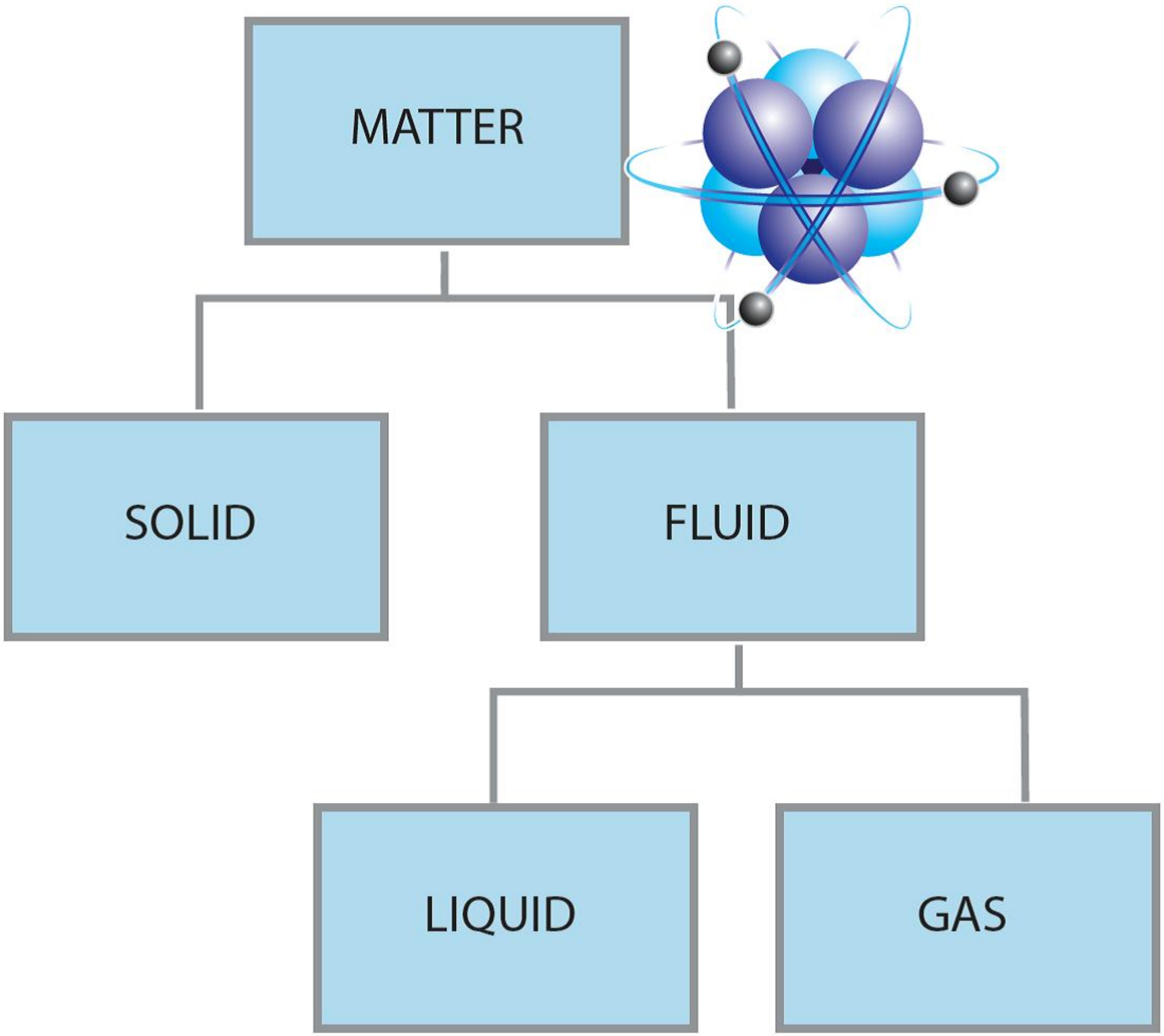
د. عبدالله عبدالأمير حسين



(Fluids) الموائع

- Three (common) phases of matter:

1. **Solid:** Maintains shape & size (approx.), even under large forces.
2. **Liquid:** No fixed shape. Takes shape of container.
3. **Gas:** Neither fixed shape, nor fixed volume. Expands to fill container.

Lump **2.** & **3.** into category of ***FLUIDS*****.**

Fluids: Have the ability to flow.

المائع لديه القدرة على الانسياب.

Density & Specific Gravity

الكثافة

- ***Density,*** ρ (lower case Greek ***rho***, ***NOT*** **p**!) of object, mass **M** & volume **V**:

كثافة المادة نسبة الى كثافة الماء

$$\rho \equiv (M/V) \qquad (kg/m^3 = 10^{-3}\ g/cm^3)$$

- ***Specific Gravity (SG):*** Ratio of density of a substance to density of water.

$$\rho_{water} = 1\ g/cm^3 = 1000\ kg/m^3$$

See table!!

$$\rho = (M/V) \quad SG = (\rho/\rho_{water}) = 10^{-3}\rho$$

$$(\rho_{water} = 10^3\ kg/m^3)$$

Table 10–1
Densities of Substances†

Substance	Density, ρ (kg/m^3)
Solids	
Aluminum	2.70×10^3
Iron and Steel	7.8×10^3
Copper	8.9×10^3
Lead	11.3×10^3
Gold	19.3×10^3
Concrete	2.3×10^3
Granite	2.7×10^3
Wood (typical)	$0.3–0.9 \times 10^3$
Glass, common	$2.4–2.8 \times 10^3$
Ice	0.917×10^3
Bone	$1.7–2.0 \times 10^3$
Liquids	
Water (4°C)	1.00×10^3
Blood, plasma	1.03×10^3
Blood, whole	1.05×10^3
Sea water	1.025×10^3
Mercury	13.6×10^3
Alcohol, ethyl	0.79×10^3
Gasoline	0.68×10^3
Gases	
Air	1.29
Helium	0.179
Carbon dioxide	1.98
Water (steam) (100°C)	0.598

† Densities are given at 0°C and 1 atm pressure unless otherwise specified.

- ***Note:*** $\rho = (\mathbf{M/V})$

$\Rightarrow$ **Mass** of body, density ρ, volume **V** is

$$\mathbf{M} = \rho\mathbf{V}$$

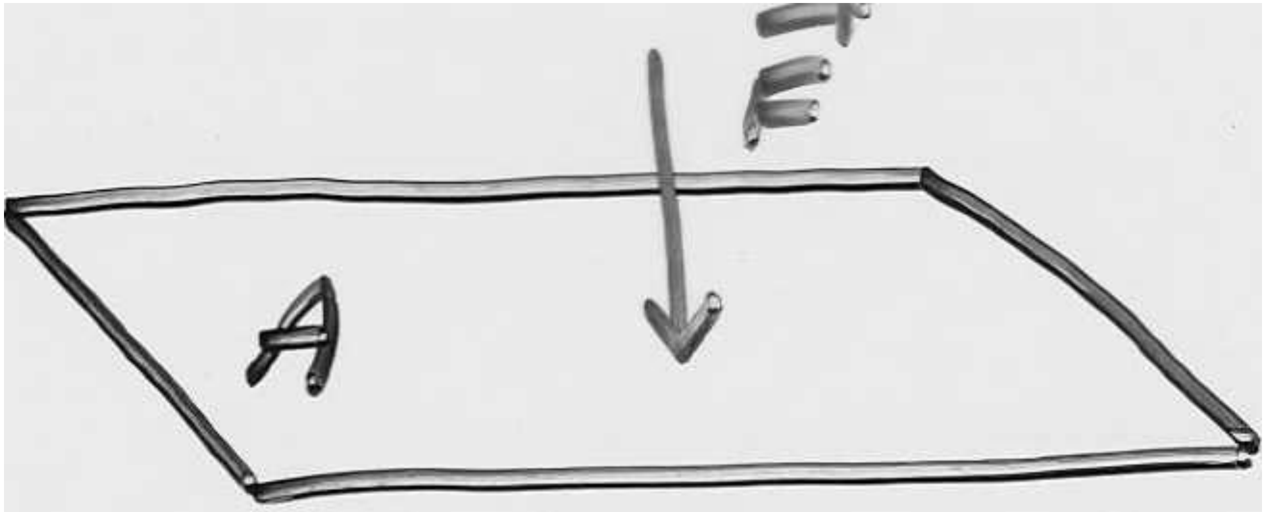
$\Rightarrow$ **Weight** of body, density ρ, volume **V** is

$$\mathbf{Mg} = \rho\mathbf{Vg}$$

Pressure in Fluids

- Definition: Pressure = Force/Area

$$\mathbf{P \equiv (F/A)}$$

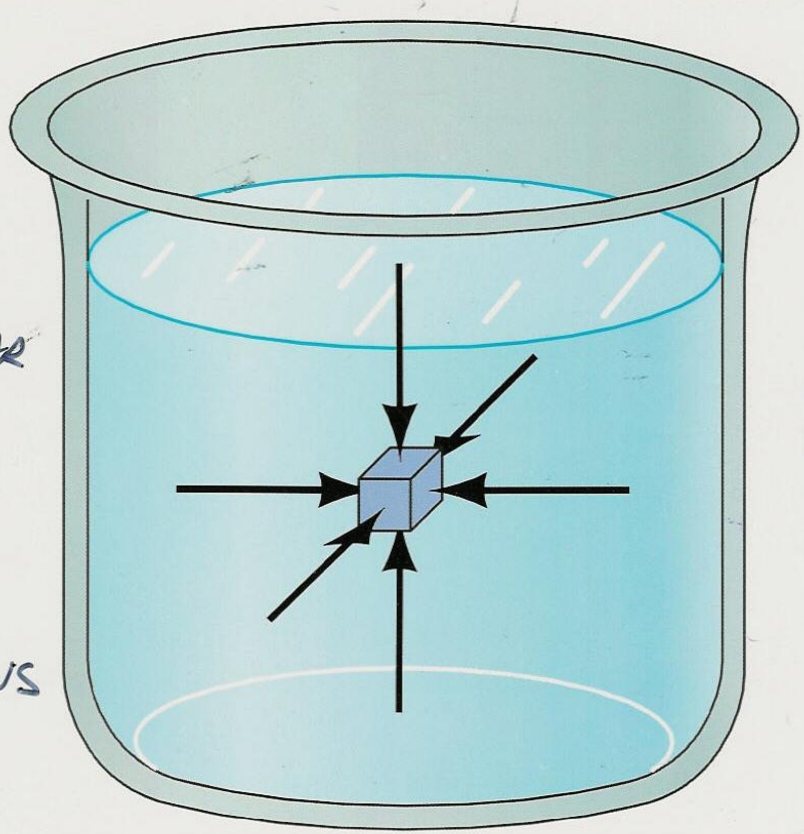


F applied **perpendicular** to **A**

SI units: $\mathbf{N/m^2}$

$$\mathbf{1\ N/m^2 = 1\ Pa\ (Pascal)}$$

AT A PARTICULAR POINT, P IS SAME IN ALL DIRECTIONS



P IS ⊥ ANY SURFACE

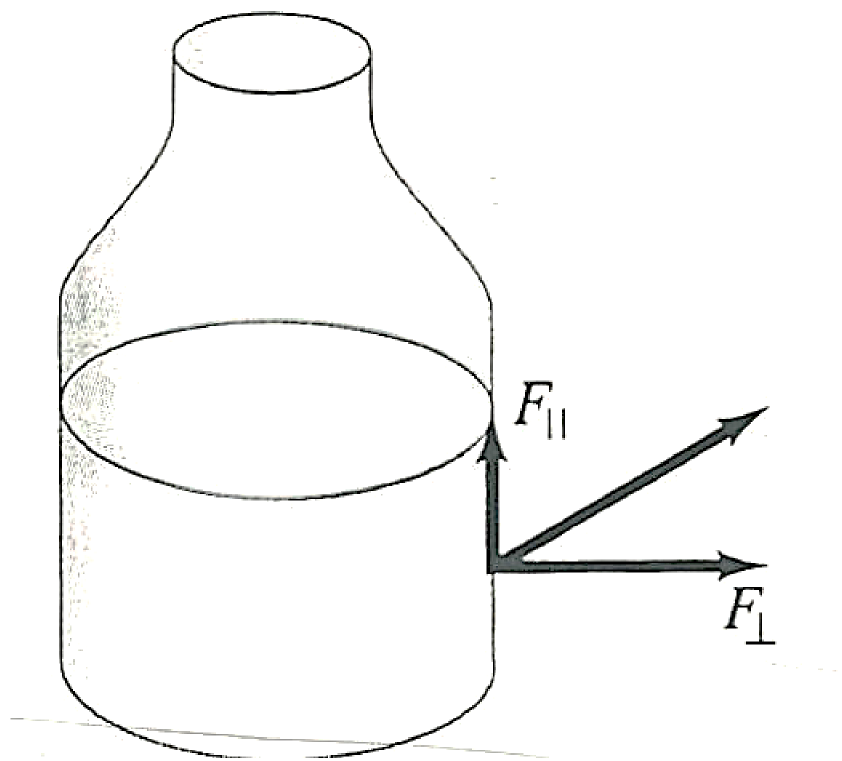
FIGURE 10–1 Pressure is the same in every direction in a fluid at a given depth; if it weren't, the fluid would be in motion.

FLUID AT REST

EXPERIMENTAL FACT: FLUID AT REST EXERTS A PRESSURE IN ALL DIRECTIONS.

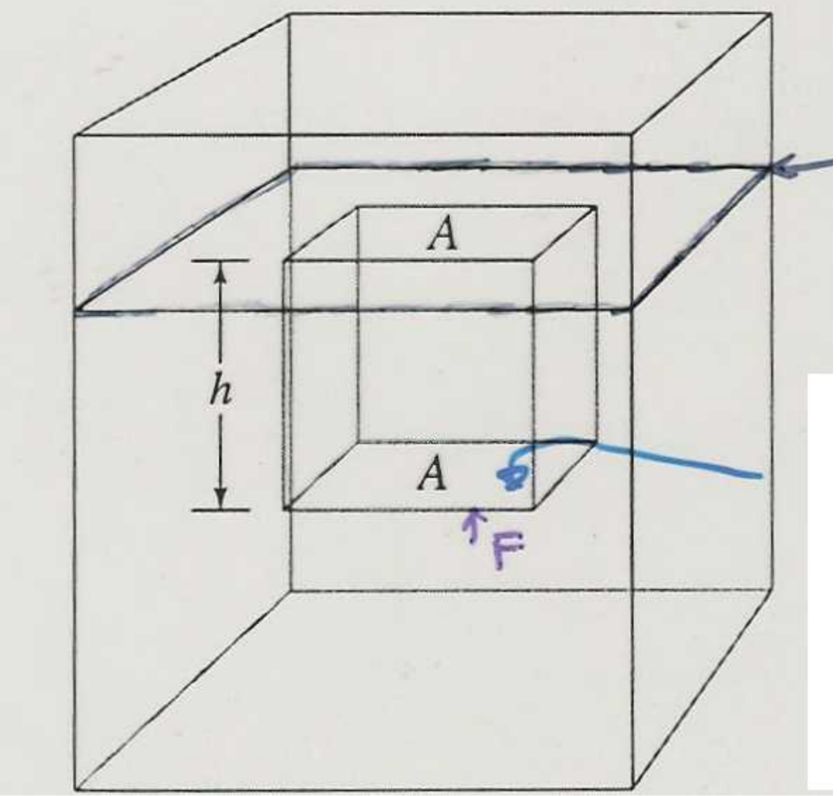
- **P** is ⊥ any fluid surface: $\mathbf{P = (F_{\perp}/A)}$

FIGURE 10–2 If there were a component of force parallel to the solid surface, the liquid would move in response to it; for a liquid at rest, $F_{\parallel} = 0$.



- ***Experimental Fact***: **Pressure depends on depth.**
  Consider a fluid ***at rest***. Depth **h** below surface:

FIGURE 10–3 Calculating the pressure at a depth h in a liquid.



At rest $\Rightarrow \sum \mathbf{F_y} = \mathbf{0}$

or, $\mathbf{F - mg = 0 \Rightarrow F = mg}$

$\mathbf{F = mg = \rho Vg, \; V = Ah}$

$\Rightarrow \mathbf{F = \rho Ahg}$

$\Rightarrow \mathbf{P \equiv F/A = \rho gh}$

Pressure at depth **h** (fluid at rest)

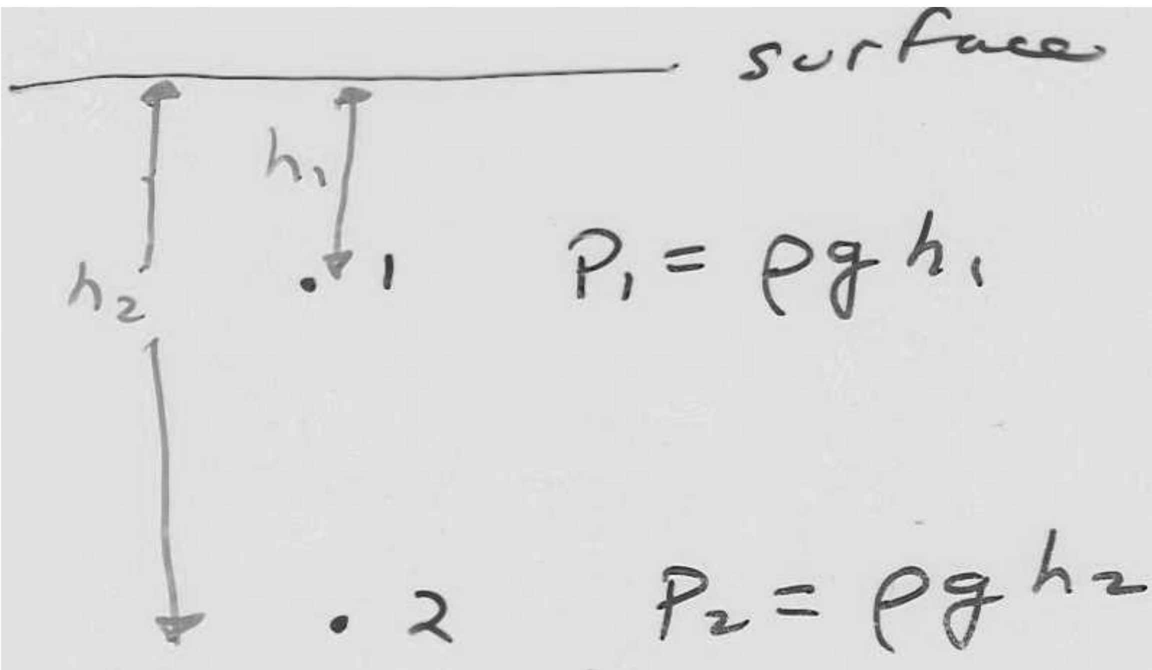
$$\mathbf{P = \rho gh}$$

- Depth **h** below surface of liquid: $\mathbf{P = \rho g h}$

⇒ ***Change in pressure with change in depth***:

يتغير الضغط بتغير العمق

$\mathbf{\Delta P = \rho g \Delta h}$ (for a fluid ***at rest*** only!)

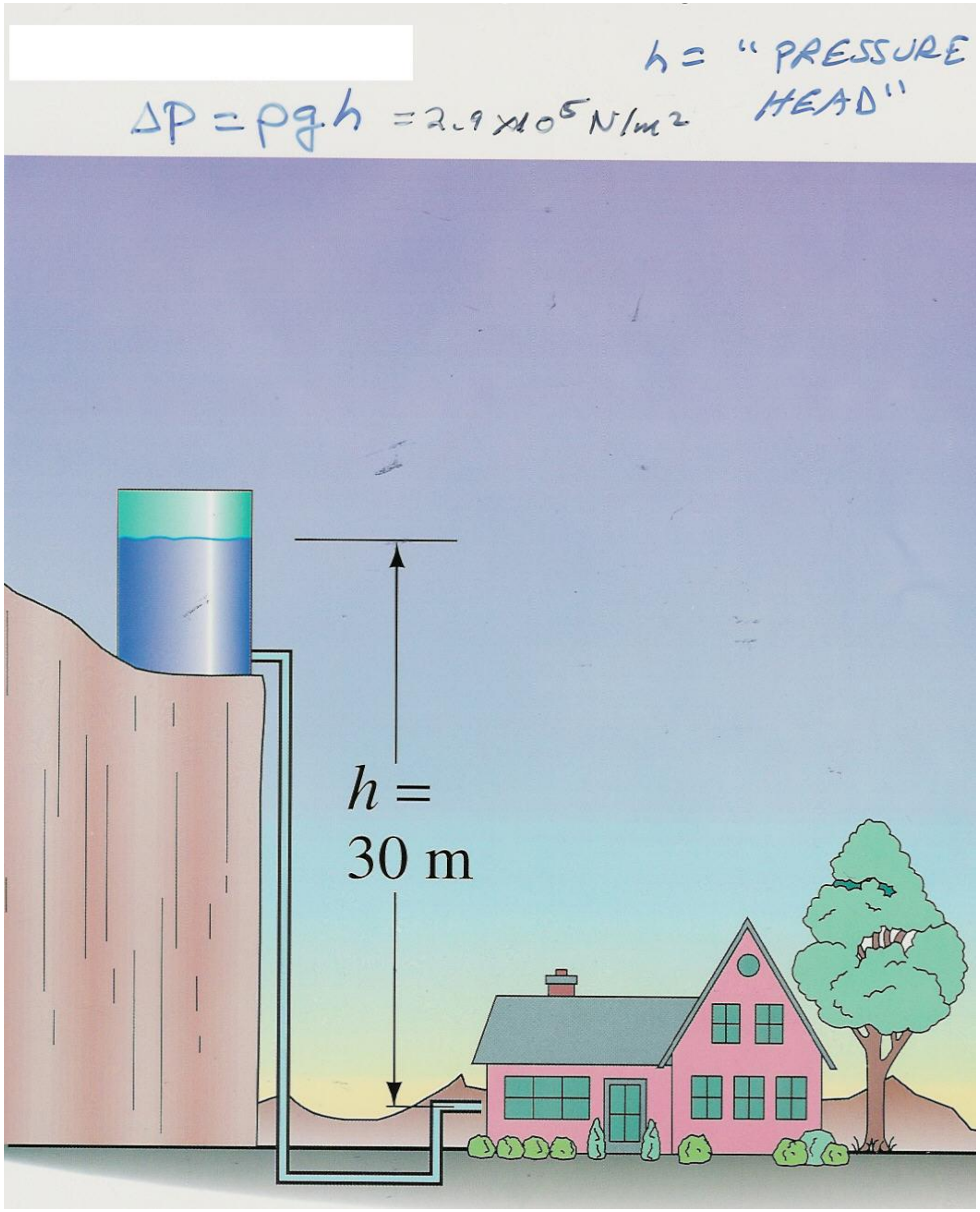


$\mathbf{\Delta P = P_2 - P_1}$

$\mathbf{= \rho g(h_2 - h_1)}$

$\mathbf{\rho g \Delta h}$

Example



Atmospheric Pressure

- **Earth's atmosphere:** A fluid.
  - But doesn't have a fixed top "surface"!
- Change in height **Δh** above Earth's surface:

$\Rightarrow$ Change in pressure: $\mathbf{\Delta P = \rho g \Delta h}$

- Sea level: $\mathbf{P_A \equiv 1.013 \times 10^5\ N/m^2}$

  $\mathbf{= 101.3\ kPa \equiv 1\ atm}$
  - Old units: $\mathbf{1\ bar = 1.00 \times 10^5\ N/m^2}$
- ***Physics:*** **Cause** of pressure at any height:

  Weight of air above that height!

Gauge Pressure

- Pressure gauges (like tire gauges, etc.) measure difference between atmospheric pressure $\mathbf{P_A}$ & internal pressure (of tire, for example).

- **Gauge pressure:** $\mathbf{P_G = P - P_A}$

Conceptual Example

P = ?

Pressure on **A**:

$\mathbf{P_{down} = P + P_{mg}}$

$\mathbf{P_{up} = P_A}$

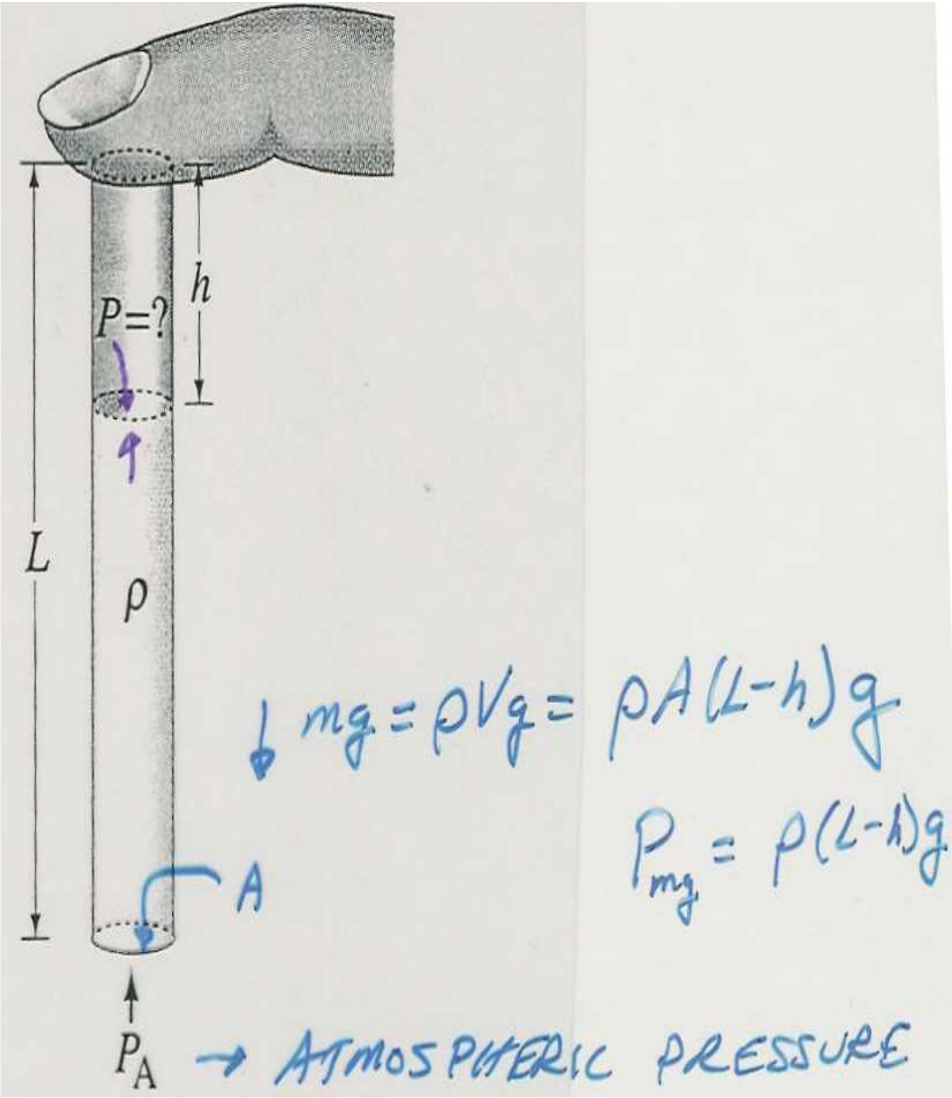
At rest $\Rightarrow \sum \mathbf{F_y = 0}$

$\Rightarrow \mathbf{P_{up} = P_{down}}$

or $\mathbf{P_A = P + P_{mg}}$

$\Rightarrow \mathbf{P = P_A - P_{mg} < P_A}$

So, air pressure holds fluid in straw!



Section 10-5: Pascal's Principle

- Experimental fact:

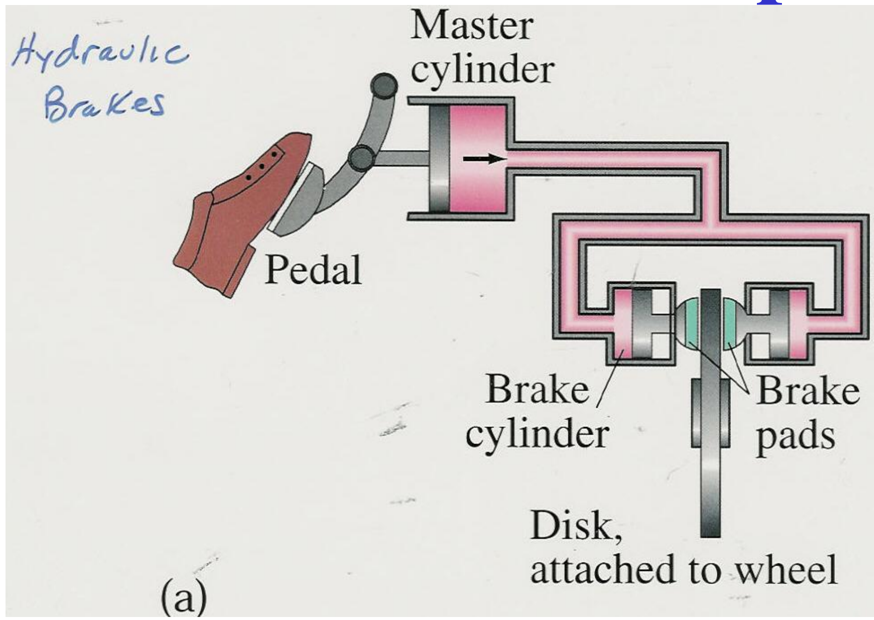
An external pressure P applied to confined fluid increases the pressure throughout by P

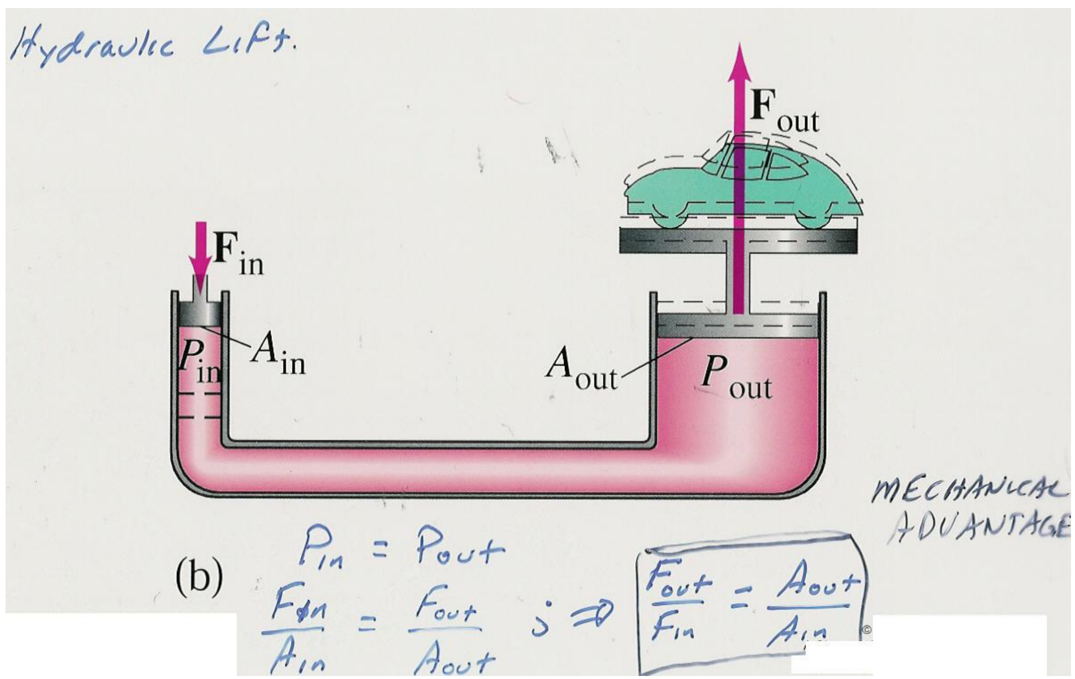
$\equiv$ ***Pascal's Principle***

- Simple example: Water in a lake (at rest). At depth h below surface, pressure is

$\mathbf{P = P_A + \rho g h}$ (P_A = atmospheric pressure)

Pascal's Principle

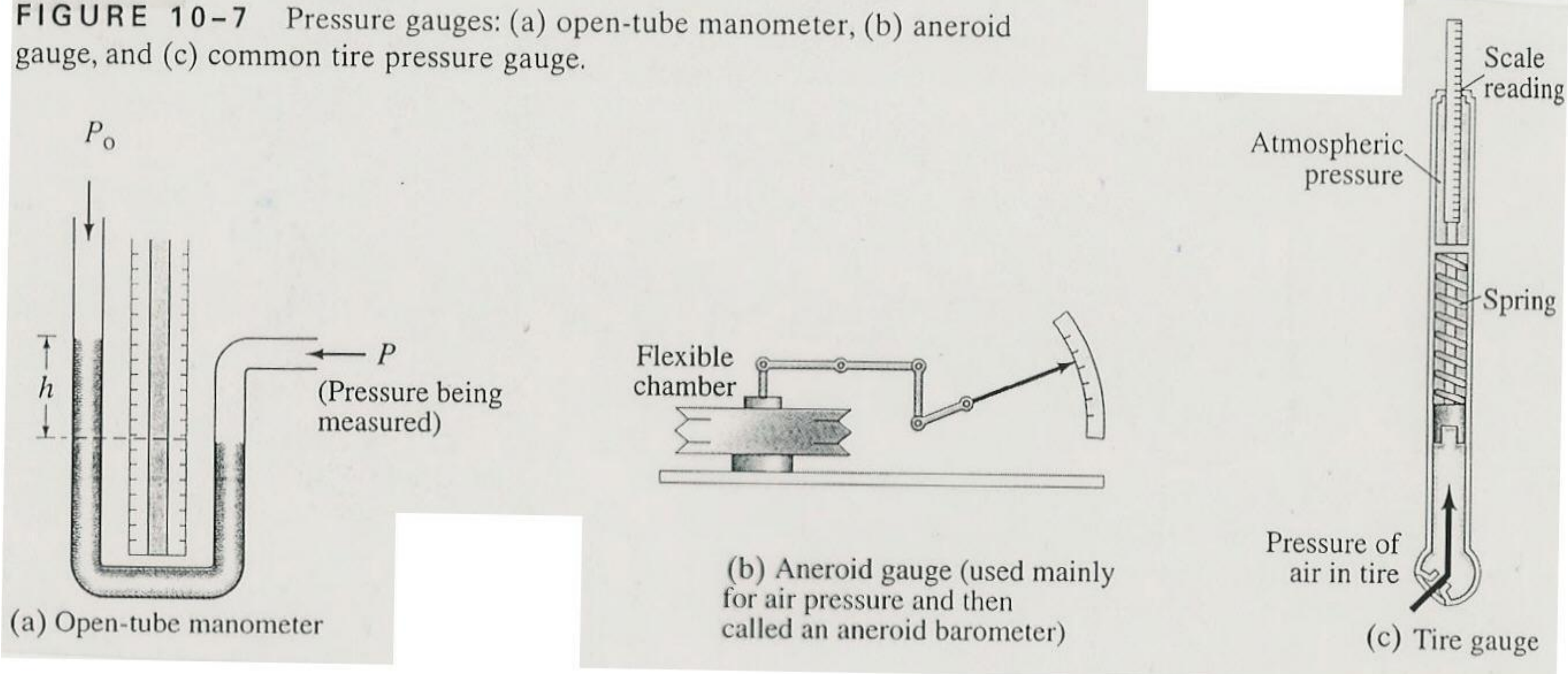




Section 10-6: Pressure Measurement

- Many types of pressure measurement devices. Most use $\mathbf{P - P_A = \rho g h = P_G}$ = gauge pressure

FIGURE 10–7 Pressure gauges: (a) open-tube manometer, (b) aneroid gauge, and (c) common tire pressure gauge.



Various Pressure Units

- Gauge Pressure: $\mathbf{P_A = \rho g h}$

⇒ ***Alternate unit of pressure:*** Instead of calculating ρ**gh**, common to use standard liquid (mercury, Hg or alcohol, where ρ is standard) & measure **h**

⇒ **Quote pressure in length units**! For example:

“millimeters of mercury” ≡ **mm Hg**

For **h = 1 mm Hg =** $\mathbf{10^{-3}}$ **m Hg**

$$\rho_{mercury}\, gh = (1.36 \times 10^4\ \mathrm{kg/m^3})\ (9.8\ \mathrm{m/s^2})(10^{-3}\ \mathrm{m})$$

$$= 133\ \mathrm{N/m^2} = 133\ \mathrm{Pa} \equiv 1\ \mathrm{Torr}$$

(another pressure unit!)

mm Hg & **Torr** are not proper SI pressure units!

- About as many ***pressure units*** as there are measurement devices!!

TABLE 10–2
Conversion Factors Between Different Units of Pressure

In Terms of 1 Pa = 1 N/m^2	Related to 1 atm
1 atm = 1.013×10^5 N/m^2	1 atm = 1.013×10^5 N/m^2
= 1.013×10^5 Pa = 101.3 kPa	
1 bar = 1.000×10^5 N/m^2	1 atm = 1.013 bar
1 dyne/cm^2 = 0.1 N/m^2	1 atm = 1.013×10^6 dyne/cm^2
1 lb/in^2 = 6.90×10^3 N/m^2	1 atm = 14.7 lb/in^2
1 lb/ft^2 = 47.9 N/m^2	1 atm = 2.12×10^3 lb/ft^2
1 cm-Hg = 1.33×10^3 N/m^2	1 atm = 76 cm-Hg
1 mm-Hg = 133 N/m^2	1 atm = 760 mm-Hg
1 torr = 133 N/m^2	1 atm = 760 torr
1 mm-H_2O (4°C) = 9.81 N/m^2	1 atm = 1.03×10^4 mm-H_2O (4°C)

- ***Preferred* (SI)** unit: **1 Pa** (Pascal) **= 1 N/m^2**

Mercury Barometer

- **Weather reports:** Barometric pressure (atmospheric pressure): **28-32 inches Hg**

  76 cm = 760 mm

  = 29.29 inches

  When **h = 760 mm**,

  $\mathbf{P = \rho_{mercury}\, gh =}$

  $\mathbf{1.013 \times 10^5\ N/m^2}$

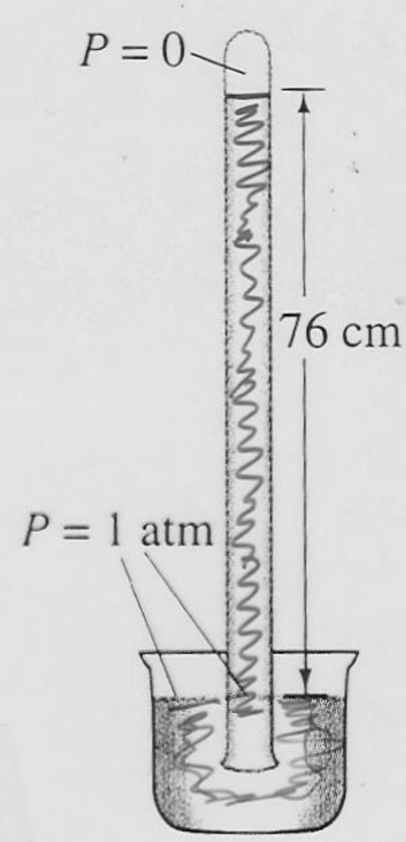
  = 1 atm

- If use water

  $\mathbf{P = 1atm = \rho_{water}\, gh}$

$\Rightarrow$ **h ≈ 10 m ≈ 30 feet!**

FIGURE 10–8 Diagram of mercury barometer, when the air pressure is 76 cm-Hg.



Prob. 17: (A variation on Example)

Tank depth **= 5 m**
Pipe length **= 110 m**
Hill slope **= 58º**

Gauge Pressure $\mathbf{P_G}$ = ?
Height water **H** shoots from broken pipe at bottom?

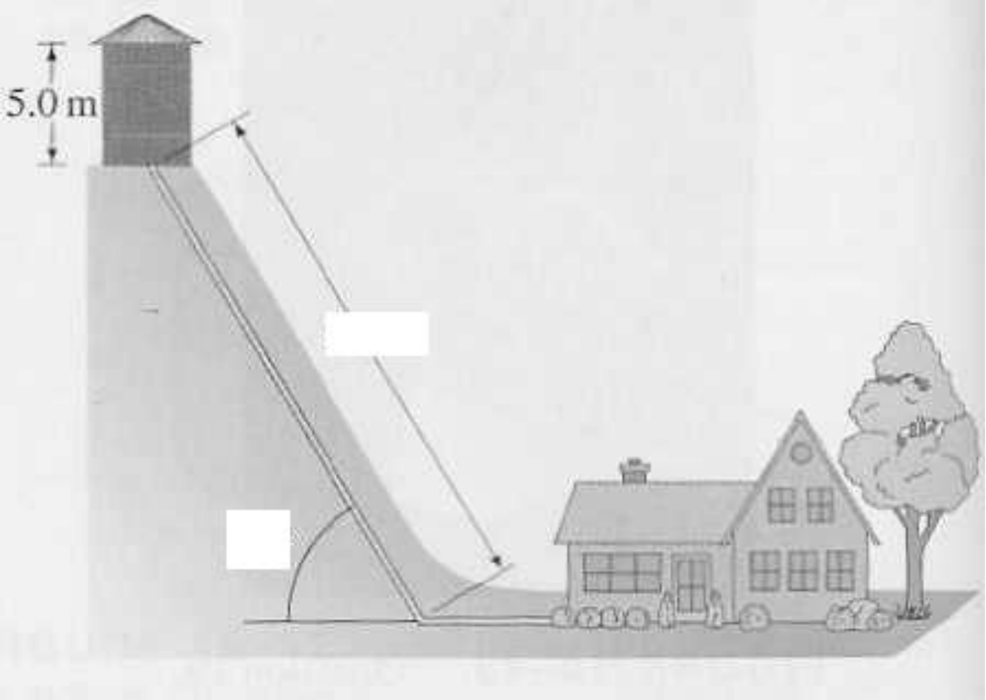


FIGURE 10–47 Problem 17.

Height of water level in tank from house level: $\mathbf{h = (5 + 110\sin 58^o) = 98.3\ m}$

$\mathbf{P_G} = \rho_{\mathbf{water}}\mathbf{gh = (1\times10^3\ kg/m^3)(9.8\ m/s^2)(98.3\ m) = 9.6\times10^5\ N/m^2}$

Conservation of energy: $\mathbf{H = h = 98.3\ m}$

(Neglects frictional effects, etc.)