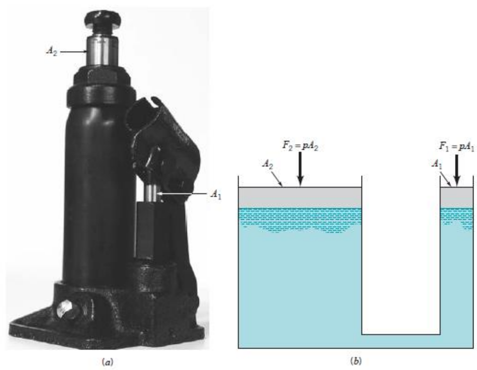


Figure (*a) Hydraulic jack, (b) Transmission of fluid pressure.*

As shown in Fig (b) a piston located at one end of a closed system filled with a liquid, such as oil, can be used to change the pressure throughout the system, and thus transmit an applied force F_1 to a second piston where the resulting force is F_2 .

Since the pressure *p acting on the faces* of both pistons is the same

$$\boxed{F_2 = (A_2 / A_1) F_1}$$

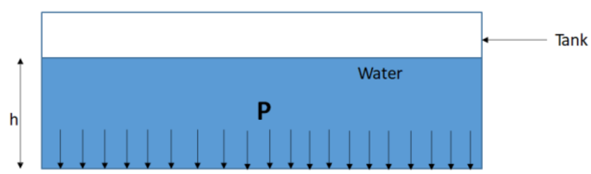
The piston area A_2 can be made much larger than A_1 and therefore a large mechanical advantage can be developed; that is, a small force applied at the smaller piston can be used to develop a large force at the larger piston.

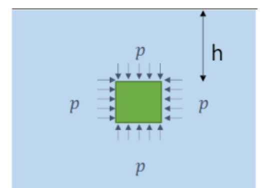
Hydraulic Pressure

- The intensity of pressure at a depth h in a liquid of density ρ is given by:

$$P = \rho g h$$

- S.I unit of pressure has the unit of pascal Pa (as special name for N/m2)
- Hydraulics pressure is exerted equally in all directions.





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Pressure head

- Pressures are sometimes expressed in term of 'head' h.

$$\boxed{h = \frac{P}{\rho g}}$$

- This is the height of a column of a named liquid that would cause an equal pressure to that being measured.

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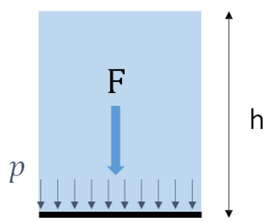
Hydrostatic Force

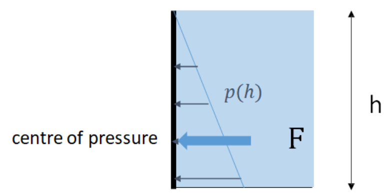
- The hydrostatic force F acting on the surface is the average intensity of pressure P times the surface area A:
- Hydrostatic force on immersed surface:

$$F = PA$$



Horizontal Surface Force

$$F = \frac{1}{2} P_{max} A$$



Vertical Surface Force

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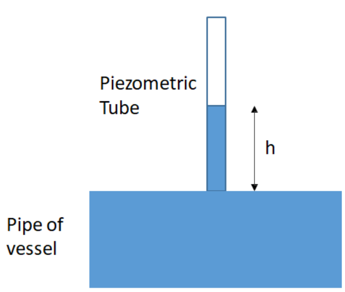
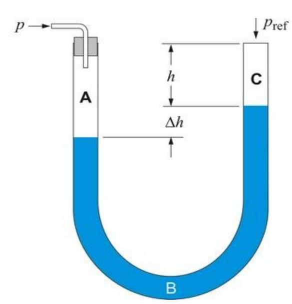
Measurement of Pressure



Piezometer



U-Tube Manometers

Please read 3.2: Cengel and Cimbala

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TUTORIAL QUESTIONS

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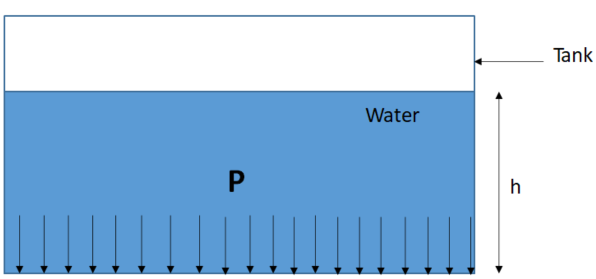
Example 1

Freshwater in a tank 5 m deep has a density of 1000 kg/m³. What pressure does this exert on the base of the tank?

Solution:



$$
\begin{aligned}
P &= \rho g h \\
&= 1000 \times 9.81 \times 5 \\
&= 49050 \text{ Pa} \\
&= \underline{49.05 \text{ kPa}}
\end{aligned}
$$

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Example 2

From Example 1 on freshwater in a tank what is the pressure head on the base of the tank:

(a) In terms of metres of seawater (saltwater), if the density of seawater is 1025 kg/m^3?

(b) In terms of metres of mercury, if the density of mercury is 13 600 kg/m^3?

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Solution:

(a) $h = \frac{490550}{1025 \times 9.81}$ = 4.88 m head of seawater

(b) $h = \frac{490550}{13600 \times 9.81}$ = 0.368 m head of mercury

- Because of its high density, value expressed in metres head of mercury are usually very small.

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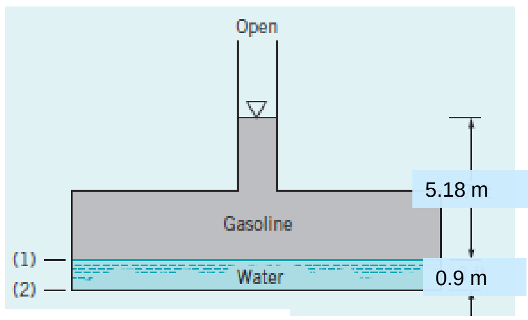
Example 3

Because of a leak in a buried gasoline storage tank, water has seeped in to the depth shown in Fig. The specific gravity of the gasoline is SG = 0.68. Determine the pressure at the gasoline–water interface and at the bottom of the tank. Express the pressure head in meters of water.



Example 4

A force , P of 500 N is applied to the smaller cylinder of a hydraulic jack. The area, a of a small piston is 20 cm^2 while the area, A of larger piston is 200 cm^2. What mass can be lifted on the larger piston?

Example 5

- Express a pressure of 155 kPa (gauge) as an absolute pressure.
- Express a pressure of –31 kPa (gauge) as an absolute pressure.

Consider the local atmospheric pressure as 101 kPa (abs).

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Example 6

What will be the gauge pressure and absolute pressure of water at a depth 12m below the surface?

Take ρ_{water} = 1000 kg/m^3 and P_{atm} = 101 kN/m^2

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Example 7

A cylinder contains a fluid at a gauge pressure of 200 kN/m^2. Express this pressure in terms of

I. head of water (ρ =1000 kg/m^3)

II. head of mercury (SG=13.6)

III. What would be the absolute pressure if the atmospheric pressure is, P_{atm} = 101.3 kN/m^2.

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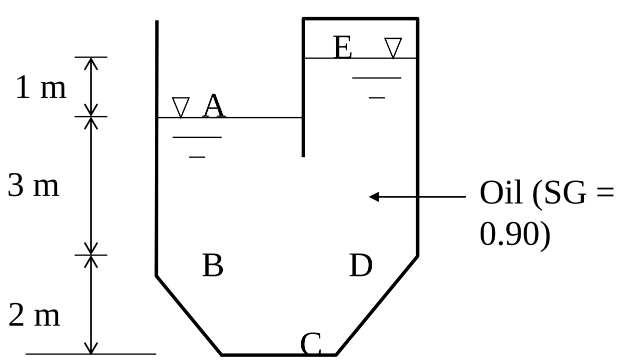
Example 8

Figure below shows a tank with one side open to the atmosphere and the other side sealed with air above the oil (SG=0.90). Calculate the gauge pressure at points A,B,C,D,E.



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Summary

Covered Chapter 2-Part 2

- ❖Continuum, density/specific gravity/Viscosity
- ❖Pressure/Measurement of Pressure
- ❖Hydraulic pressure/Pressure head
- ❖Hydrostatic force
- ❖Problem solving (VERY IMPORTANT)

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Thank You

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"You've got to get up every morning with determination if you're going to go to bed with satisfaction."

– George Lorimer

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