قسم الهندسة المدنية

المرحلة الثانية

Al-Mansour University College

Civil Eng. Dept.

2^{nd}. Stage

Fluid Mechanics

2022 - 2023

ميكانيك الموائع

Lec.1

Ministry of Higher Education and Scientific Researches
Al-Mansour University College
Department of Civil Engineering
CE 205 Fluid Mechanics

Fluid Properties

Dr Ameer Badr Khudhair

Units & Dimensions

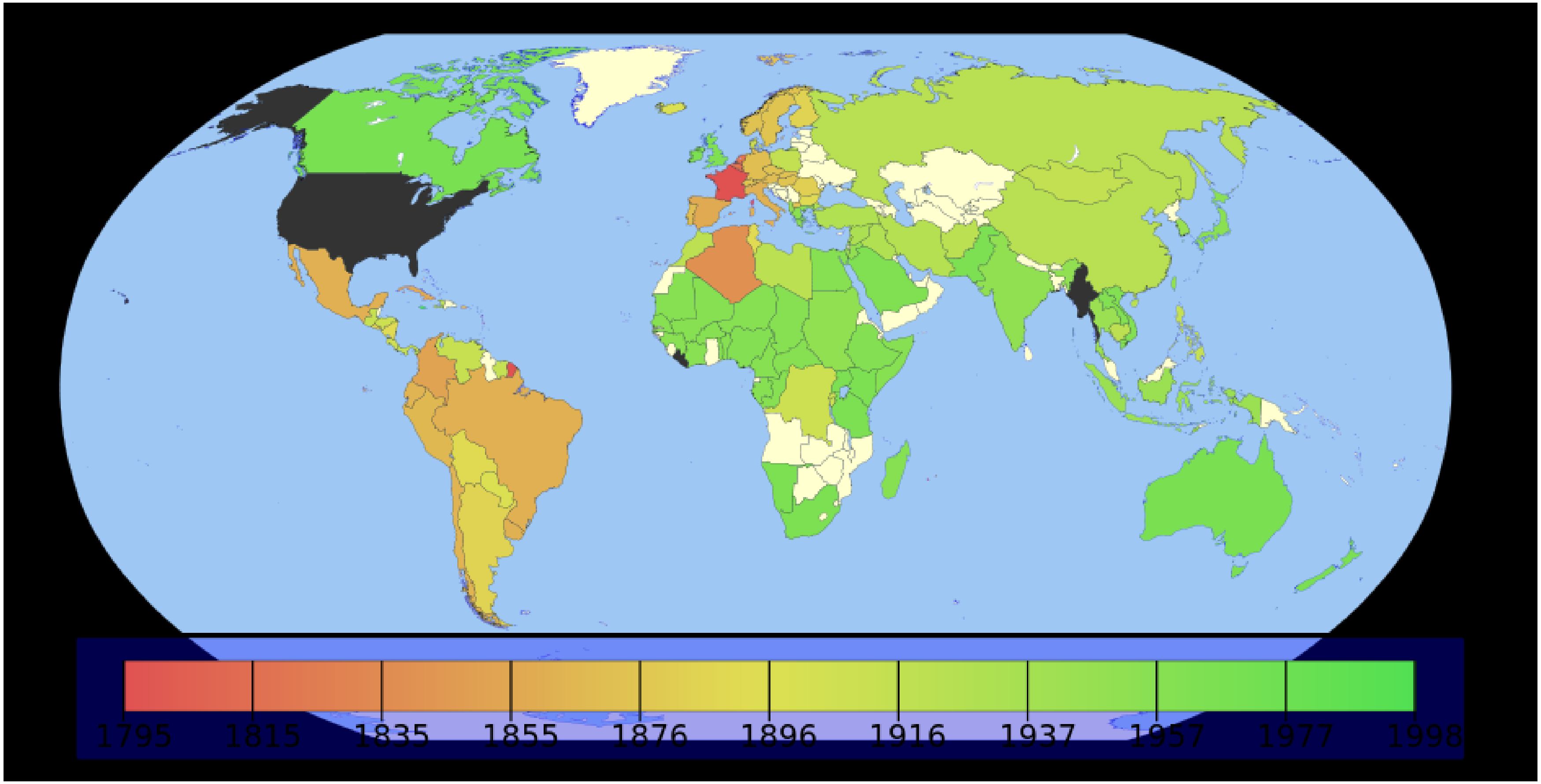
English Unit/ Imperial system

- United Kingdom, Canada and other countries formerly part of the British Empire

Unit	Symbols	Unit equivalent in SI	Equal
inch	in	Millimeter	25.4
foot	ft	Meter	0.3048
mile	mi	Kilometer	1.609344
fluid ounce (fl)	oz	Milliliter	28.4130625
gallon	gal	liter	4.54609
pound	lb	kilograms	0.45359237

Metric unit

- Internationally agreed decimal system of measurement
- Introduced by the First French Republic in 1799
- "International System of Units“ (SI)



Units & Dimensions

Quantity	Dimension	Unit	Shortcut
Length	L	Meter	M
Mass	M	Kilogram	Kg
Time	T	Second,	s
Temperature	t	Celsius degree	˚C
Force	F	Newton	N
Velocity	v	Meter per second	m/s
acceleration	a	Meter per square second	m/s^2
pressure	P	Pascal	Pa
Density	D	kg/m^3	ρ
Power	p	watt	W

Mass density (ρ)

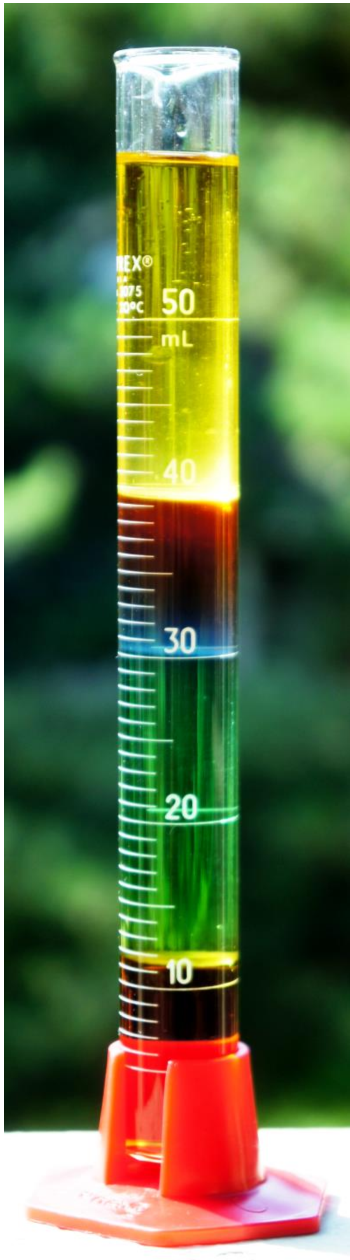
Density of a substance is its mass per unit volume

ρ (rho)

ρ = mass/ volume

kg/m^3, kg/L, g/mL, ton/m^3

Material	ρ (kg/m3)
Air	1.2
Wood	700
Water (salt)	1,030
Water (fresh)	1,000
Ice	916.7
Concrete	2,000
Iron	7,870
Silver	10,500
Gold	19,320



Specific volume (S.V)

Specific volume is defined as the number of cubic meters occupied by one kilogram of a particular substance.

S.V= Volume/ mass,

S.V= $1/\rho$

Units: m^3/ kg, ft^3/ lb

Specific gravity (S)

Specific gravity is the ratio of the density of a substance to the density of water.

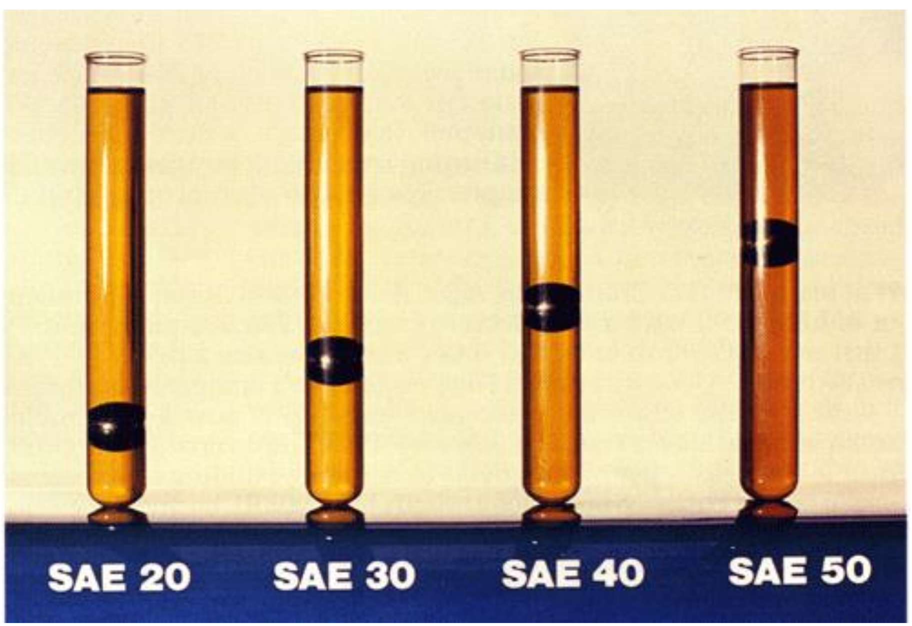
For liquid water used as reference at 4°C & 1 atm (101.325 kPa)

$$\mathbf{S = \rho / \rho_w}$$

Material	Specific gravity
Oak wood	0.75
Water	1
Blood	~1.060
Iron	7.87
Gold	19.3

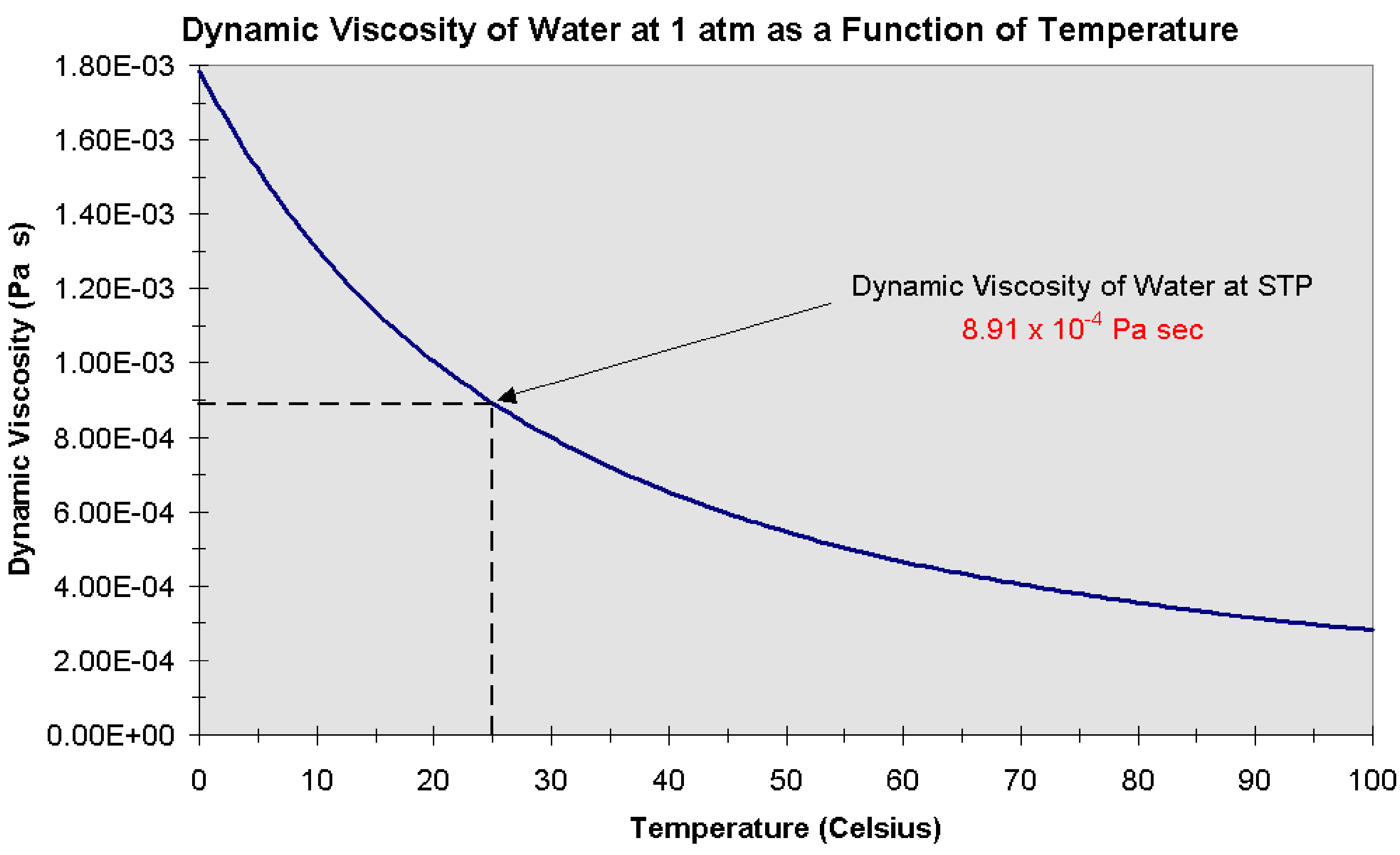
Viscosity (μ)

- μ: mu
- The viscosity of a fluid is a measure of its resistance to shear or angular deformation.
- Motor oil, for example, has high viscosity and resistance to shear, is cohesive, and feels “sticky,” whereas gasoline has low viscosity.
- The friction forces in flowing fluid result from the cohesion and momentum interchange between molecules.

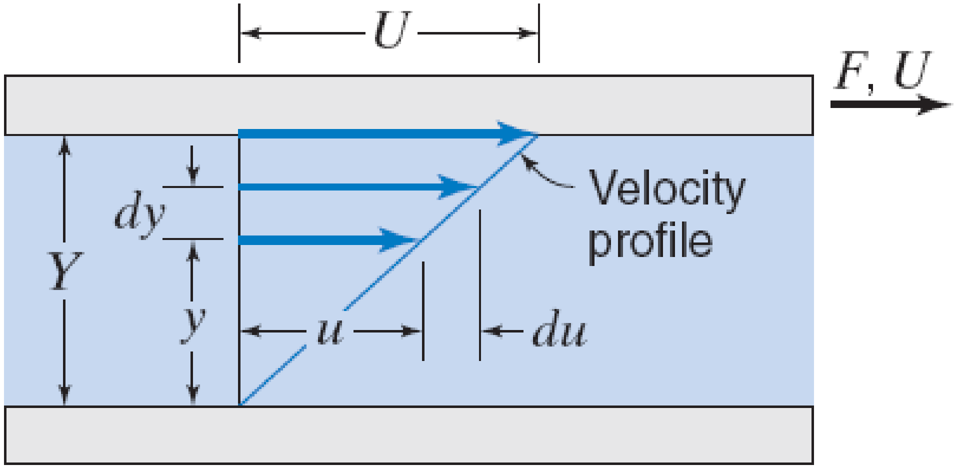


As the temperature increases, the viscosities of all liquids decrease, while the viscosities of all gases increase.

This is because the force of cohesion, which diminishes with temperature, predominates with liquids.



$$F \propto \frac{Av}{y}$$



$$\tau = \frac{F}{A}$$

$$\tau = \mu \times \frac{dv}{dy}$$ ..... Newton's equation of viscosity

τ (tau): shear stress (Pa, N/m^2)

μ: coefficient of viscosity, absolute viscosity, dynamic viscosity, viscosity, Pa.s, $N.s/m^2$

- A widely used unit for viscosity is the **poise** (P), named after Jean Louis Poiseuille (1799–1869).
- He was trained in physics and mathematics. He was interested in the flow of human blood in narrow tubes.
- poise = 0.10 N. s/m2

kinematic viscosity (υ)

- υ : nu
- In many problems involving viscosity the absolute viscosity is divided by density.
- This ratio defines the kinematic viscosity, so called because force is not involved.

$$\upsilon = \frac{\mu}{\rho}$$

m^2/s

stoke (St), after Sir George Stokes (1819–1903)

$$1\ \text{St} = \frac{m^2}{s} \times 10^{-4} = 0.0001\ \frac{m^2}{s}$$

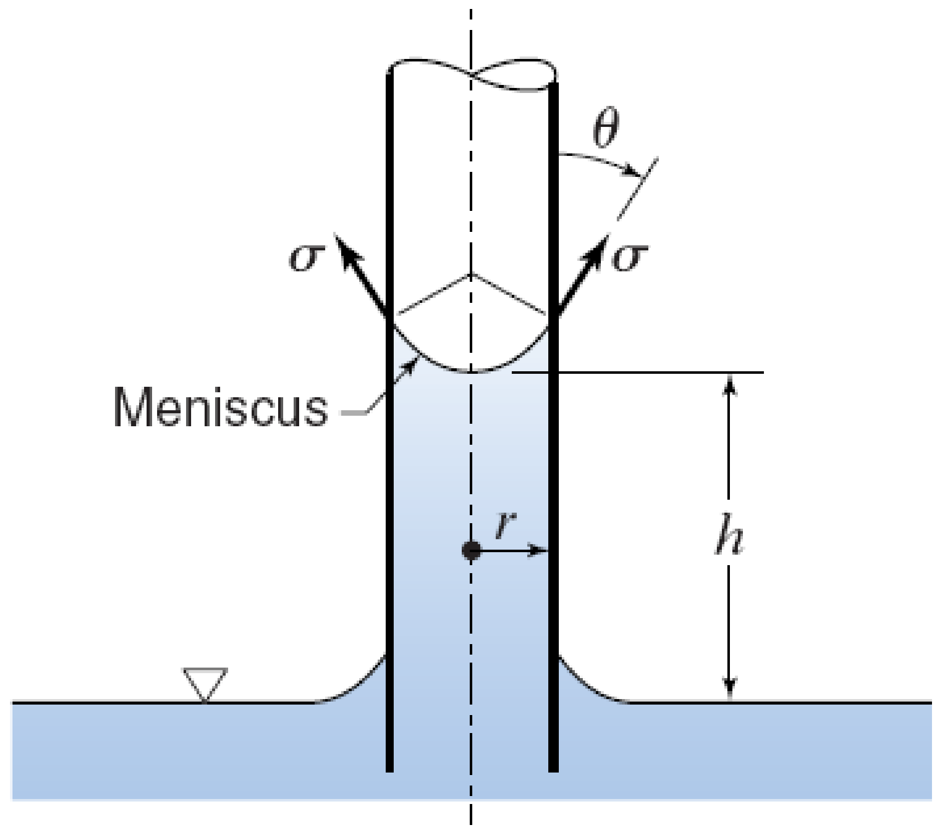
θ (theta): angle of contact, depend on the type of liquid & type of surface

Weight of liquid = h.r^{2}π. γ

Tensile force = 2r.π.σ.cosθ

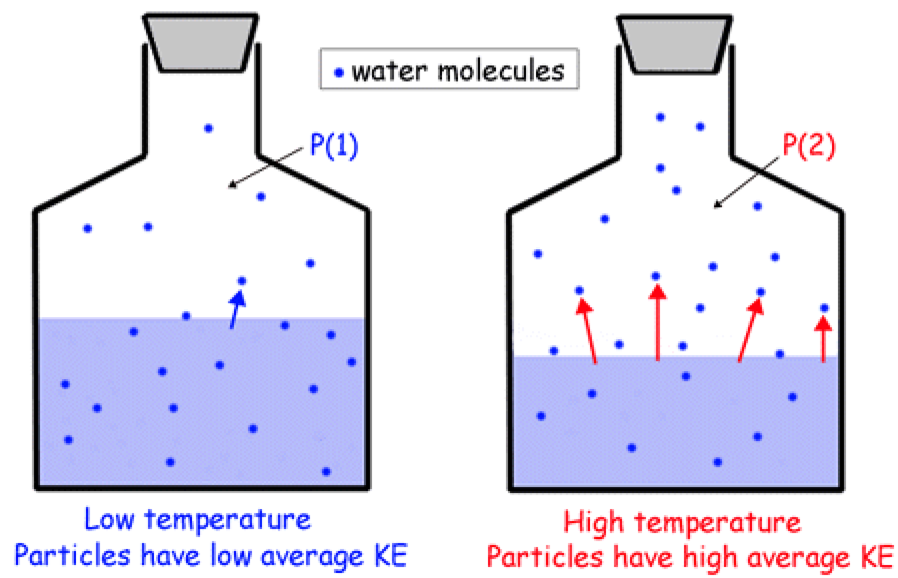
h.r^2 π. γ = 2r.π.σ.cosθ

$$h = \frac{2\ \sigma.cos\theta}{\gamma.r}$$



Vapor pressure

- All liquids tend to evaporate or vaporize, which they do by projecting molecules into the space above their surfaces.
- If this is a confined space, the partial pressure exerted by the molecules increases until the rate at which molecules reenter the liquid is equal to the rate at which they leave. For this equilibrium condition, we call the vapor pressure the **saturation pressure**.
- Saturation pressure increases with increasing temperature and decreasing pressure



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Pressure on static fluid

Dr Ameer Badr Khudhair

Atmospheric Pressure

- It is defined as weight of air per unit surface area of earth.

- It decreases with increase in elevation w.r.t. surface of earth.
- Standard atmospheric pressure at mean-sea-level is

$=101.3 KN/m^2$

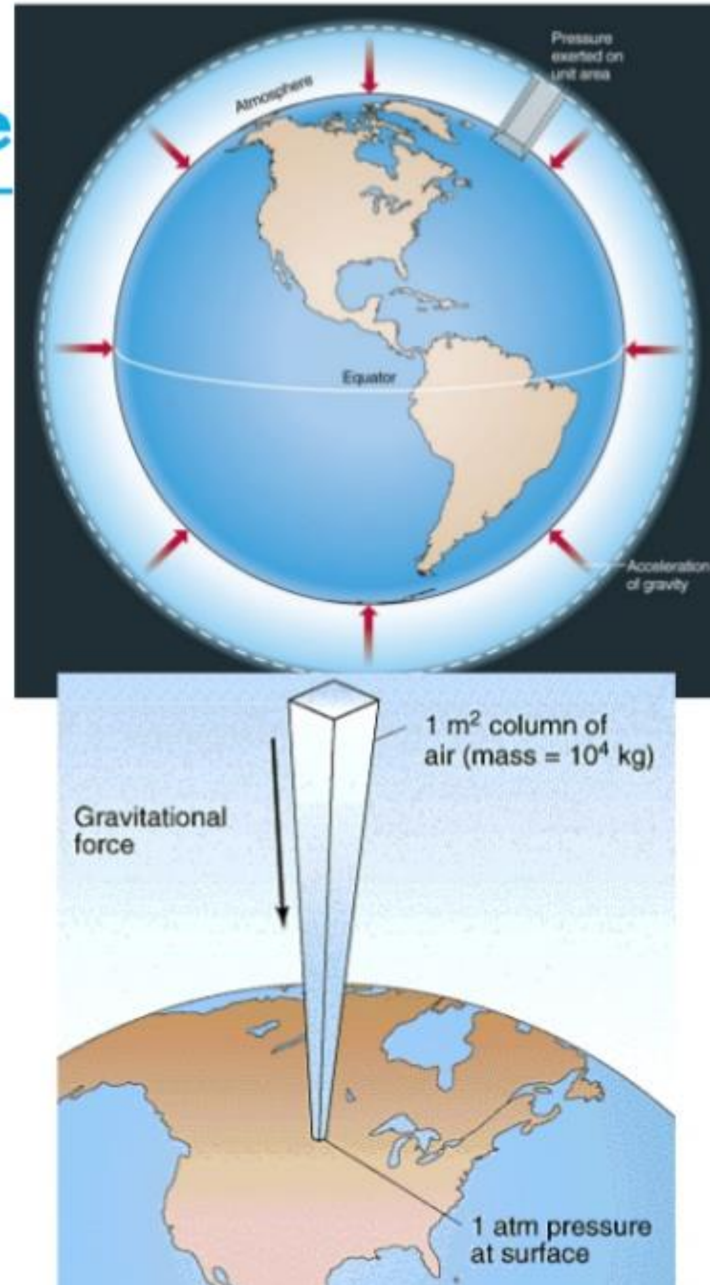
$=1.013 bar$

$=14.7 psi$

$=760 mm$ of Hg

$=33.9 ft$ of water

$=10.3 m$ of water



How to measure Fluid pressure

1.

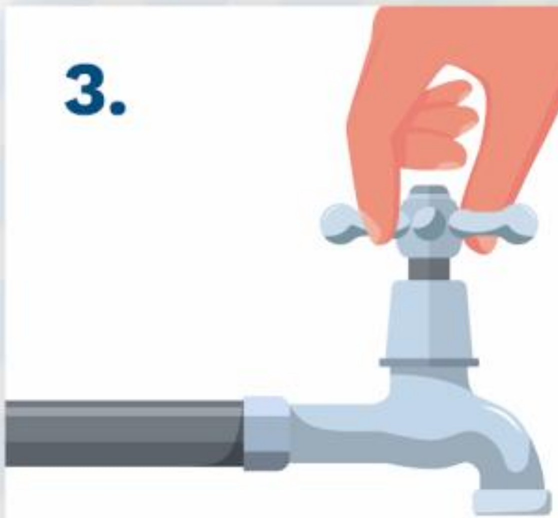
Ensure all taps in and outside of your home are turned off.

2.

Secure the pressure gauge to your outside tap.

https://www.youtube.com/watch?v=LD_xm6zUkkU

3.

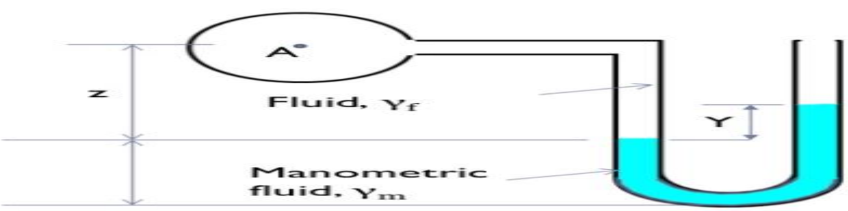


Turn the tap on full.

4.

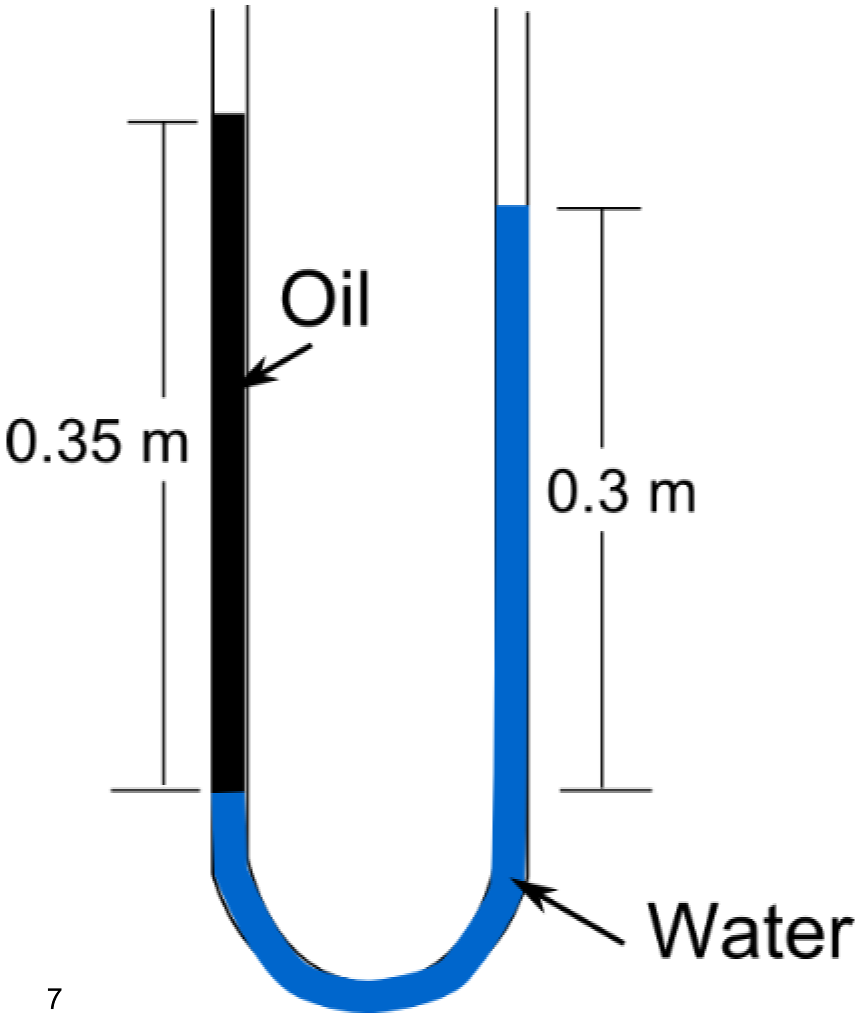
Review the readings on your gauge. The ideal psi is between 40 to 60 psi.

- **a). Simple Manometer**
- Figure shows a set up of simple manometer.
- It consists of a U shaped tube, part of which is filled with manometric fluid.
- One end of tube is connected with the pipe whose pressure is required to be determined.
- Due to pressure, level of manometric fluid rises on one side while it falls on other side.
- The difference in levels is measured to estimate the pressure.



- Y=Manometric reading
- γ_f =Specific weight of fluid in pipe
- γ_m =Specific weight of manometric fluid

U- tube manometer



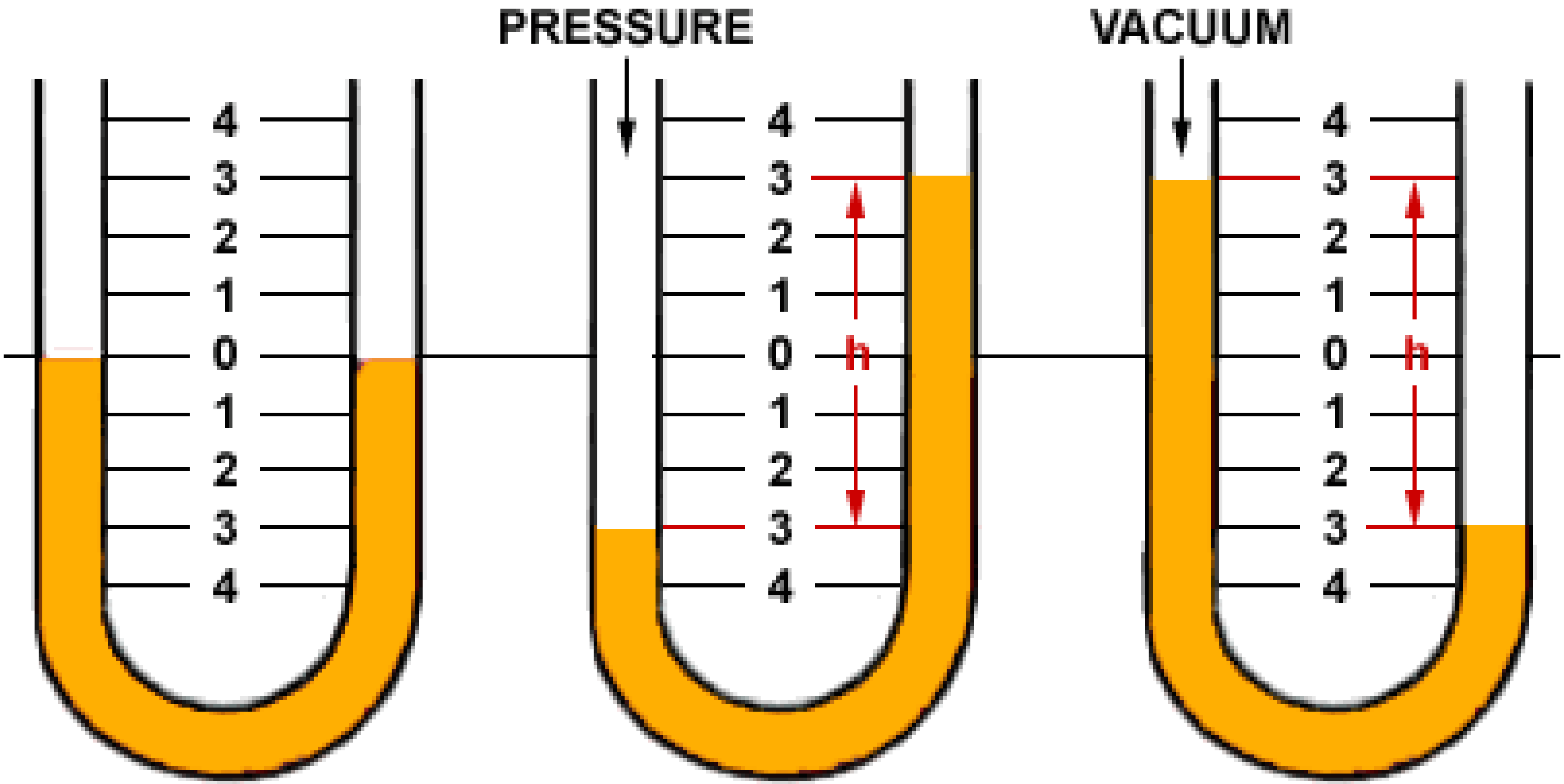
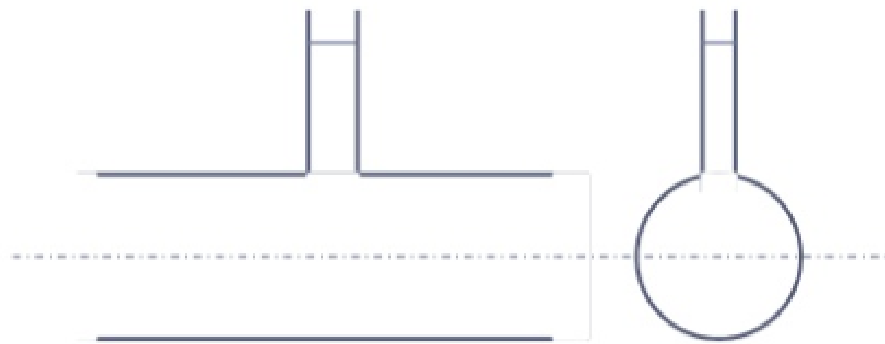


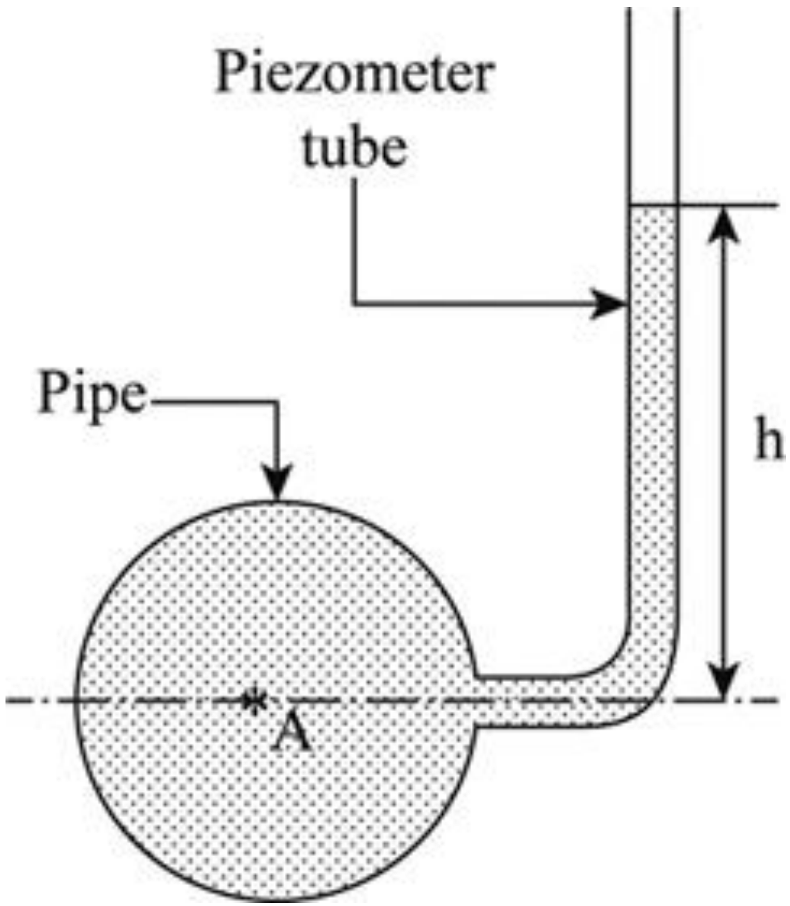
Figure 1 Figure 2 Figure 3

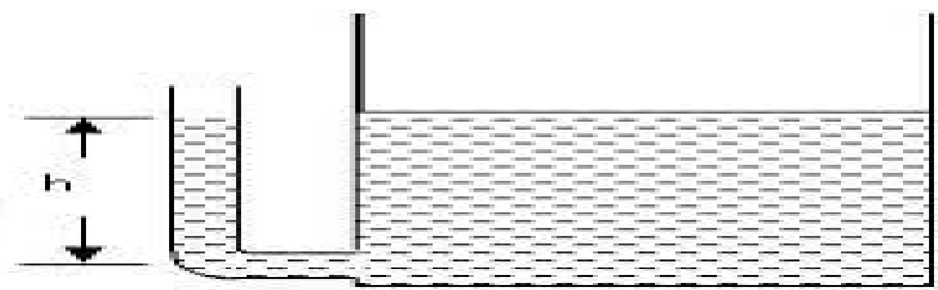
1. Piezometer

- It is used to measure pressure in pipes or vessels.
- In it simplest form, it consists of a transparent tube open from other ends
- The diameter of tube should > ½" to avoid capillarity action
- Piezometers may be connected to sides or bottom of pipe to avoid eddies that are produced in the top region of pipe
  - **Limitations:**
  - It must only be used for liquids
  - It should not be used for high pressure
  - It cannot measure vacuum (-ve) pressure



- When connected to pipes, the water level rises in it which gives a measure of pressure.

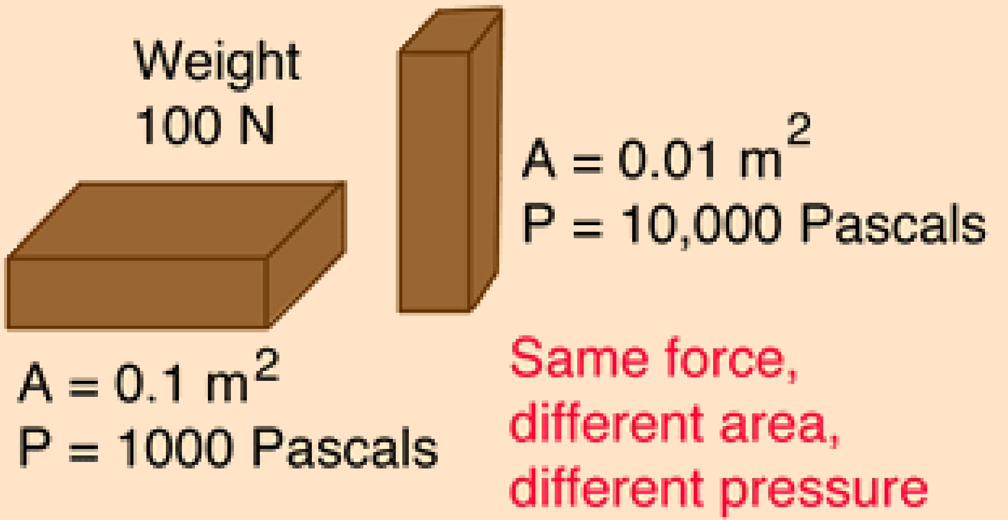

Piezometer
tube
Pipe
h
A



Pressure

- Pressure is defined as **force per unit area**.
- It is usually more convenient to use pressure rather than force to describe the influences upon fluid behavior.
- The standard unit for pressure is the **Pascal**, which is a **Newton per square meter**.
- For an object sitting on a surface, the force pressing on the surface is the weight of the object, but in different orientations it might have a different area in contact with the surface and therefore exert a different pressure.

$$Pressure = \frac{Force}{Area} = \frac{F}{A}$$



Static Fluid Pressure

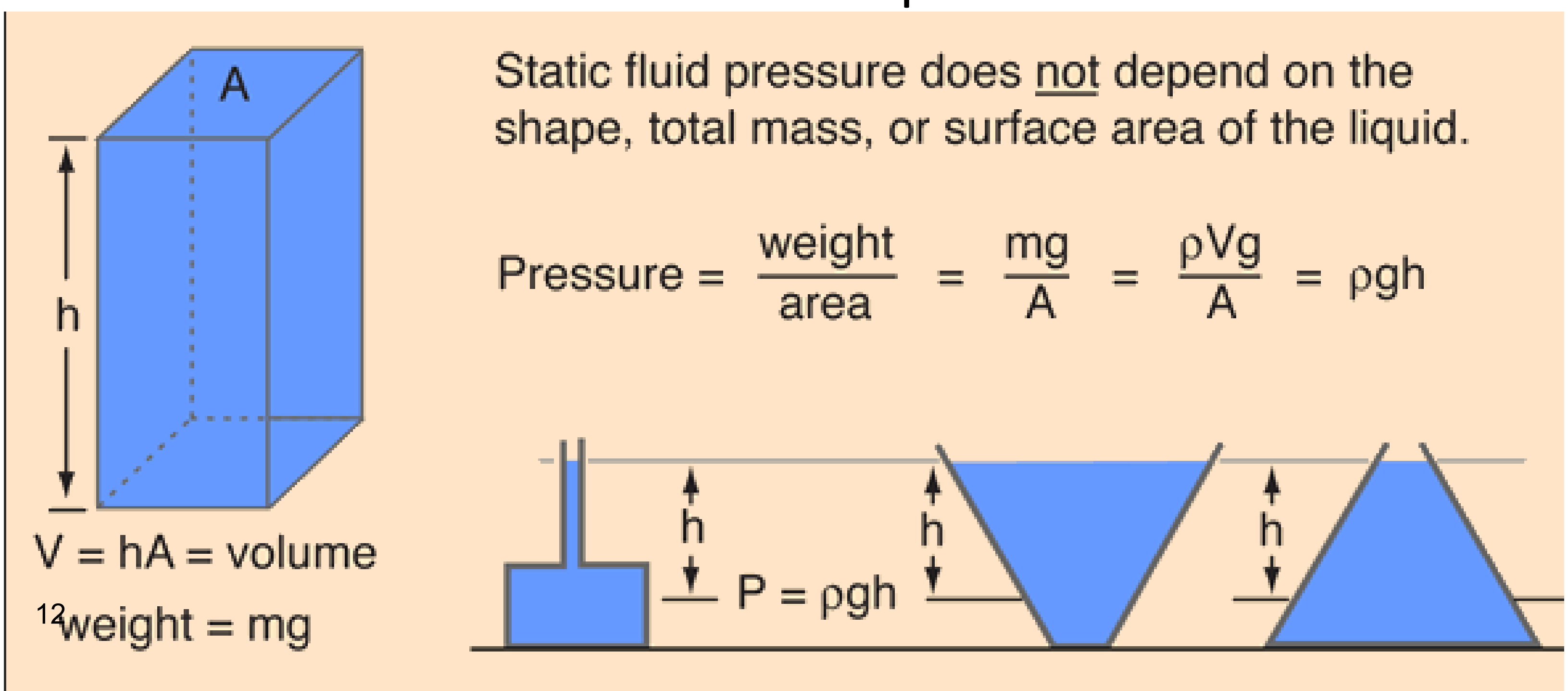
- The pressure exerted by a static fluid depends only upon the depth of the fluid, the density of the fluid, and the acceleration of gravity.
- The **pressure** in a static fluid arises from the **weight** of the fluid and is given by the expression

$$P_{\text{static fluid}} = \rho.g.h$$

$\rho = m/V$ = fluid density

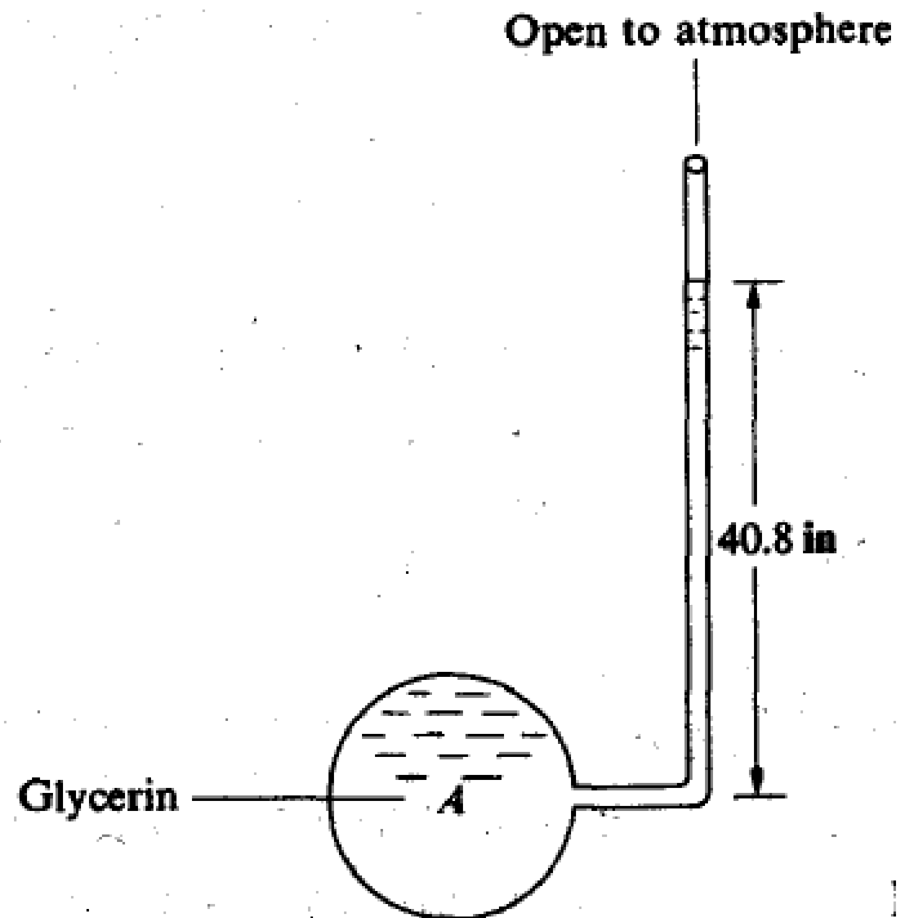
g = acceleration of gravity

h = depth of fluid



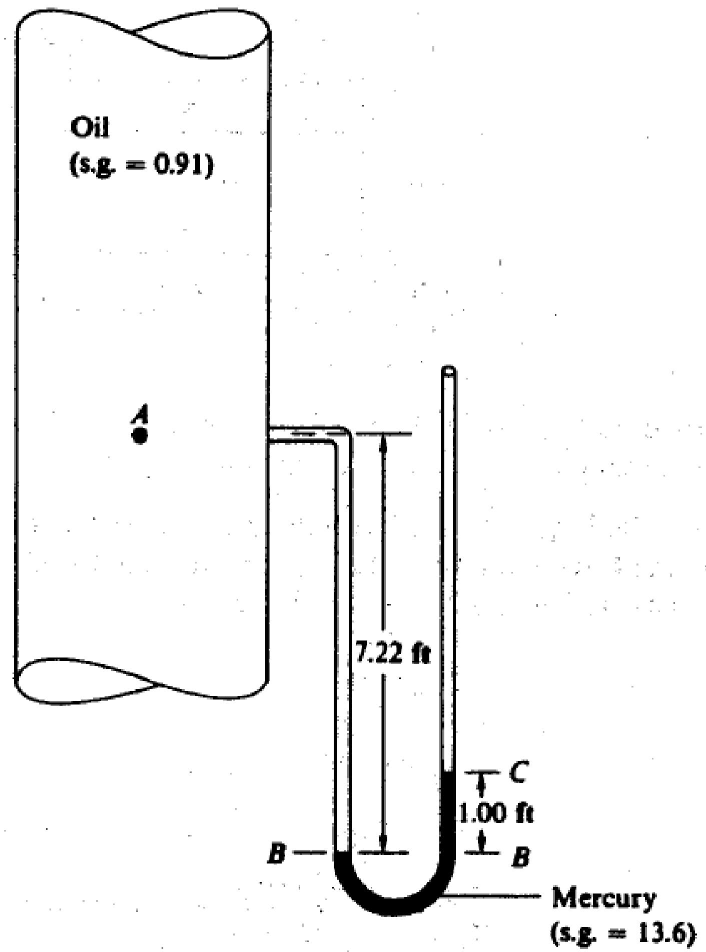
Example: for the pressure vessel containing glycerin, with piezometer attached as shown below, what is the pressure at point A?

Specific weight	Imperial unit (lb/ft^3)	
Water	62.4	9.81
air	0.0765	



1000 mm

Example: for the vertical pipe with manometer attached as shown below, find the pressure in the oil at point A.



$p_A + [(0.91)(62.4)](7.22) - [(13.6)(62.4)](1.00) = 0 \qquad p_A = 438.7\ \text{lb/ft}^2 \quad \text{or} \quad 3.05\ \text{lb/in}^2$

Example: The closed tank in figure below is at 20°C. If the pressure at point A is 98 kPa abs, what is the absolute pressure at point B? what percent error results from neglecting the specific weight of the air?

Note: specific weight of air 0.0118 kN/m³ , specific weight of water at 20°C = 9.79 kN/m³

$p_A + \gamma_{air} h_{AC} - \gamma_{H_2O} h_{DC} - \gamma_{air} h_{DB} = p_B$, $98 + (0.0118)(5) - (9.790)(5-3) - (0.0118)(3) = p_B = 78.444$ kPa.
Neglecting air, $p_B = 98 - (9.790)(5-3) = 78.420$ kPa; error $= (78.444 - 78.420)/78.444 = 0.00031$, or 0.031%.

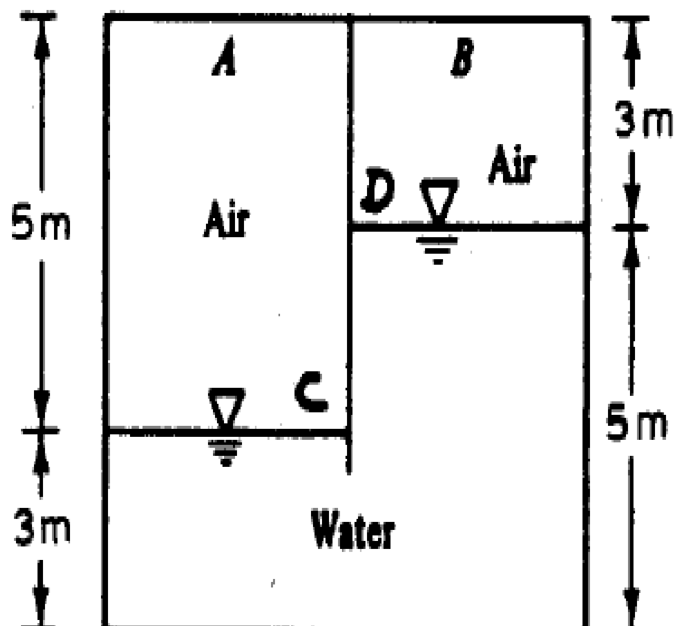


Fig. 2-3

Example: The system in figure below is at 20°C. If atmospheric pressure is 101.03 kPa and the absolute pressure at the bottom of the tank is 231.3 kPa, what is the specific gravity of olive oil?

Note: specific gravity of SAE oil = 0.89, specific gravity of mercury at 20°C = 13.6, specific gravity of water = 9.79

$$101.03 + (0.89)(9.79)(1.5) + (9.79)(2.5) + (s.g.)(9.79)(2.9) + (13.6)(9.79)(0.4) = 231.3 \qquad s.g. = 1.39$$

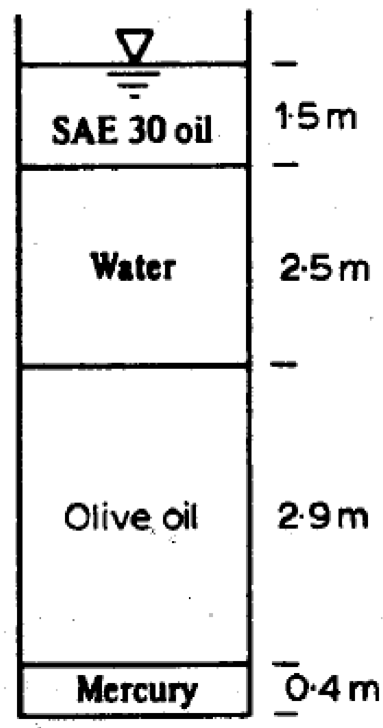
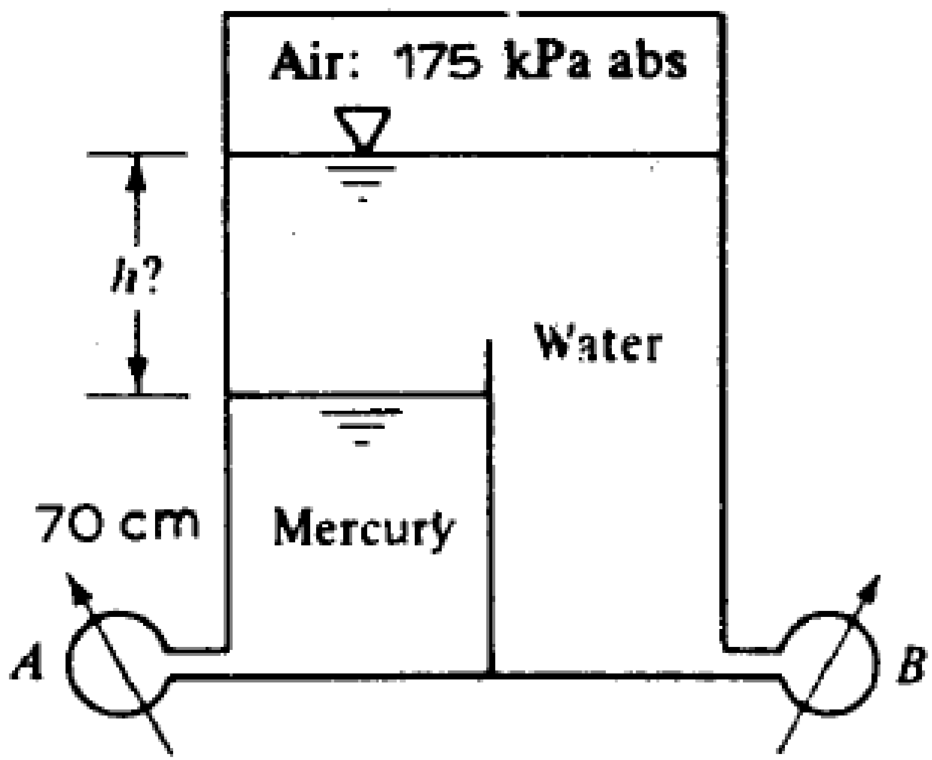


Fig. 2-5



$$290 - [(13.6)(9.79)](\tfrac{70}{100}) - 9.79h = 175 \qquad h = 2.227\ \text{m}$$

$$p_B - (9.79)(\tfrac{70}{100} + 2.227) = 175 \qquad p_B = 204\ \text{kPa}$$

Example: A differential manometer is attached to a pipe, as shown below. Calculate the pressure difference between points A and B.

$$p_A - [(0.91)(62.4)](y/12) - [(13.6)(62.4)](\tfrac{4}{12}) + [(0.91)(62.4)][(y+4)/12] = p_B$$

$$p_A - p_B = 264\ \text{lb/ft}^2$$

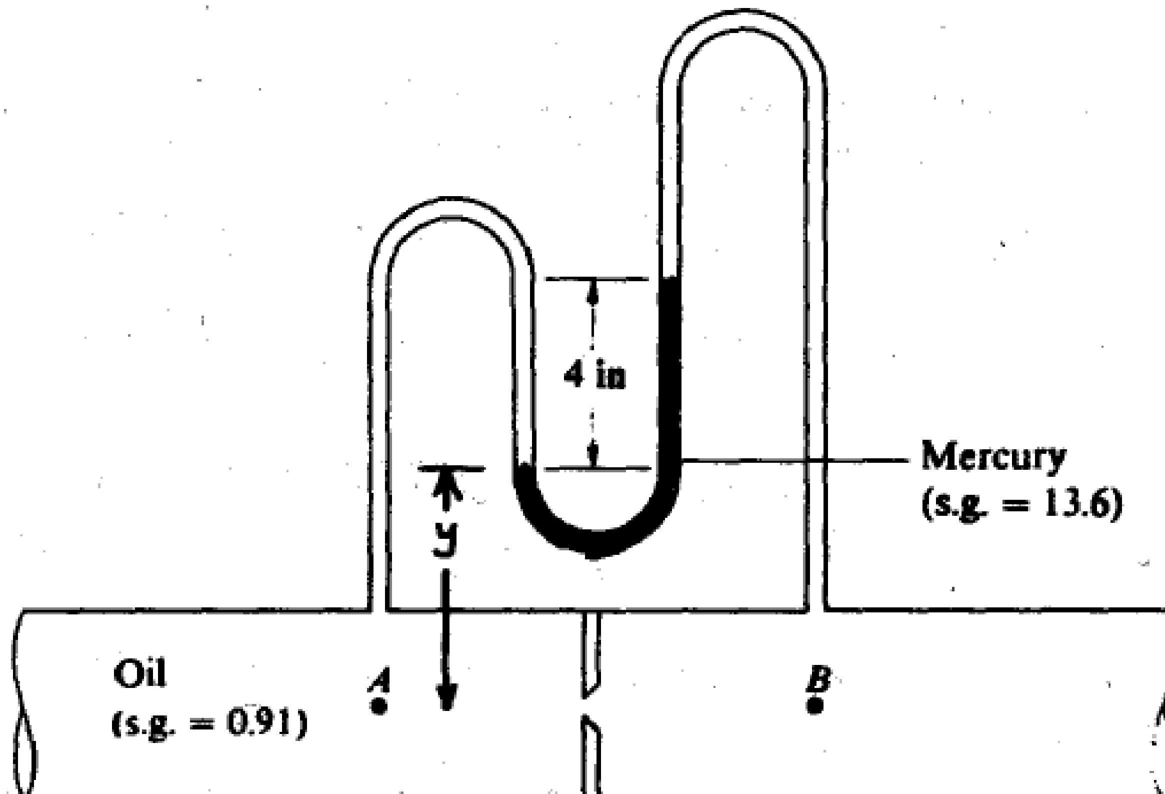
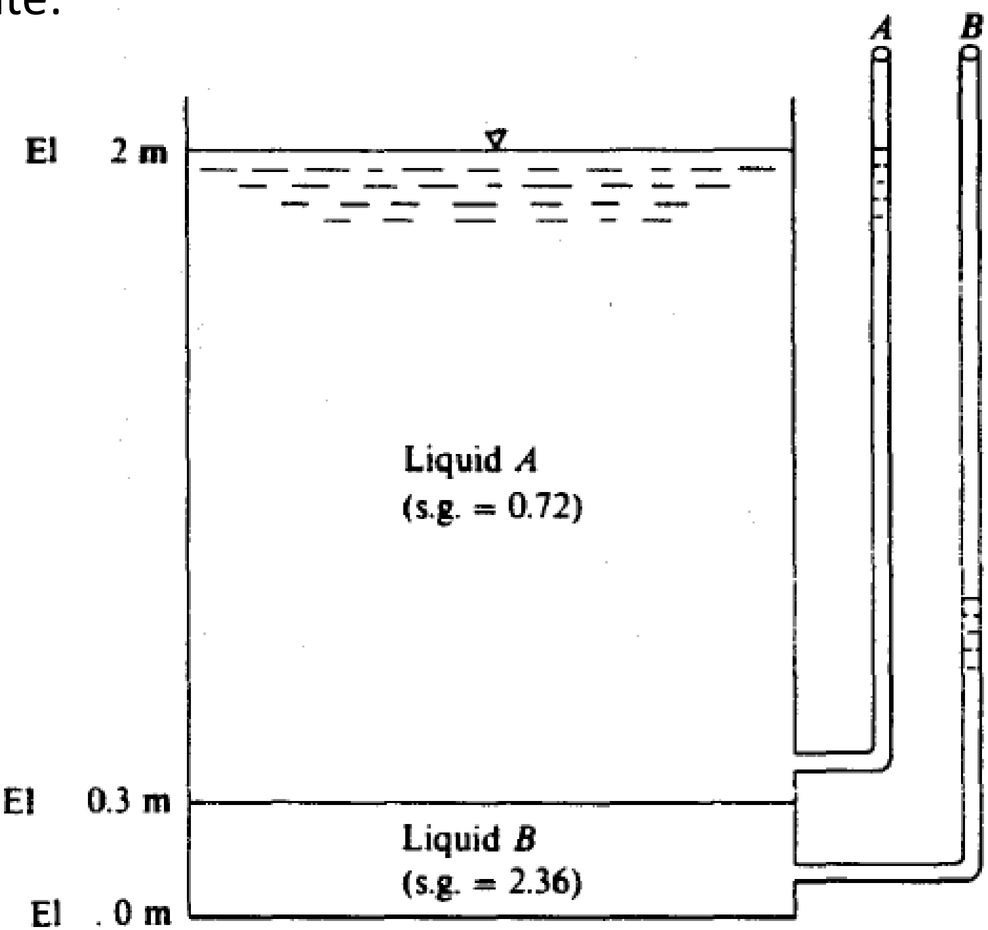


Fig. 2-35

Example: In the figure below, calculate:

- Elevation in piezometer A.
- Elevation in piezometer B
- Pressure at the bottom.



(*a*) Liquid *A* will simply rise in piezometer *A* to the same elevation as liquid *A* in the tank (i.e., to elevation 2 m). (*b*) Liquid *B* will rise in piezometer *B* to elevation 0.3 m (as a result of the pressure exerted by liquid *B*) plus an additional amount as a result of the overlying pressure of liquid *A*. The overlying pressure can be determined by $p = \gamma h = [(0.72)(9.79)](2 - 0.3) = 11.98\ \mathrm{kN/m^2}$. The height liquid *B* will rise in piezometer *B* as a result of the overlying pressure of liquid *A* can be determined by $h = p/\gamma = 11.98/[(2.36)(9.79)] = 0.519$ m. Hence, liquid *B* will rise in piezometer *B* to an elevation of 0.3 m + 0.519 m, or 0.819 m.

(*c*) $p_{\text{bottom}} = [(0.72)(9.79)](2 - 0.3) + [(2.36)(9.79)](0.3) = 18.9$ kPa.

I Let W = weight of the piston. $W/[(\pi)(1)^2/4] - [(0.86)(9.79)](1) = 70.0$, $W = 61.6\ \text{kN}$.

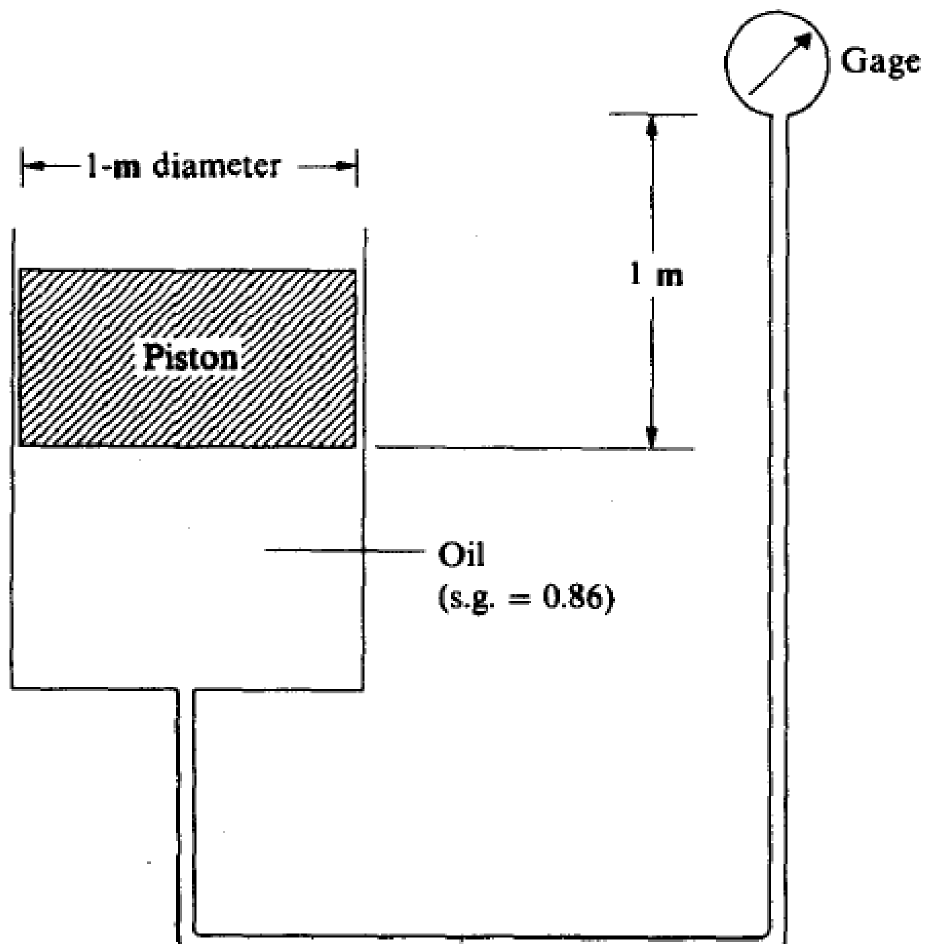


Fig. 2-36

Example: The tube shown in figure below is filled with oil. Determine the pressure heads at A and B in meters of water.

$(h_{H_2O})(\gamma_{H_2O}) = (h_{oil})(\gamma_{oil}) = (h_{oil})[(s.g._{oil})(\gamma_{H_2O})]$; therefore, $h_{H_2O} = (h_{oil})(s.g._{oil})$. Thus, $h_A = -(2.2 + 0.6)(0.85) = -2.38$ m H_2O and $h_B = (-0.6)(0.85) = -0.51$ m H_2O.

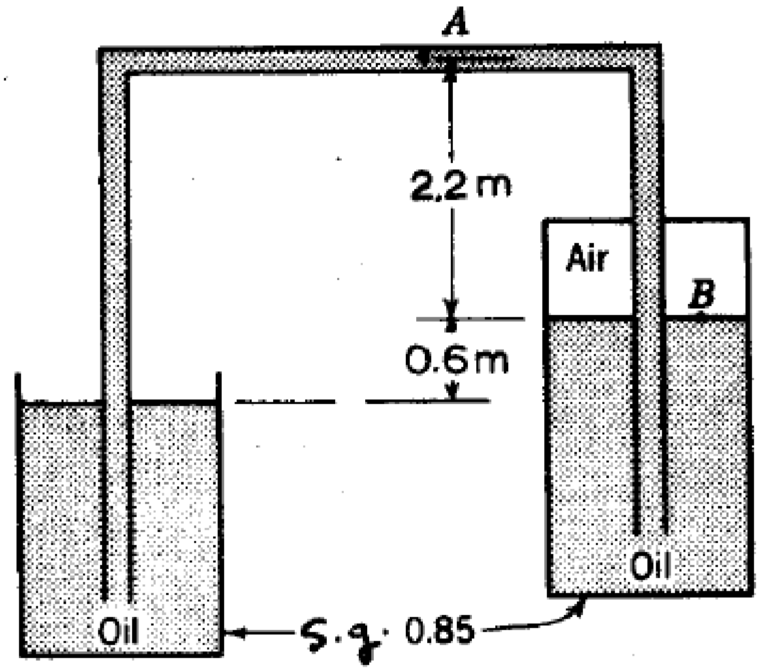
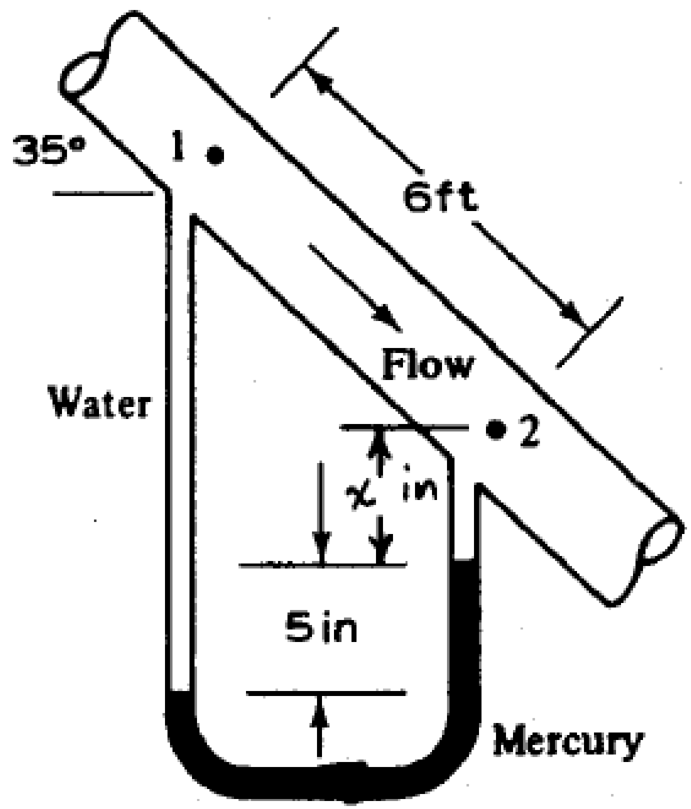


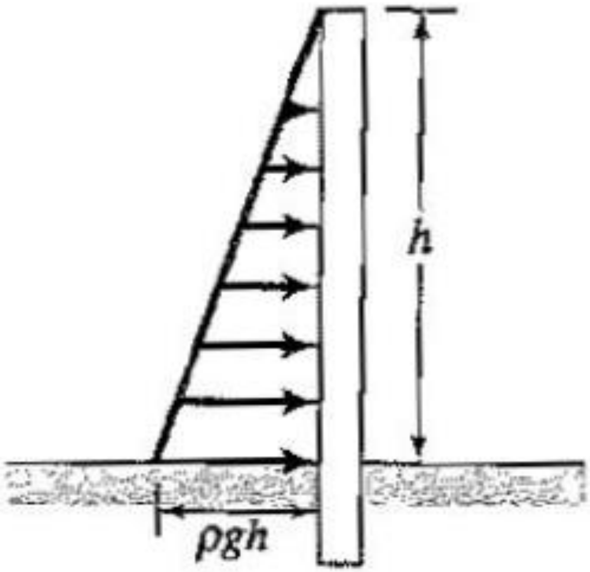
Fig. 2-7

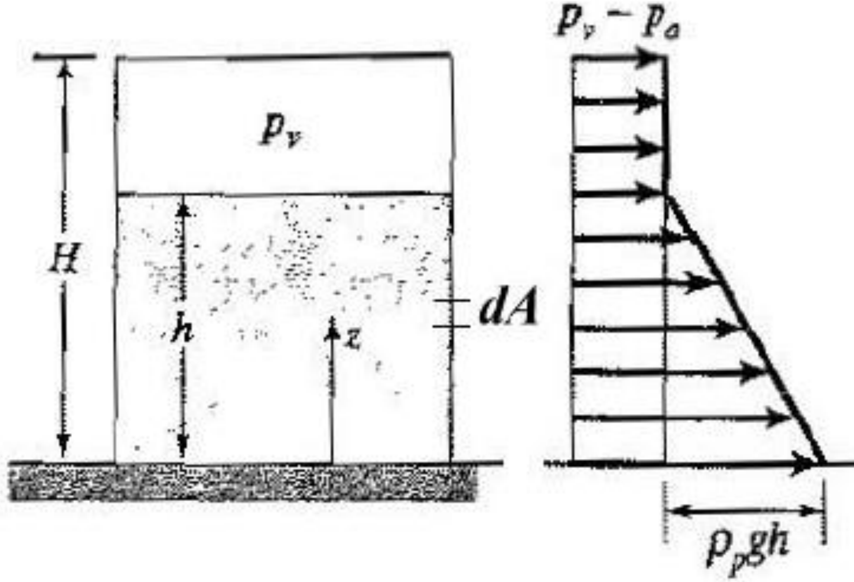
Example: Water flows downward in a pipe at 35°, as shown below. The pressure drop p1 – p2 is partly due to gravity and partly due to friction. The mercury manometer reads a 5-in height difference. What is the total pressure drop p1 - p2?

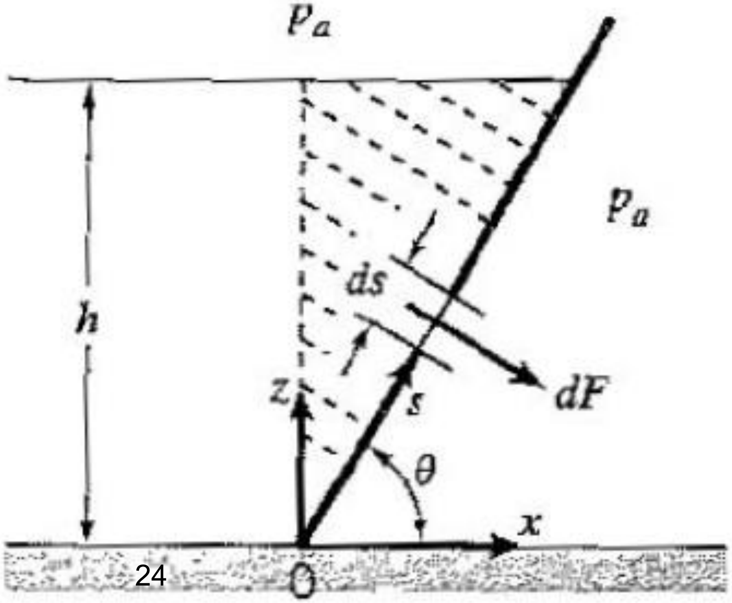


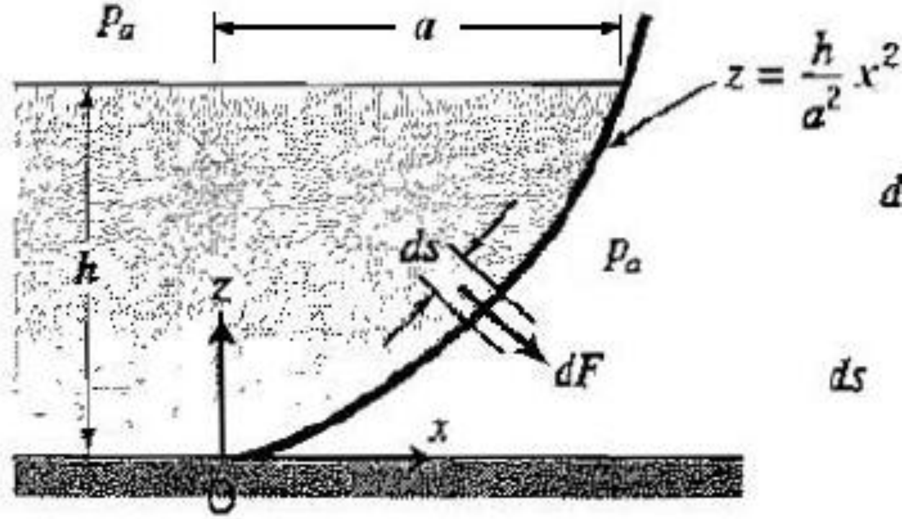
$$p_1 + (62.4)(6 \sin 35° + x/12 + \tfrac{5}{12}) - [(13.6)(62.4)](\tfrac{5}{12}) - (62.4)(x/12) = p_2$$

$$p_1 - p_2 = 112.9 \text{ lb/ft}^2 \qquad \text{(total pressure drop)}$$


h
ρgh


$p_v - p_a$
p_v
H
h
z
dA
$\rho_p gh$


p_a
p_a
h
ds
dF
z
s
θ
x
O


p_a
a
$z = \frac{h}{a^2} x^2$
ds
p_a
h
z
dF
x
O

Total Hydrostatic Force on Plane Surfaces

For horizontal plane surface submerged in liquid, or plane surface inside a gas chamber, or any plane surface under the action of uniform hydrostatic pressure, the total hydrostatic force is given by

$F=p*A$

Where: p is the uniform pressure, A is the area.

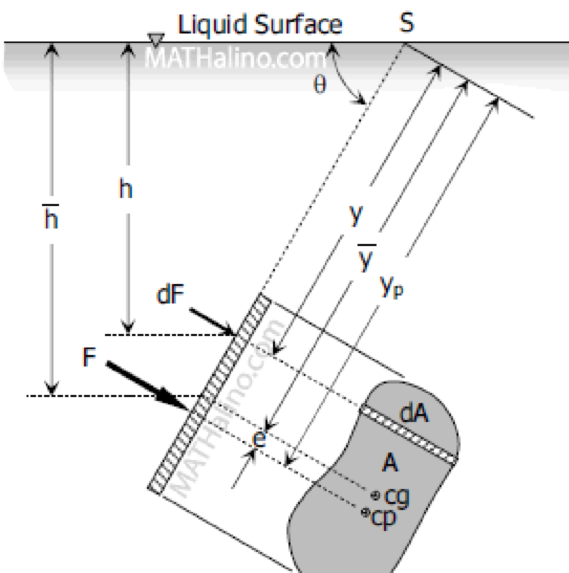
In general, the total hydrostatic pressure on any plane surface is equal to the product of the area of the surface and the unit pressure at its center of gravity.

$F=p_{cg}*A$

where : p_{cg} is the pressure at the center of gravity.

$F=\gamma*h_{average}*A$

where : $h_{average}$ is the depth of liquid above the submerged area.

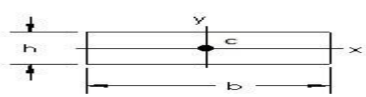
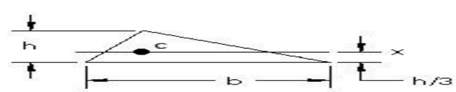
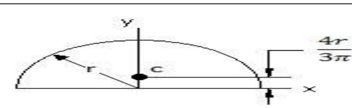
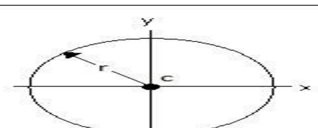


$y_{cp}=y_{cg}+e$

Where e: Eccentricity

$e= I_{cg}/A*y_{cg}$

$y_{cp}=y_{cg}+I_{cg}/A*y_{cg}$

	$A = bh$ $I_x = \frac{1}{12} bh^3$ $I_y = \frac{1}{12} hb^3$
	$A = \frac{1}{2} bh$ $I_x = \frac{1}{36} bh^3$
	$A = \frac{\pi r^2}{2}$ $I_x = \frac{1}{8}\pi r^4$ $I_y = \frac{1}{8}\pi r^4$
	$A = \pi r^2$ $I_x = \frac{1}{4}\pi r^4$ $I_y = \frac{1}{4}\pi r^4$

If a triangle of height d and base b is vertical and submerged in liquid with its vertex at the liquid surface (see Fig. 3-1), derive an expression for the depth to its center of pressure.

$$h_{cp} = h_{cg} + \frac{I_{cg}}{h_{cg}A} = \frac{2d}{3} + \frac{bd^3/36}{(2d/3)(bd/2)} = \frac{3d}{4}$$

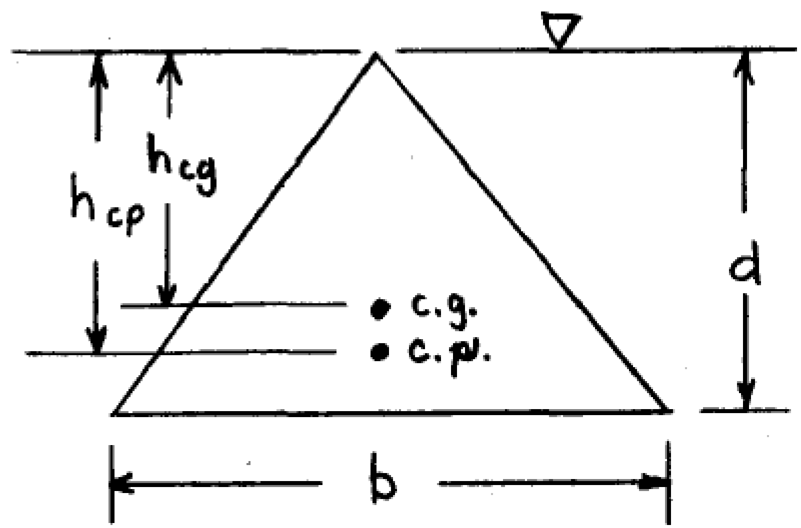


Fig. 3-1

If a triangle of height d and base b is vertical and submerged in liquid with its base at the liquid surface (see Fig. 3-3), derive an expression for the depth to its center of pressure.

▌

$$h_{cp} = h_{cg} + \frac{I_{cg}}{h_{cg}A} = \frac{d}{3} + \frac{bd^3/36}{(d/3)(bd/2)} = \frac{d}{3} + \frac{d}{6} = \frac{d}{2}$$

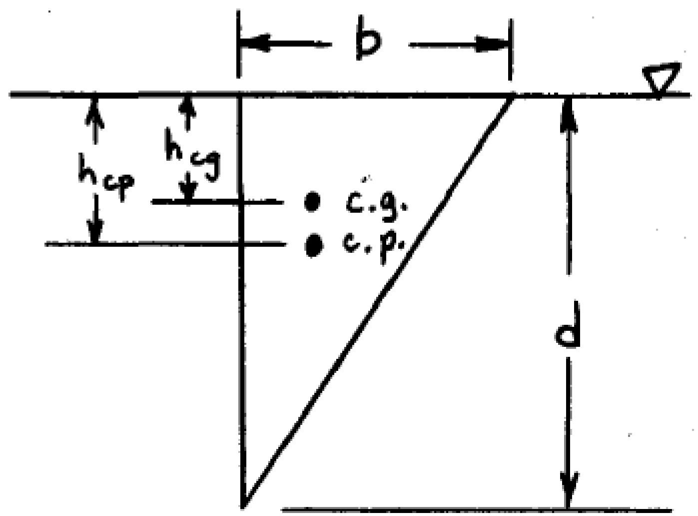


Fig. 3-3

A circular area of diameter d is vertical and submerged in a liquid. Its upper edge is coincident with the liquid surface (see Fig. 3-4). Derive an expression for the depth to its center of pressure.

$$h_{cp} = h_{cg} + \frac{I_{cg}}{h_{cg}A} = \frac{d}{2} + \frac{\pi d^4/64}{(d/2)(\pi d^2/4)} = \frac{d}{2} + \frac{d}{8} = \frac{5d}{8}$$

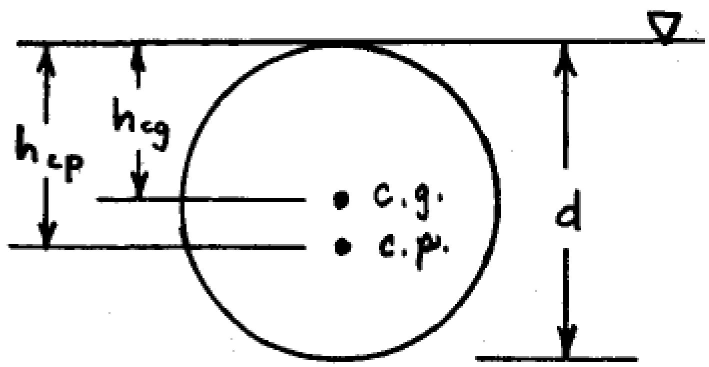
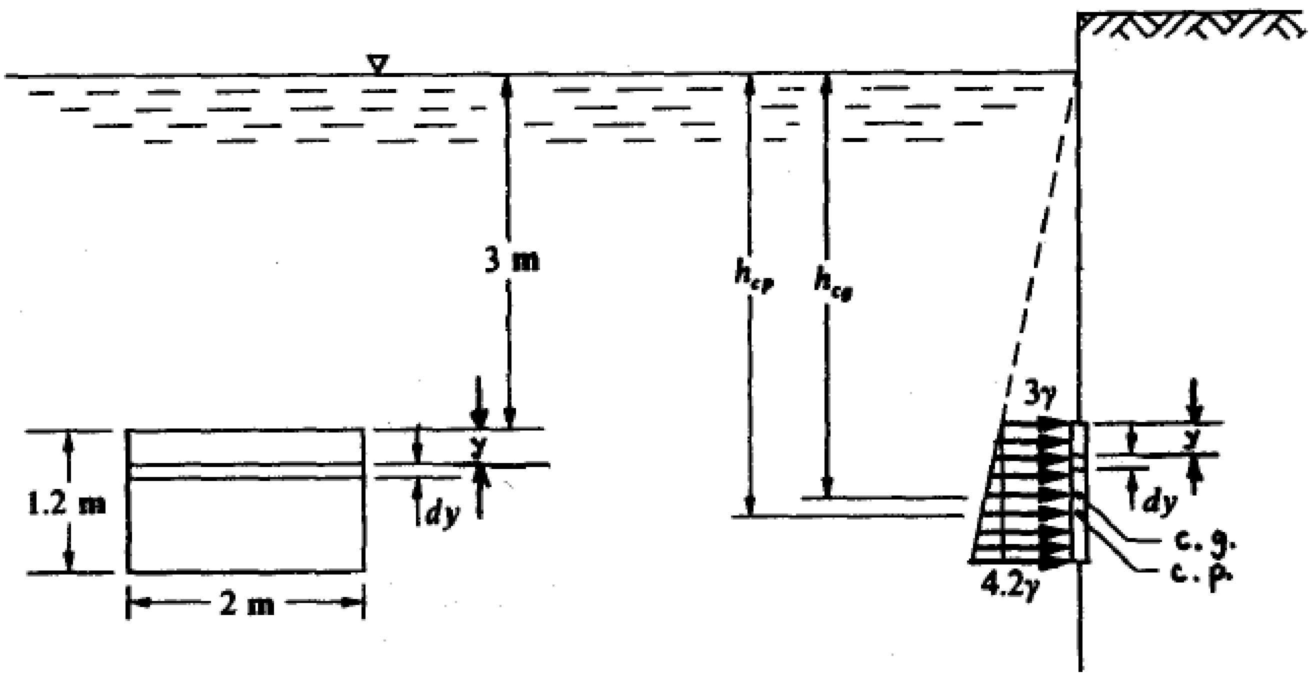


Fig. 3-4

A vertical, rectangular gate with water on one side is shown in Fig. 3-7. Determine the total resultant force acting on the gate and the location of the center of pressure.

$$F = \gamma h_{cg} A = (9.79)(3 + 1.2/2)[(2)(1.2)] = 84.59 \text{ kN}$$

$$h_{cp} = h_{cg} + \frac{I_{cg}}{h_{cg}A} = \left(3 + \frac{1.2}{2}\right) + \frac{(2)(1.2)^3/12}{(3 + 1.2/2)[(2)(1.2)]} = 3.633 \text{ m}$$



A tank containing water is shown in Fig. 3-12. Calculate the total resultant force acting on side $ABCD$ of the container and the location of the center of pressure.

$$F = \gamma h A = (62.4)[(0+6)/2][(20)(6)] = 22\,500 \text{ lb}$$

$$h_{cp} = (\tfrac{2}{3})(6) = 4.00 \text{ ft} \qquad \text{(vertically below the water surface)}$$

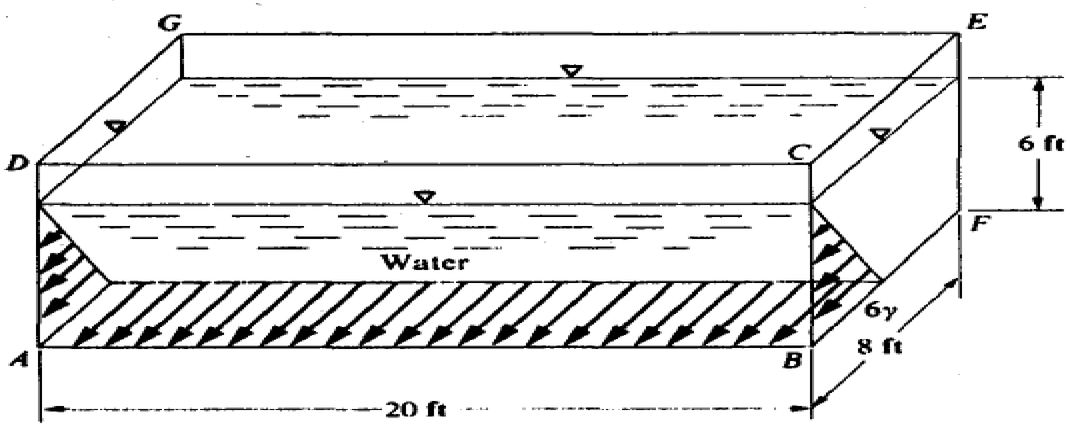


Fig. 3-12

A dam 20 m long retains 7 m of water, as shown in Fig. 3-6. Find the total resultant force acting on the dam and the location of the center of pressure.

▌ $F = \gamma h A = (9.79)[(0+7)/2][(20)(7/\sin 60°)] = 5339$ kN. The center of pressure is located at two-thirds the total water depth of 7 m, or 4.667 m below the water surface (i.e., $h_{cp} = 4.667$ m in Fig. 3-6).

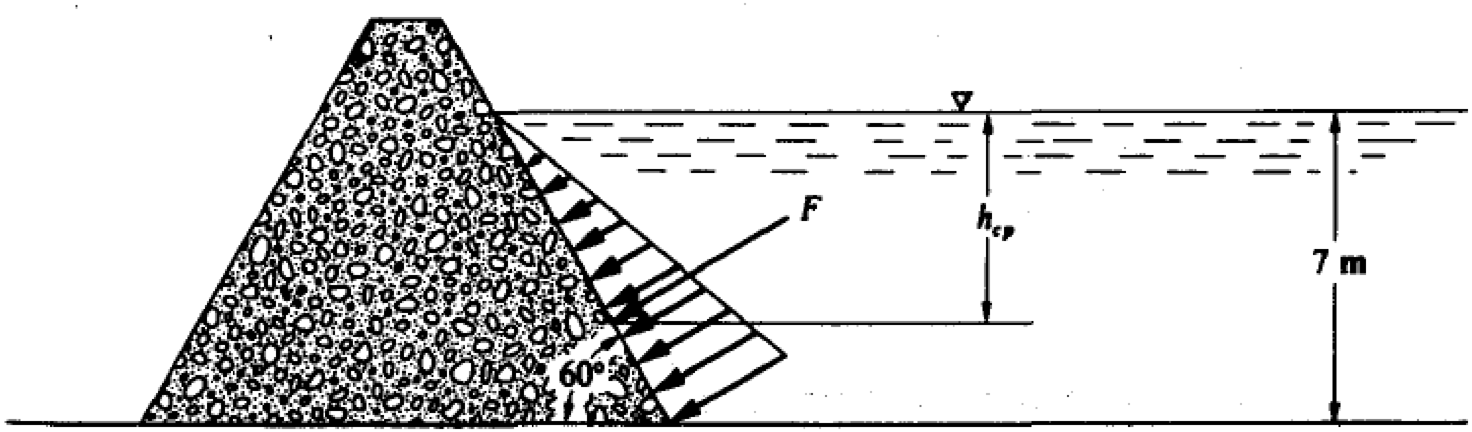
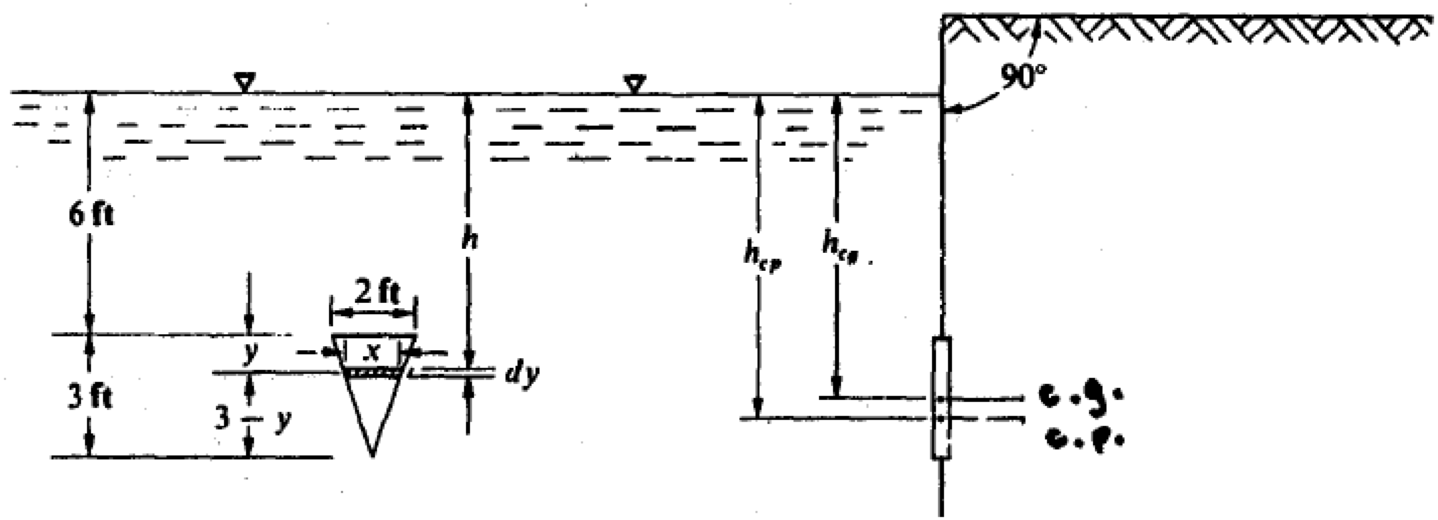


Fig. 3-6

A vertical, triangular gate with water on one side is shown in Fig. 3-8. Determine the total resultant force acting on the gate and the location of the center of pressure.

$$F = \gamma h_{cg} A = (62.4)(6 + 3/3)[(2)(3)/2] = 1310 \text{ lb}$$

$$h_{cp} = h_{cg} + \frac{I_{cg}}{h_{cg} A} = \left(6 + \frac{3}{3}\right) + \frac{(2)(3)^3/36}{(6 + 3/3)[(2)(3)/2]} = 7.07 \text{ ft}$$



An inclined, rectangular gate with water on one side is shown in Fig. 3-9. Determine the total resultant force acting on the gate and the location of the center of pressure.

$$F = \gamma h_{cg} A = (62.4)[8 + \tfrac{1}{2}(4 \cos 60°)][(4)(5)] = 11\,230 \text{ lb}$$

$$z_{cp} = z_{cg} + \frac{I_{cg}}{z_{cg}A} = \left(\frac{8}{\cos 60°} + \frac{4}{2}\right) + \frac{(5)(4)^3/12}{(8/\cos 60° + \frac{4}{2})[(4)(5)]} = 18.07 \text{ ft}$$

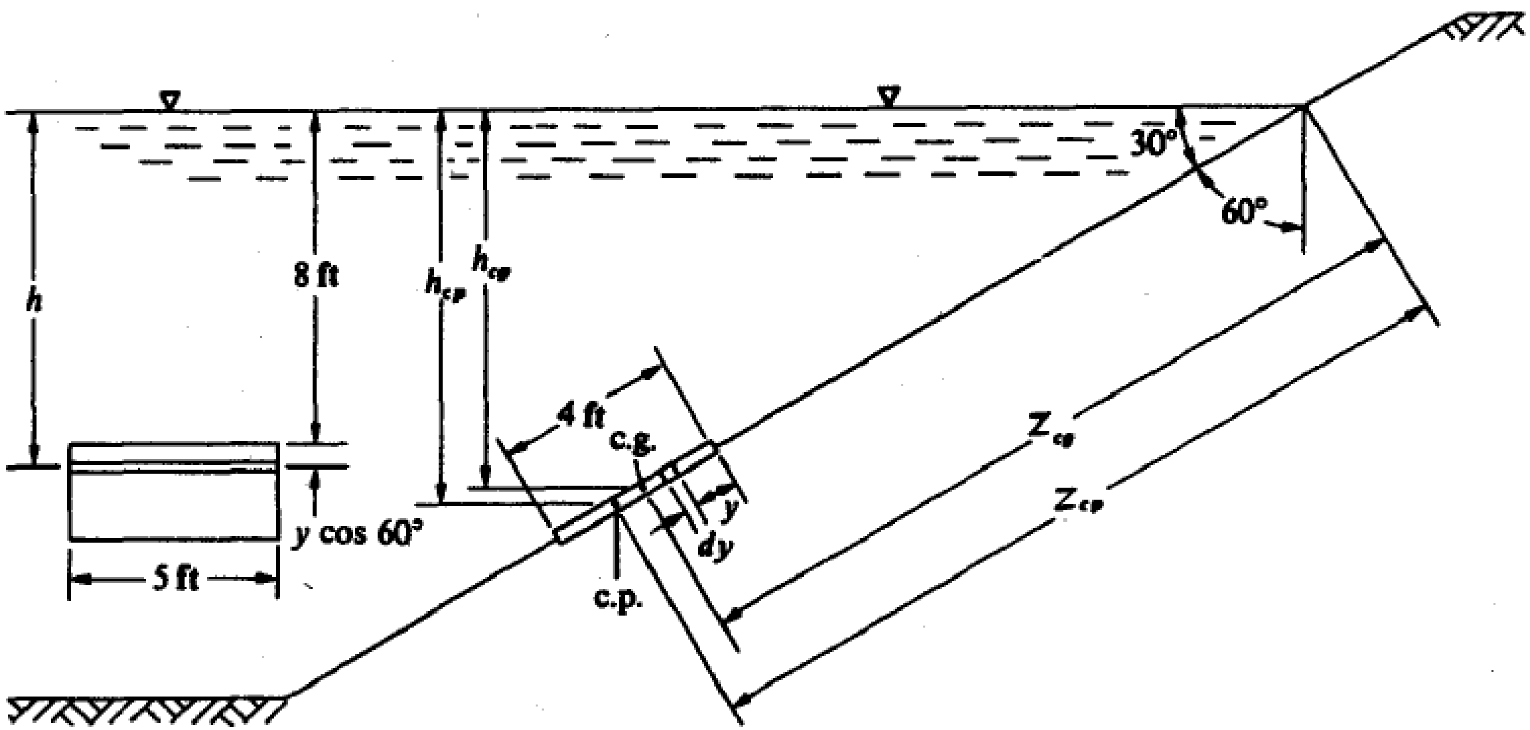


Fig. 3-9

An inclined, circular gate with water on one side is shown in Fig. 3-10. Determine the total resultant force acting on the gate and the location of the center of pressure.

$$F = \gamma h_{cg} A = (9.79)[1.5 + \tfrac{1}{2}(1.0 \sin 60°)][\pi(1.0)^2/4] = 14.86 \text{ kN}$$

$$z_{cp} = z_{cg} + \frac{I_{cg}}{z_{cg} A} = \left[\frac{1.5}{\sin 60°} + \frac{1}{2}(1.0)\right] + \frac{\pi(1.0)^4/64}{[1.5/\sin 60° + \frac{1}{2}(1.0)][\pi(1.0)^2/4]} = 2.260 \text{ m}$$

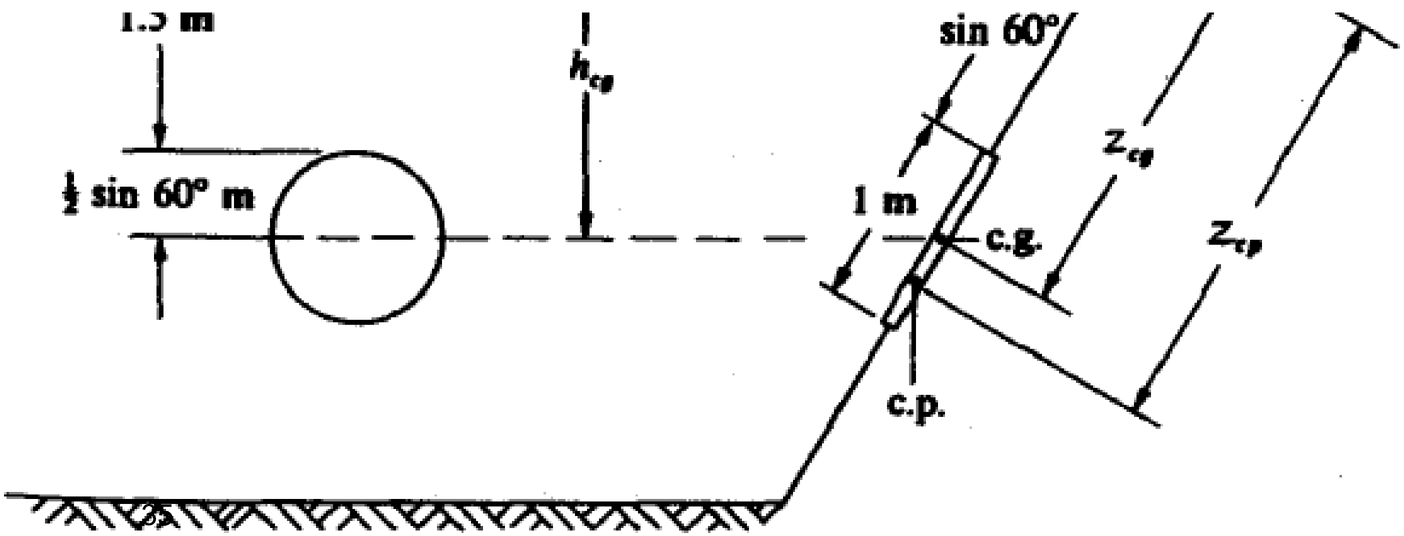


Fig. 3-10

A vat holding paint (s.g. = 0.80) is 8 m long and 4 m deep and has a trapezoidal cross section 3 m wide at the bottom and 5 m wide at the top (see Fig. 3-17). Compute **(*a*)** the weight of the paint, **(*b*)** the force on the bottom of the vat, and **(*c*)** the force on the trapezoidal end panel.

I (*a*) $$W = \gamma V = [(0.80)(9.79)][(8)(4)(5+3)/2] = 1002\ \text{kN}$$

(*b*) $$F = \gamma h_{cg} A \qquad F_{\text{bottom}} = [(0.80)(9.79)](4)[(3)(8)] = 752\ \text{kN}$$

(*c*) $$F_{\text{end}} = F_{\text{square}} + 2F_{\text{triangle}} = [(0.80)(9.79)][(0+4)/2][(4)(3)] + (2)[(0.80)(9.79)](\tfrac{4}{3})[(4)(1)/2] = 230\ \text{kN}$$

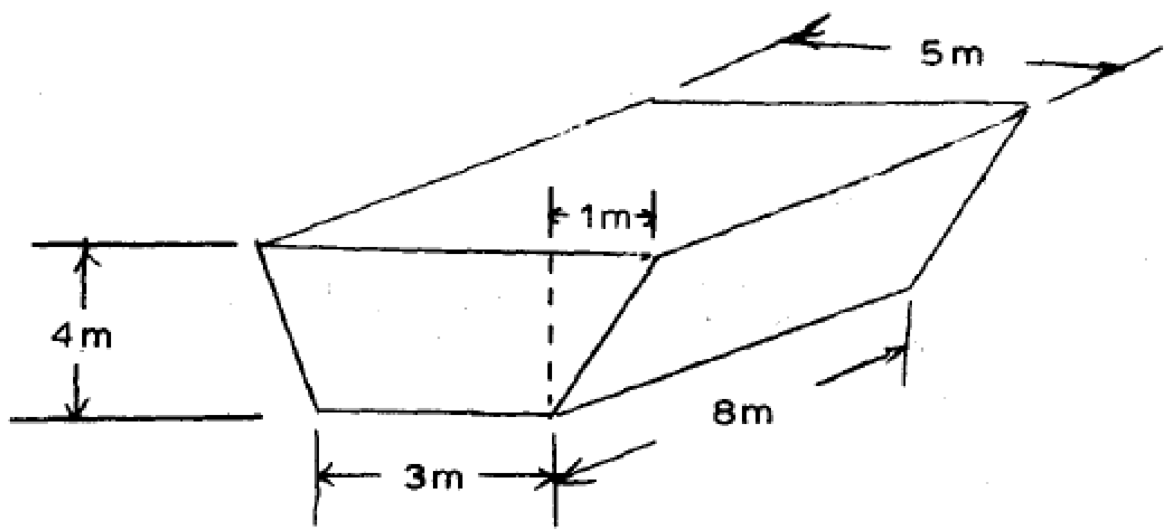


Fig. 3-17

A fishpond gate 6 ft wide and 9 ft high is hinged at the top and held closed by water pressure as shown in Fig. 3-16. What horizontal force applied at the bottom of the gate is required to open it?

▌

$$F = \gamma h_{cg} A = (62.4)(8+4.5)[(6)(9)] = 42\,120 \text{ lb}$$

$$h_{cp} = h_{cg} + \frac{I_{cg}}{h_{cg}A} = (8+4.5) + \frac{(6)(9)^3/12}{(8+4.5)[(6)(9)]} = 13.04 \text{ ft}$$

$$\sum M_A = 0 \qquad (P)(9) - (42\,120)(13.04 - 8) = 0 \qquad P = 23\,587 \text{ lb}$$

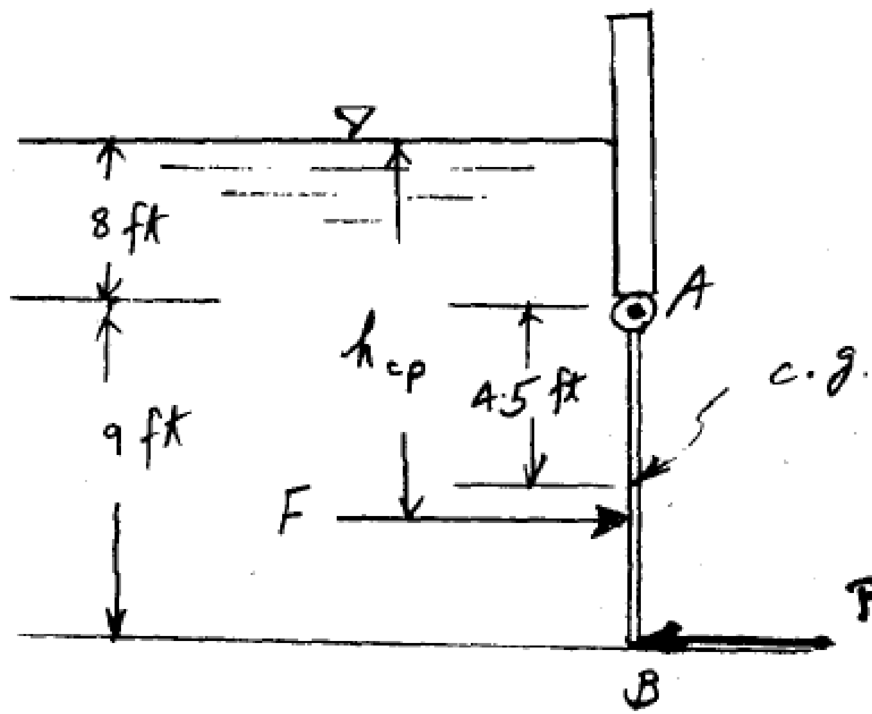


Fig. 3-16

Gate AB in Fig. 3-18 is 5 ft wide, hinged at point A, and restrained by a stop at point B. Compute the force on the stop and the components of the reaction at A if water depth h is 9 ft.

$$F = \gamma h_{cg} A = (62.4)(9 - \tfrac{3}{2})[(3)(5)] = 7020 \text{ lb}$$

$$y_{cp} = \frac{-I_{xx} \sin\theta}{h_{cg} A} = \frac{-[(5)(3)^3/12](\sin 90°)}{(9 - 3/2)[(3)(5)]} = -0.100 \text{ ft}$$

$$\sum M_A = 0 \qquad (B_x)(3) - (7020)(1.5 + 0.100) = 0 \qquad B_x = 3744 \text{ lb}$$

$$\sum F_x = 0 \qquad 7020 - 3744 - A_x = 0 \qquad A_x = 3276 \text{ lb}$$

If gate weight is neglected, $A_y = 0$.

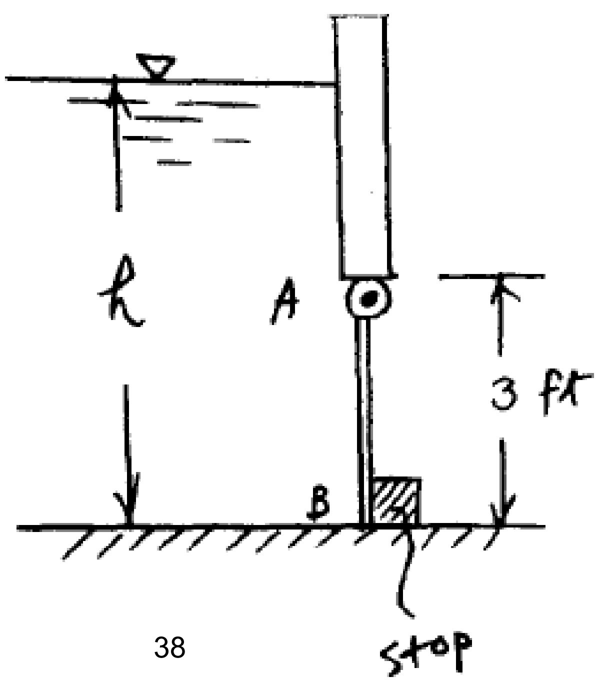


Fig. 3-18(a)

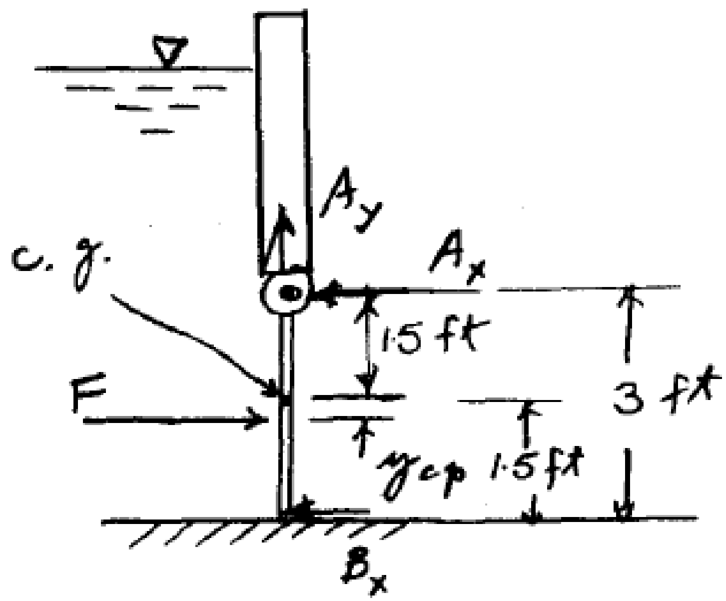


Fig. 3-18(b)

Gate AB in Fig. 3-23a is 16 ft long and 8 ft wide. Neglecting the weight of the gate, compute the water level h for which the gate will start to fall.

■

$$F = \gamma h_{cg} A = (62.4)(h/2)[(8)(h/\sin 60°)] = 288.2h^2$$

$$y_{cp} = \frac{-I_{xx}\sin\theta}{h_{cg}A} = \frac{-[8(h/\sin 60°)^3/12](\sin 60°)}{(h/2)[8(h/\sin 60°)]} = -0.1925h$$

$$\sum M_B = 0 \qquad (11\,000)(16) - (288.2h^2)[(h/\sin 60°)/2 - 0.1925h] = 0 \qquad h = 11.7\text{ ft}$$

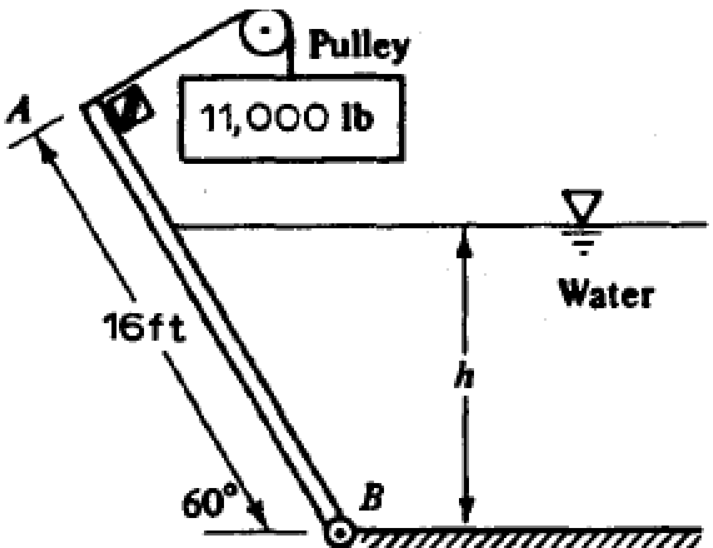


Fig. 3-23(a)

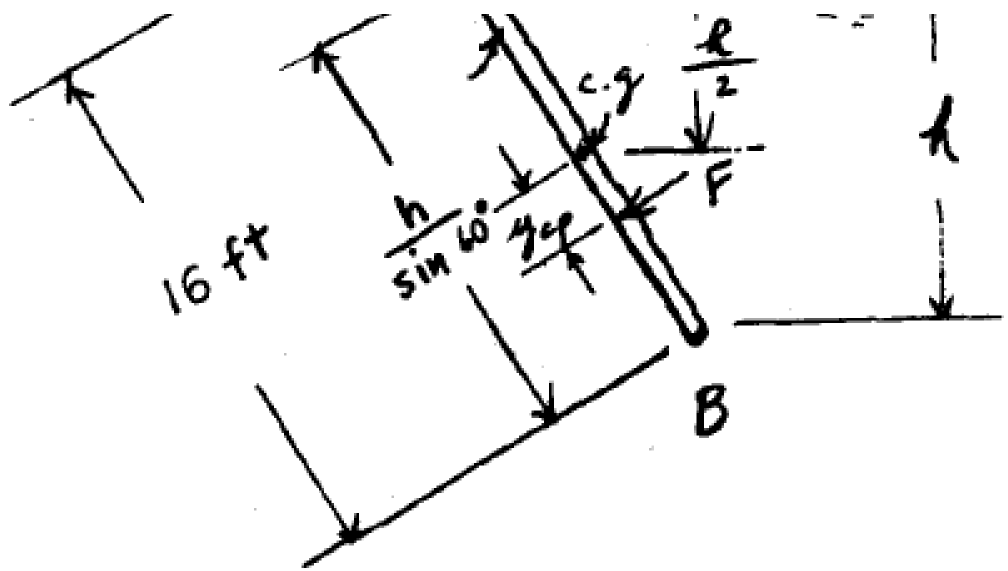


Fig. 3-23(b)

Gate AB in Fig. 3-15 is 1.0 m long and 0.9 m wide. Calculate force F on the gate and the position X of its center of pressure.

$$F = \gamma h_{cg} A = [(0.81)(9.79)][3 + (1 + 1.0/2)(\sin 50°)][(0.9)(1.0)] = 29.61 \text{ kN}$$

$$y_{cp} = \frac{-I_{XX} \sin \theta}{h_{cg} A} = \frac{-[(0.9)(1.0)^3/12](\sin 50°)}{[3 + (1 + 1.0/2)(\sin 50°)][(0.9)(1.0)]}$$

$$= -0.015 \text{ m from the centroid}$$

$$X = 1.0/2 + 0.015 = 0.515 \text{ m from point } A$$

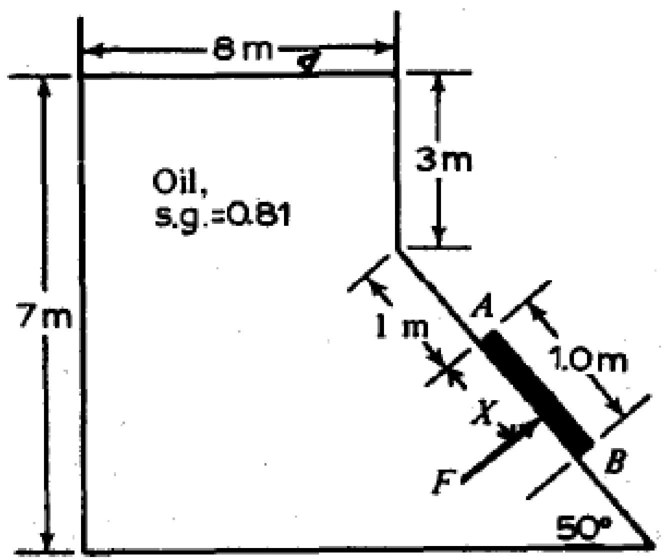


Fig. 3-15

Gate AB in Fig. 3-25 is semicircular, hinged at B. What horizontal force P is required at A for equilibrium?

▮ $4r/(3\pi) = (4)(4)/(3\pi) = 1.698\ \text{m}$ $\qquad F = \gamma h_{cg} A = (9.79)(6 + 4 - 1.698)[\pi(4)^2/2)] = 2043\ \text{kN}$

$$y_{cp} = \frac{-I_{xx} \sin\theta}{h_{cg} A} = \frac{-[(0.10976)(4)^4](\sin 90°)}{(6 + 4 - 1.698)[\pi(4)^2/2)]} = -0.1347\ \text{m}$$

$$\sum M_B = 0 \qquad (2043)(1.698 - 0.1347) - 4P = 0 \qquad P = 798\ \text{kN}$$

$$\boxed{\begin{aligned} I_{xx} &= 0.10976 r^4 \\ I_{xy} &= 0 \end{aligned}}$$

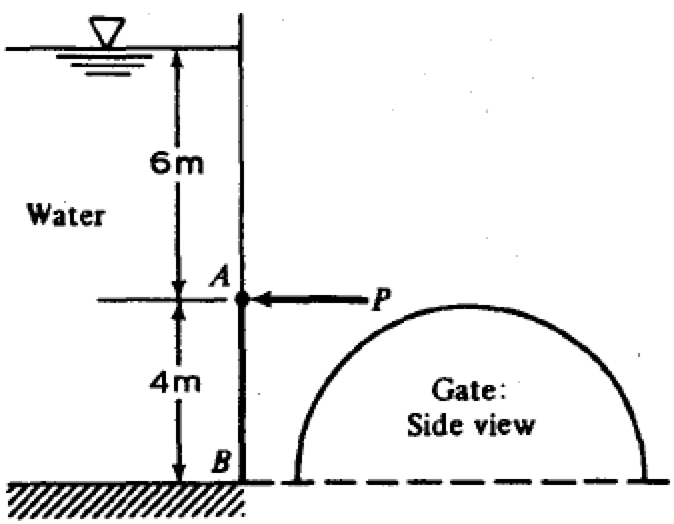


Fig. 3-25(a)

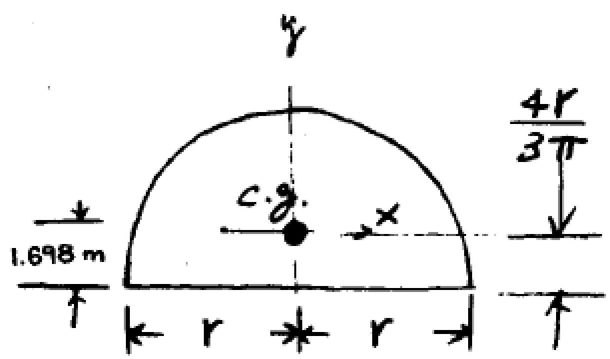


Fig. 3-25(b)

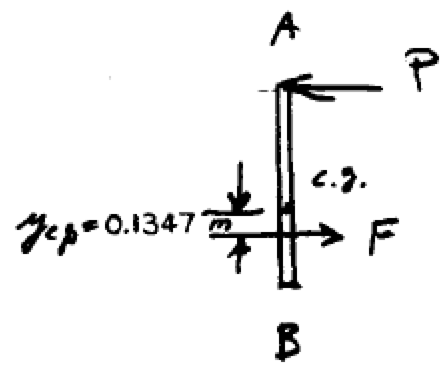


Fig. 3-25(c)

The tank in Fig. 3-28 is 40 cm wide. Compute the hydrostatic forces on horizontal panels *BC* and *AD*. Neglect atmospheric pressure.

■ $p = \gamma h \qquad p_{BC} = [(0.84)(9.79)](0.35 + 0.40) + (9.79)(0.25) = 8.615 \text{ kPa}$

$$F = pA \qquad F_{BC} = (8.615)[(1.20)(0.40)] = 4.135 \text{ kN}$$

$$p_{AD} = [(0.84)(9.79)](0.40) = 3.289 \text{ kPa} \qquad F_{AD} = (3.289)[(0.55)(0.40)] = 0.724 \text{ kN}$$

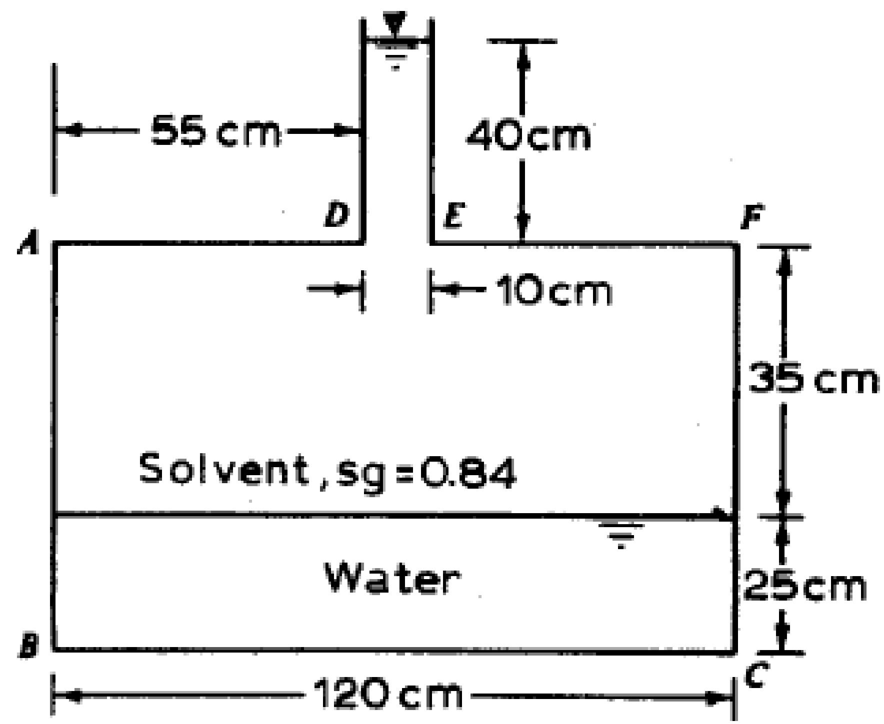


Fig. 3-28

The vertical plate shown in Fig. 3-40 is submerged in vinegar (s.g. = 0.80). Find the magnitude of the hydrostatic force on one side and the depth to the center of pressure.

$$F = \gamma h_{cg} A \qquad F_1 = [(0.80)(9.79)](2+\tfrac{7}{2})[(3)(7)] = 905\ \text{kN} \qquad h_{cp} = h_{cg} + \frac{I_{cg}}{h_{cg}A}$$

$$(h_{cp})_1 = 2 + \tfrac{7}{2} + \frac{(3)(7)^3/12}{(2+\tfrac{7}{2})[(3)(7)]} = 6.24\ \text{m} \qquad F_2 = [(0.80)(9.79)][2+3+4/2][(2)(4)] = 439\ \text{kN}$$

$$(h_{cp})_2 = [2+3+4/2] + \frac{(2)(4)^3/12}{(2+3+4/2)[(2)(4)]} = 7.19\ \text{m}$$

$$F = 905 + 439 = 1344\ \text{kN} \qquad 1344 h_{cp} = (905)(6.24) + (439)(7.19) \qquad h_{cp} = 6.55\ \text{m}$$

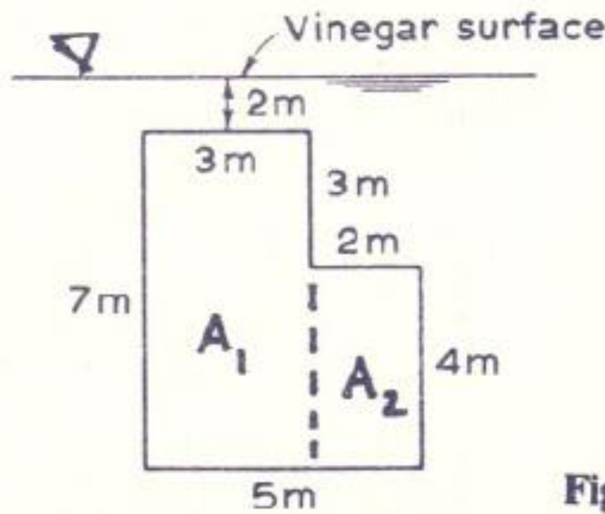


Fig. 3-40

Find the force exerted by water on one side of the vertical annular disk shown in Fig. 3-47. Also locate the center of pressure.

I

$$F = \gamma h_{cg} A = (9.79)(3)[(\pi)(1)^2 - (\pi)(\tfrac{600}{1000})^2] = 59.05\ \text{kN}$$

$$I_{cg} = (\pi)(1)^4/4 - (\pi)(\tfrac{600}{1000})^4/4 = 0.6836\ \text{m}^4$$

$$h_{cp} = h_{cg} + \frac{I_{cg}}{h_{cg}A} = 3 + \frac{0.6836}{3[(\pi)(1)^2 - (\pi)(\frac{600}{1000})^2]} = 3.113\ \text{m}$$

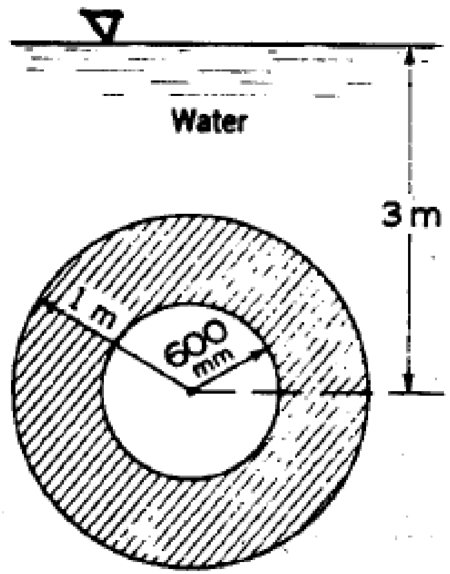
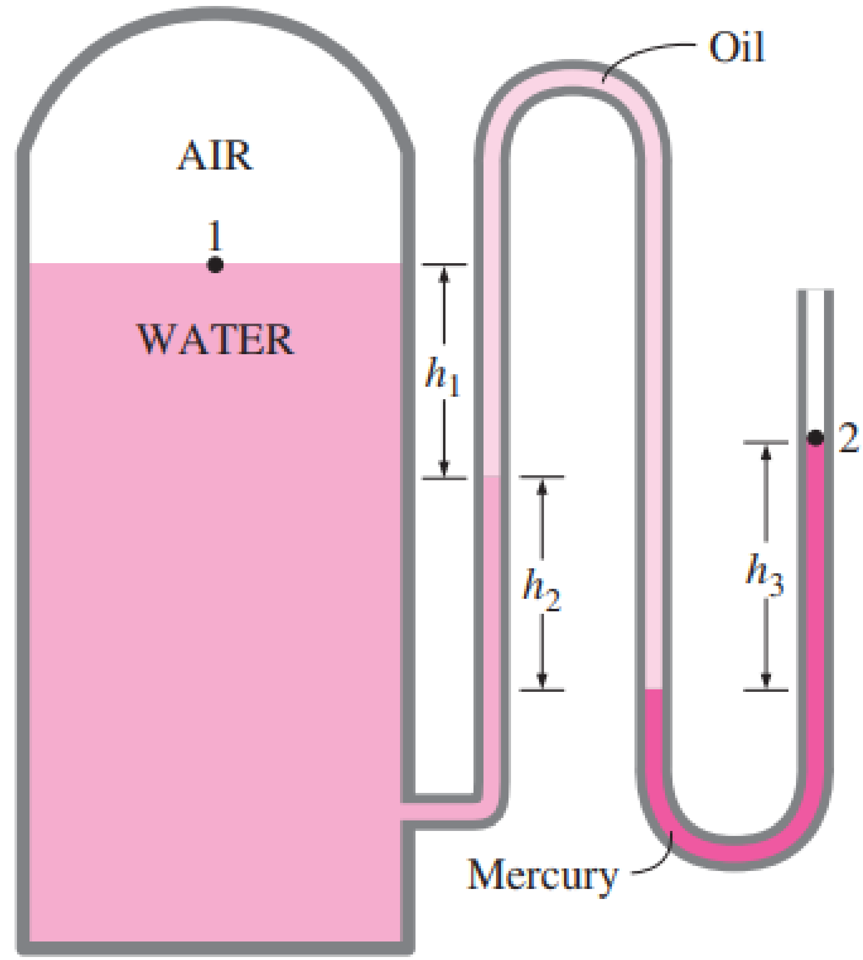
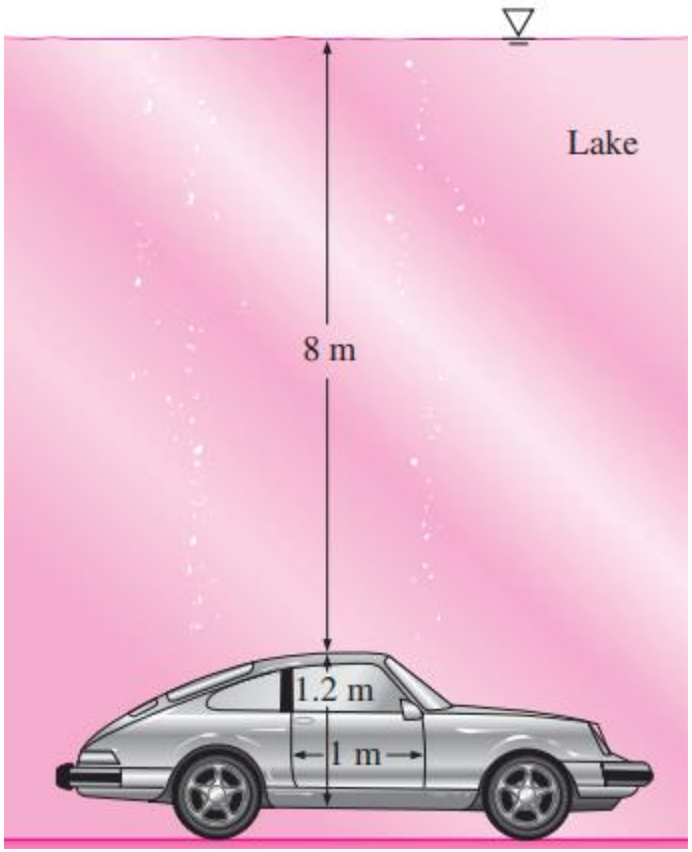
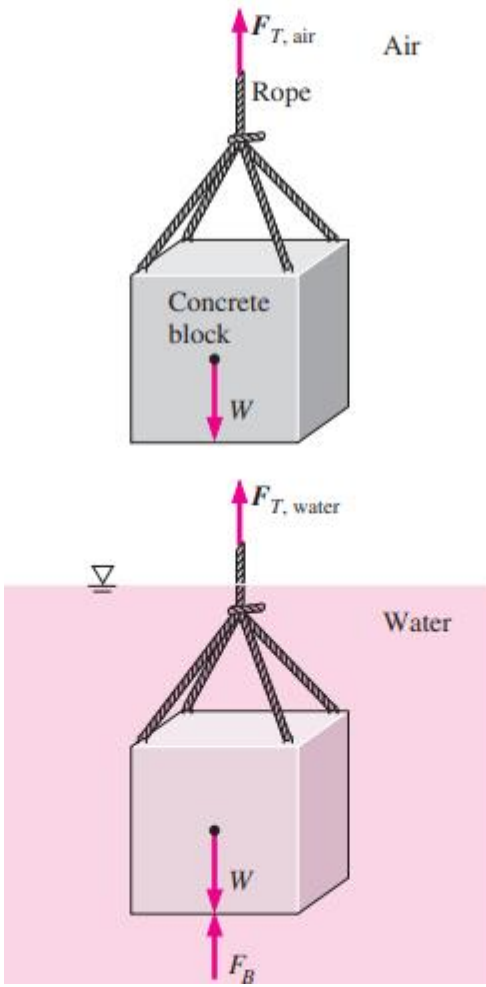


Fig. 3-47



Oil
AIR
1
WATER
h_1
h_2
h_3
2
Mercury


Lake
8 m
1.2 m
1 m



$F_{T,\text{ air}}$
Air
Rope
Concrete
block
W
$F_{T,\text{ water}}$
Water
W
F_B

قسم الهندسة المدنية

المرحلة الثانية

Al-Mansour University College

Civil Eng. Dept.

2nd. Stage

Fluid Mechanics

2022 - 2023

ميكانيك الموائع

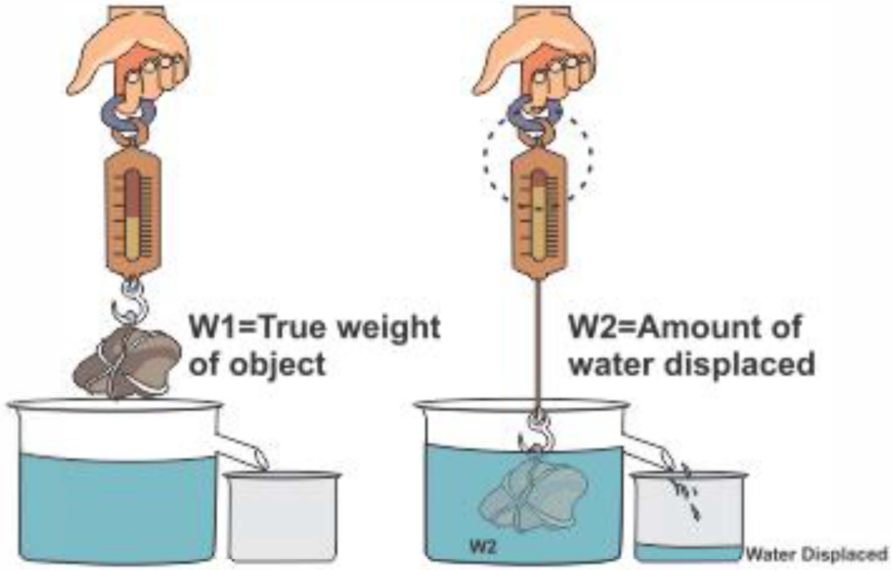
Lec.3

Ministry of Higher Education and Scientific Researches
Al-Mansour University College
Department of Civil Engineering
CE 205 Fluid Mechanics

Buoyancy & Flotation

Dr Ameer Badr Khudhair

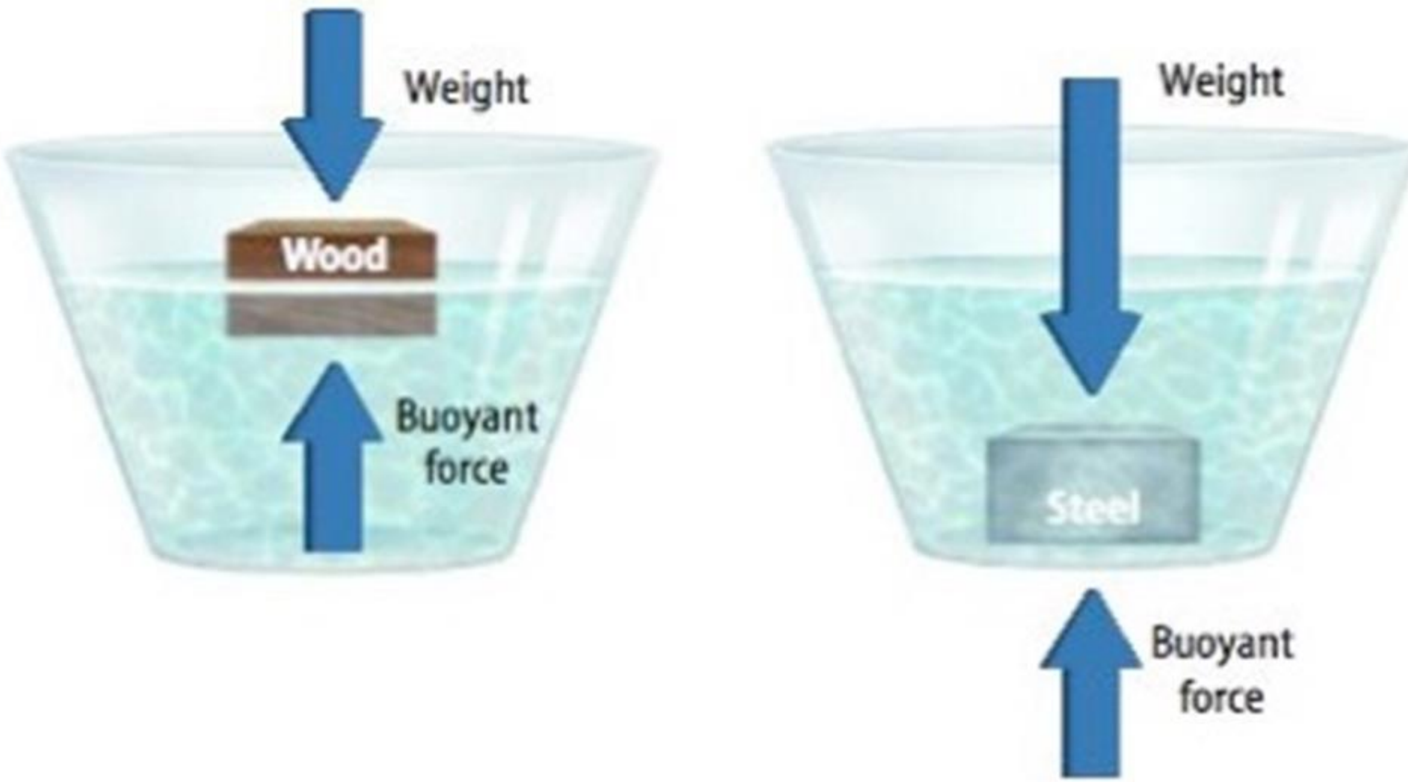
Archimedes' Principle states that when an object is partially or completely immersed in a fluid, it experiences an upthrust (upward force) which is equal to the weight of the fluid displaced by it



weight of object in water (Apparent weight)

Apparent weight of an object = True weight of object in air – upthrust (weight of water displaced)

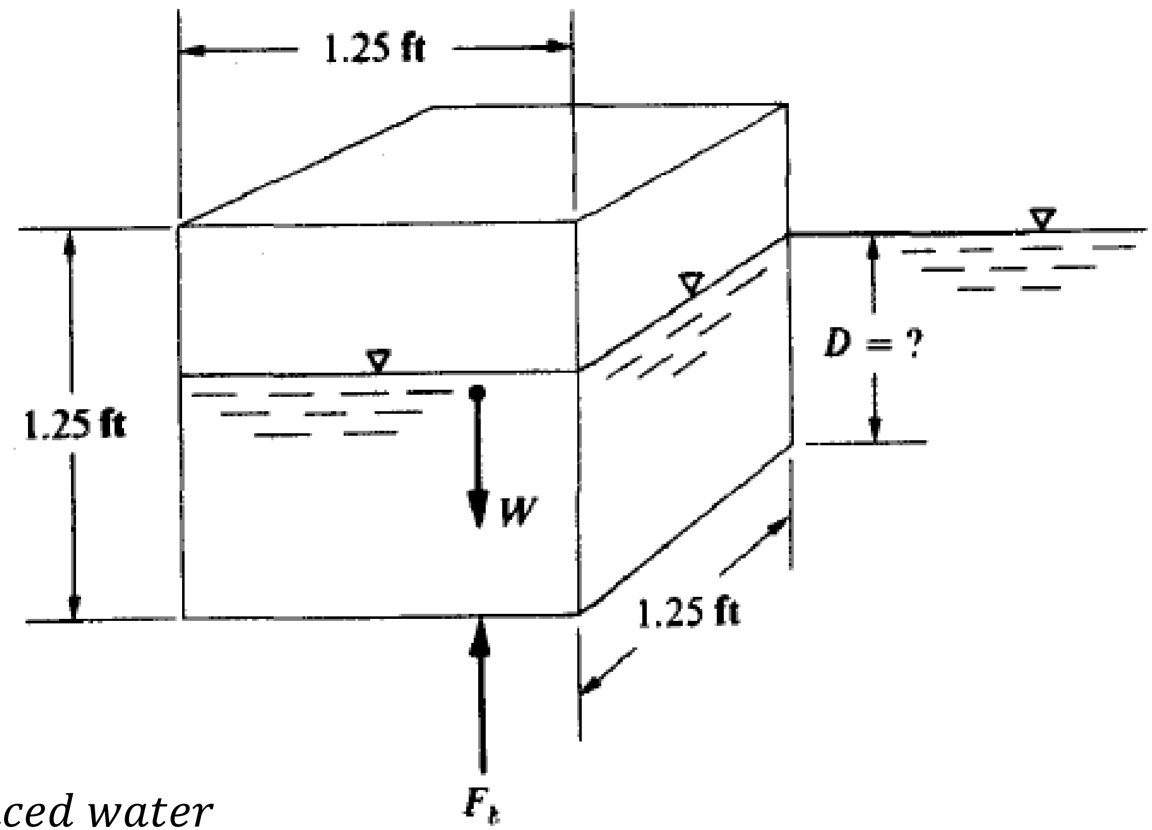
Buoyant force = weight of water displaced.



Buoyant force (F_b) = weight of water displaced by stone (W) = $105 - 67.0 = 38.0$ lb

$$W = \gamma V = 62.4V \qquad 38.0 = 62.4V \qquad V = 0.609\ \text{ft}^3$$

$$S.G = \frac{\gamma_{stone}}{\gamma_{water}} = \frac{Weight_{stone}/Volume_{stone}}{62.4} = \frac{105/0.609}{62.4} = 2.76$$



$F_b = Weight\ of\ displaced\ water$
$weight\ of\ cube = \ weight\ of\ displaced\ water$
$\gamma_{cube} \times volume\ of\ cube\ = \gamma_{water} \times volume$ of *displaced water*
(0.6 X 62.4) X((1.25X 1.25 X 1.25) = 62.4 X (1.25 X1.25 X D)
D = 0.75 ft

Example: A spar in figure below is wood (S.G. = 0.62), 2x2 in by 10 ft and floats in sea water (S.G. = 1.025). How many pounds of steel (S.G. = 7.85) should be attached to the bottom to make a buoy that floats with exactly h = 1.5 ft of the spar exposed?

$V_{spar} = (\frac{2}{12})(\frac{2}{12})(10) = 0.2778 \text{ ft}^3$ $\qquad V_{submerged} = (\frac{2}{12})(\frac{2}{12})(8.5) = 0.2361 \text{ ft}^3$

$V_{steel} = W_{steel}/[(7.85)(62.4)] = 0.002041 W_{steel}$ $\qquad F_b = W_{wood} + W_{steel}$

$[(1.025)(62.4)](0.2361 + 0.002041 W_{steel}) = [(0.62)(62.4)](0.2778) + W_{steel}$ $\qquad W_{steel} = 5.01 \text{ lb}$

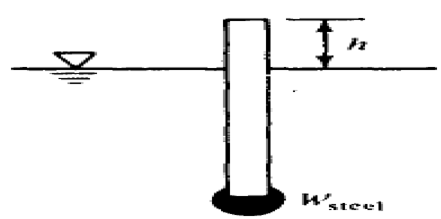


Fig. 6-12