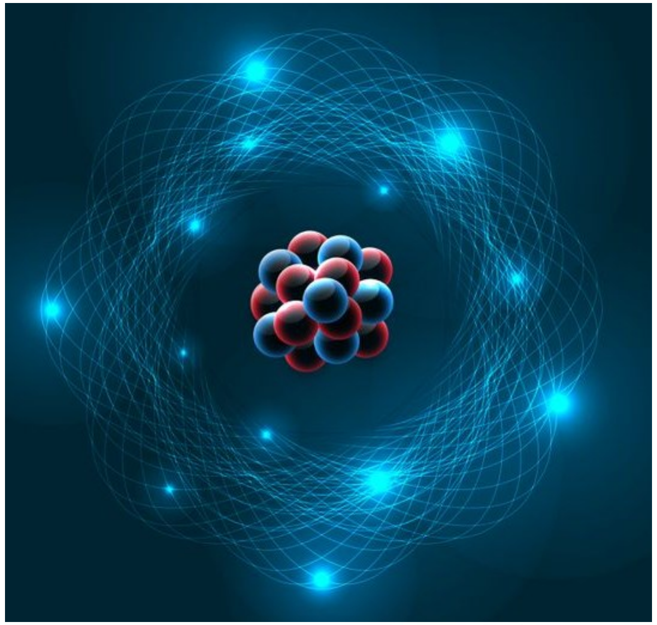
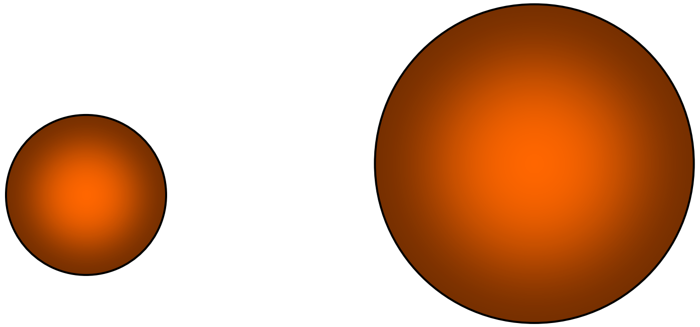
Physics 111: Mechanics
Chapter 12



Example:

The sphere on the right has twice the mass and twice the radius of the sphere on the left. Compared to the sphere on the left, the larger sphere on the right has

$$V = \frac{4}{3}\pi r^3$$



mass m
radius R

mass $2m$
radius $2R$

A. twice the density.

B. the same density.

C. 1/2 the density.

D. ✓ 1/4 the density.

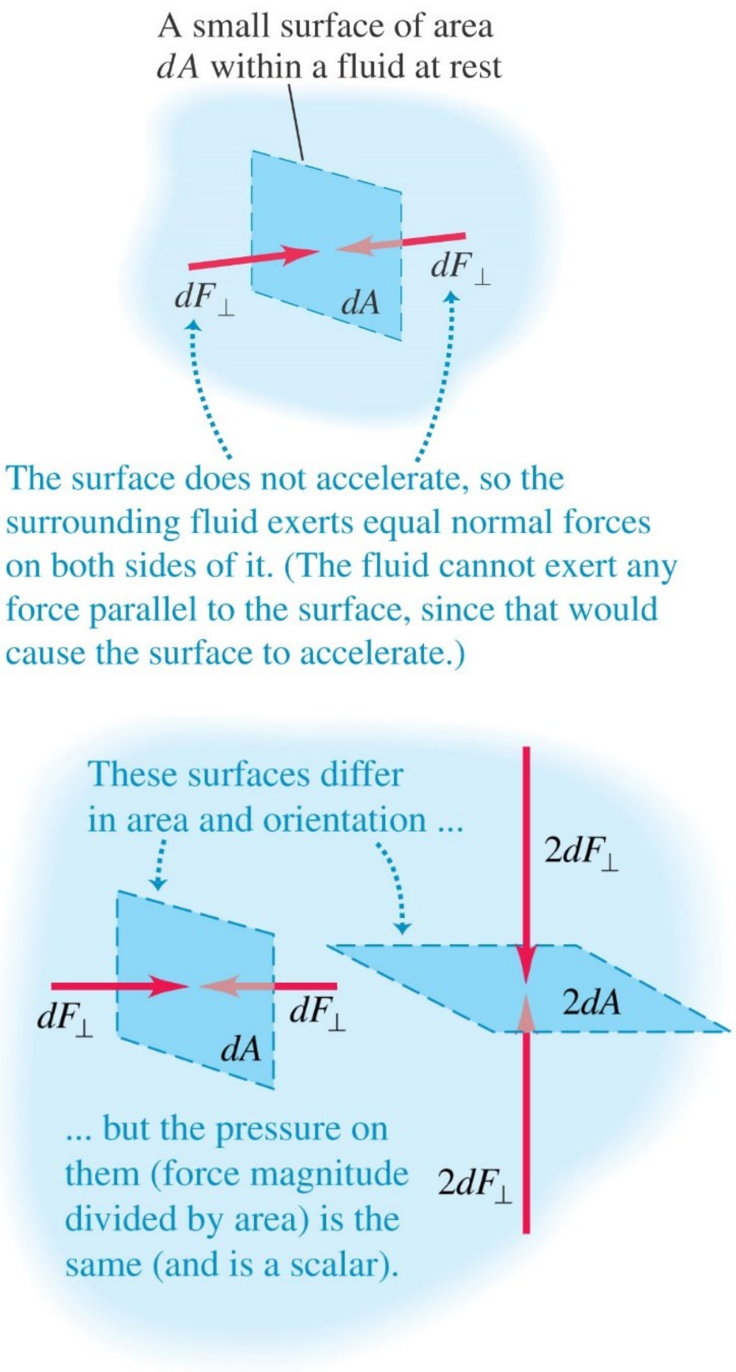
E. 1/8 the density.

$$\rho 1 = \frac{m}{(\frac{4}{3}\pi R^3)} = \frac{3m}{4\pi R^3}$$

$$\rho 2 = \frac{2m}{(\frac{4}{3}\pi 8R^3)} = \frac{3m}{16\pi R^3}$$

Pressure in a fluid

- The pressure in a fluid is the normal force per unit area $p = \frac{dF_{\perp}}{dA}$ (or $p = \frac{F_{\perp}}{A}$)
- SI units of pressure is the pascal
  1 pascal = 1 Pa = 1 N/m^2
  1 bar = 10^5 Pa, 1 millibar = 100 Pa
- Atmospheric pressure is the pressure of the earth's atmosphere
- Normal atmospheric pressure at sea level is 1 atmosphere (atm)
  1 atm = 1.013×10^5 Pa = 1.013 bar



Example: Pressure

What is the total downwards force due to air pressure on a towel of area 2 m^2 at the sea level? (1 atm = 101,325 Pa)

(A) 57,000 N

(B) 101,325 N

(C) 202,650 N ✓

(D) 73,150 N

$$p = \frac{F_\perp}{A}$$

$$F = pA = (101{,}325\ Pa)(2.0\ m^2) = 202{,}650\ N$$

Pressure at depth in a fluid

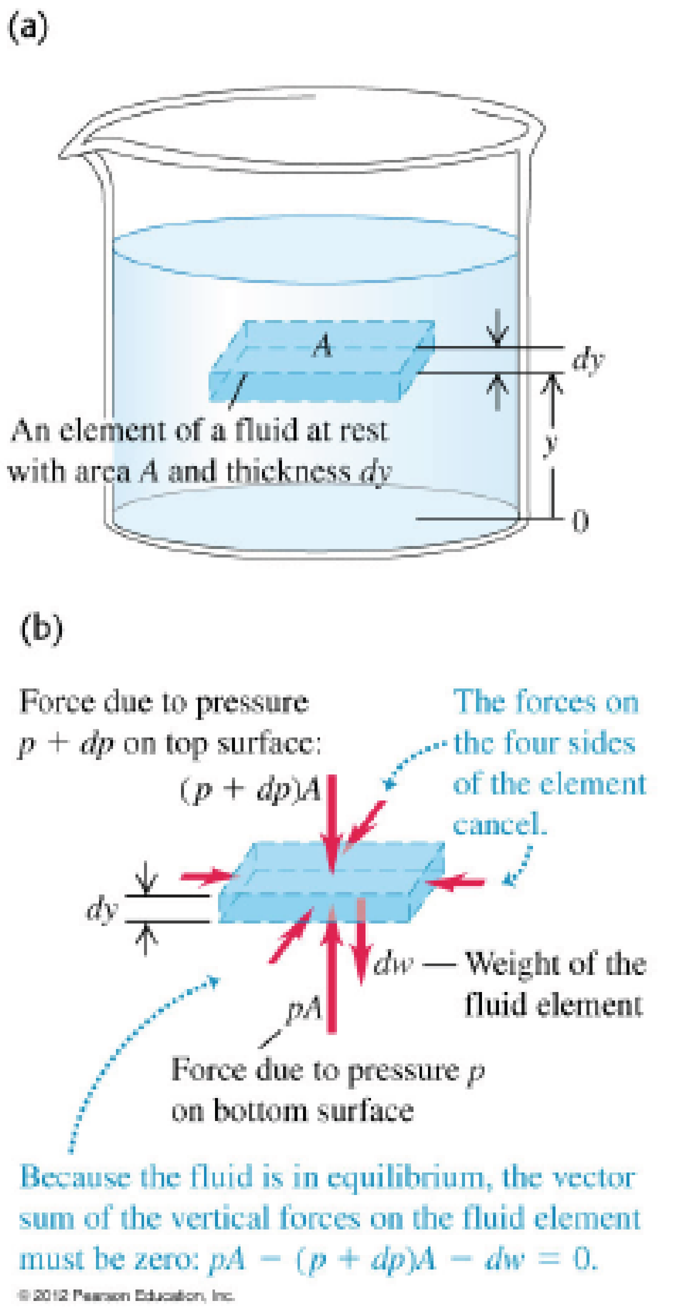
- Consider an element of a fluid at rest with area A and thickness by $dw = gdm = g\rho dV = g\rho Ady$

- The fluid element is in equilibrium $\sum F_y = 0$

$$pA - (p + dp)A - \rho gAdy = pA - pA - Adp - \rho gAdy = 0$$

$$Adp = -\rho gAdy, \text{ so } \boldsymbol{\frac{dp}{dy} = -\rho g}$$

- When y increases, p decreases. As we move upward in the fluid, pressure decreases.



Pressure at depth in a fluid

- If p_1 and p_2 are the pressure at elevations y_1 and y_2, respectively

$$p_2 - p_1 = -\rho g(y_2 - y_1)$$

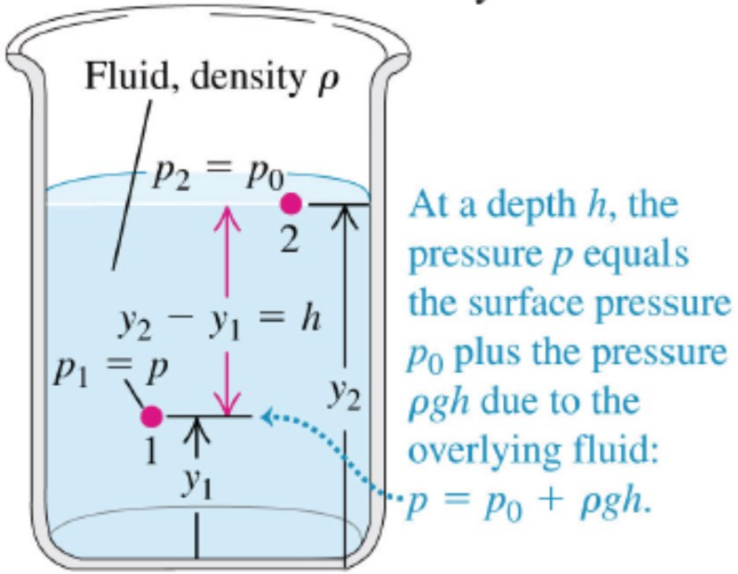
- Take point 2 at the surface of the fluid, where the pressure is p_0

$$p_0 - p_1 = -\rho g(y_2 - y_1) = -\rho g h$$

- The pressure p at a depth h is greater than p_0 at the surface by an amount $\rho g h$

$$p = p_0 + \rho g h$$

$$\frac{dp}{dy} = -\rho g$$



Pressure difference between levels 1 and 2: $p_2 - p_1 = -\rho g(y_2 - y_1)$
The pressure is greater at the lower le

Example: Pressure at depth in a fluid

Rank the pressures at different levels from big to small

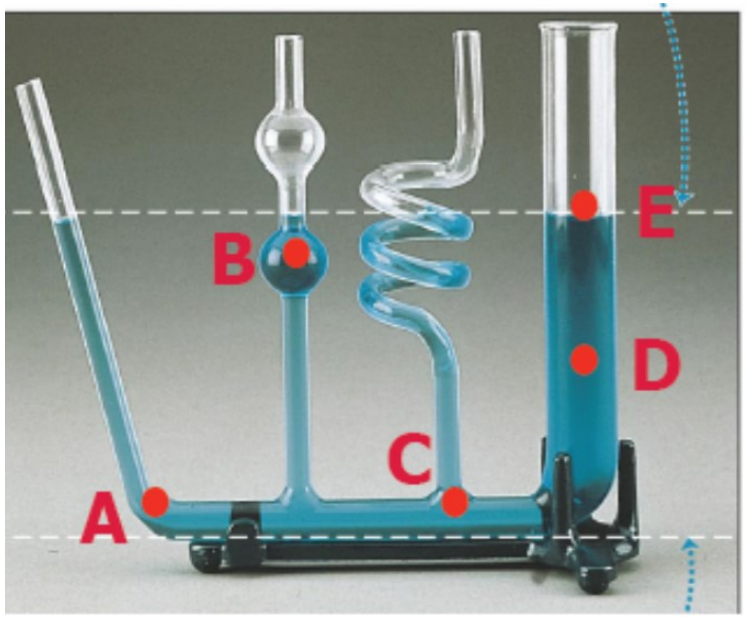
(A) D, C, A, B, E

(B) E, B, D, C, A

(C) A and C tie, D, B, E ✓

(D) D, C and A tie, B, E

(E) Need more info



The pressure at a depth h in a fluid of uniform density is given by $P = P_0 + \rho g h$.

The shape of the container does not matter.

Gauge Pressure

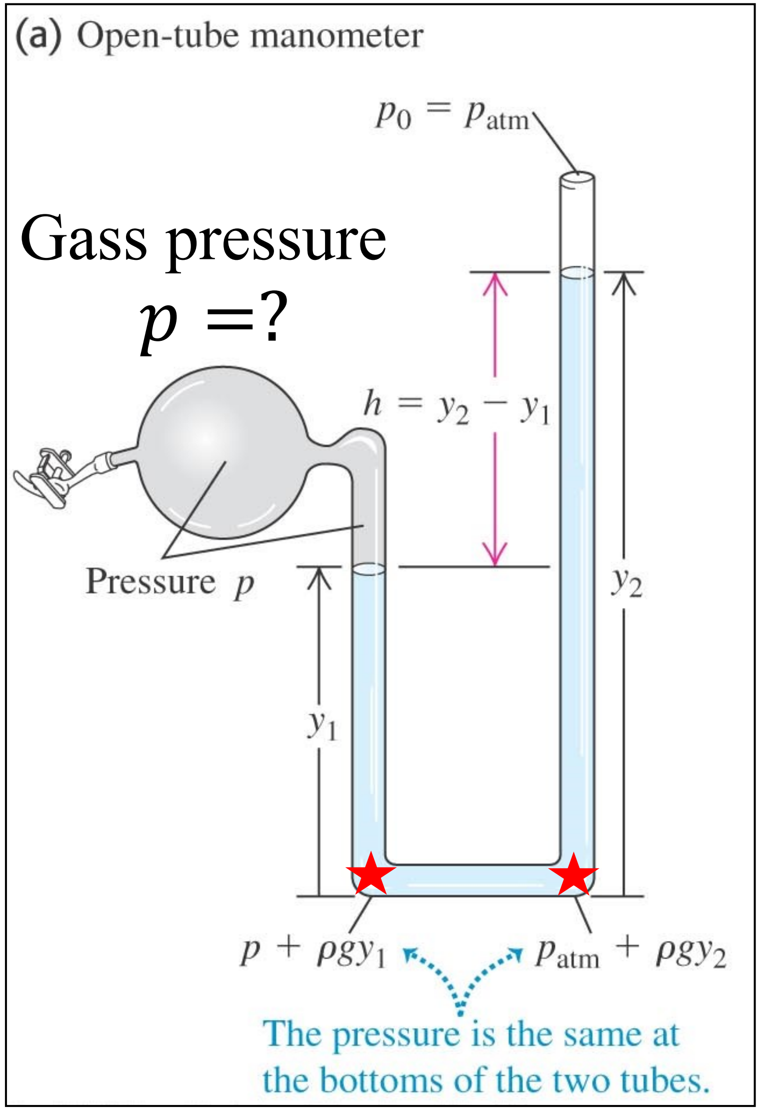
- Gauges for measuring pressure: $p = p_0 + \rho g h$

$$p + \rho g y_1 = p_{atm} + \rho g y_2$$

$$p - p_{atm} = \rho g y_2 - \rho g y_1 = \rho g h$$

The *gauge pressure* $(p - p_{atm})$ is the pressure above atmospheric pressure.

The *absolute pressure* (p) is the total pressure.



Known:

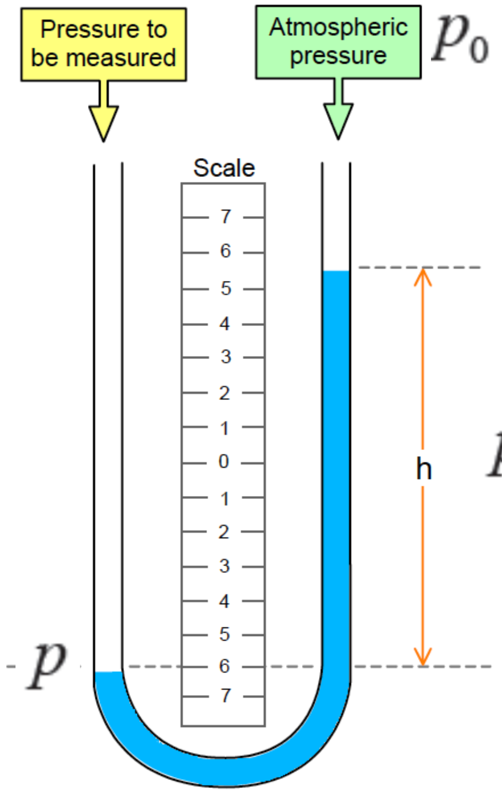
$p_0 = p_{atm}$

y_1

y_2

Two types of pressure gauge

(a) Open-tube manometer



$$p = p_0 + \rho g h$$

How to measure the atm pressure p_{atm}?

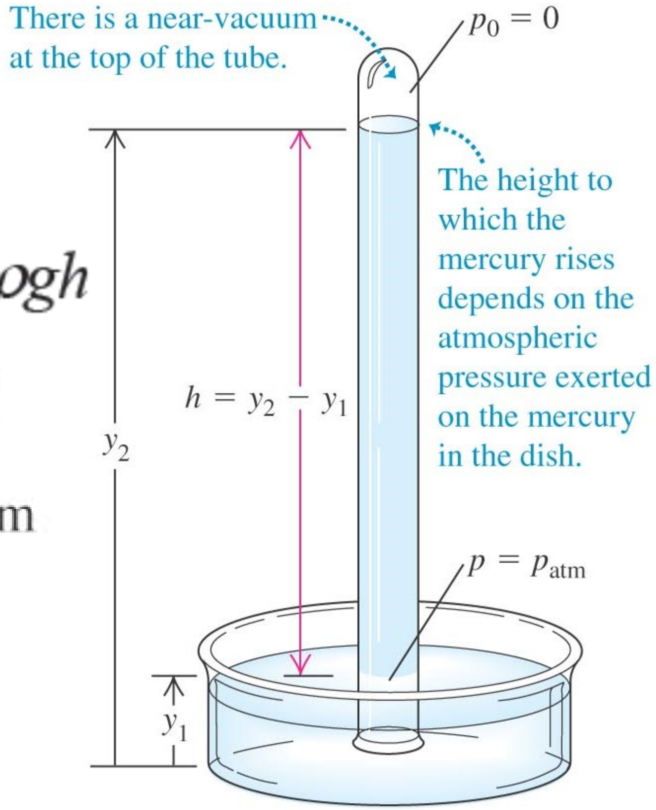
$$p = p_0 + \rho g h$$

$$p_0 = 0$$

$$p = p_{atm}$$

At 1 atm pressure, the value of h?

(b) Mercury barometer



Example: Gauge Pressure

The mercury barometer consists of a long glass tube, closed at the end, that has been filled with mercury and then inverted in a dish of mercury.

What is the mercury height "*h*" if the dish is placed at atmospheric pressure?

$$\rho_{Hg} = 13.6 \times 10^3\ \text{kg/m}^3$$

(A) 8.6 m

(B) 0.76 m ✔

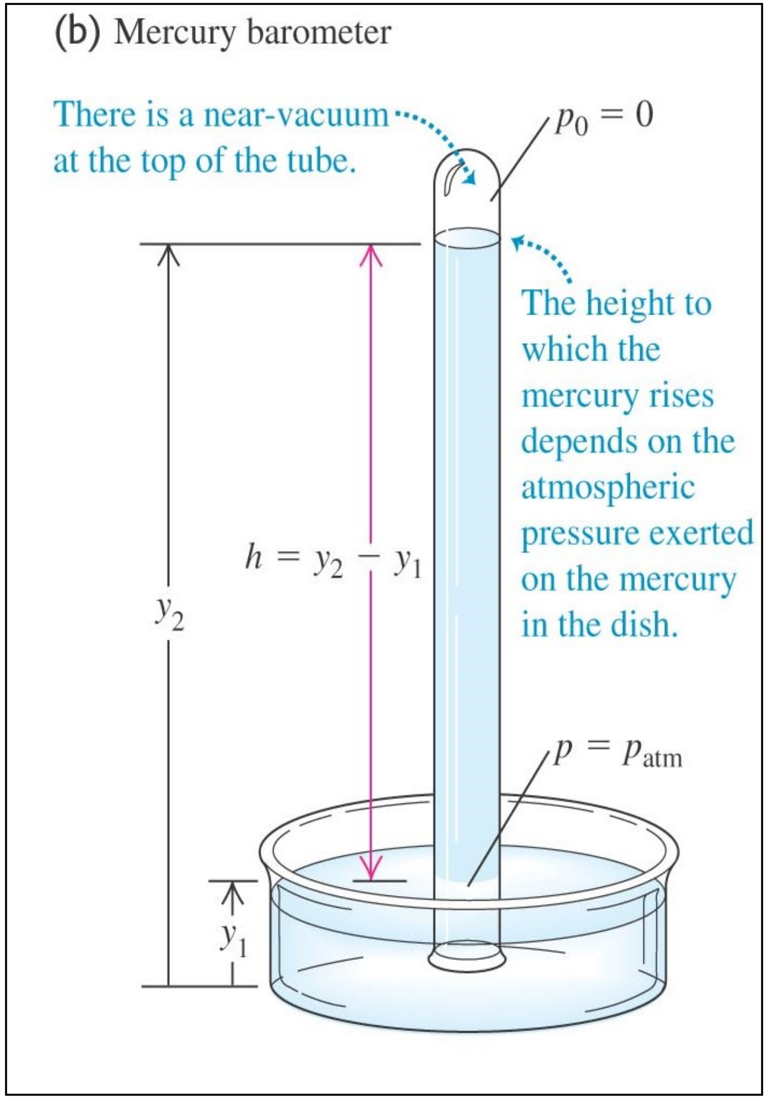
(C) 10.0 m

(D) 0.55 m

$$p = p_0 + \rho g h$$

$$p_{atm} = \rho_{Hg} g h$$

$$101{,}325\ Pa = (13.6 \times 10^3\ \text{kg/m}^3) g h$$

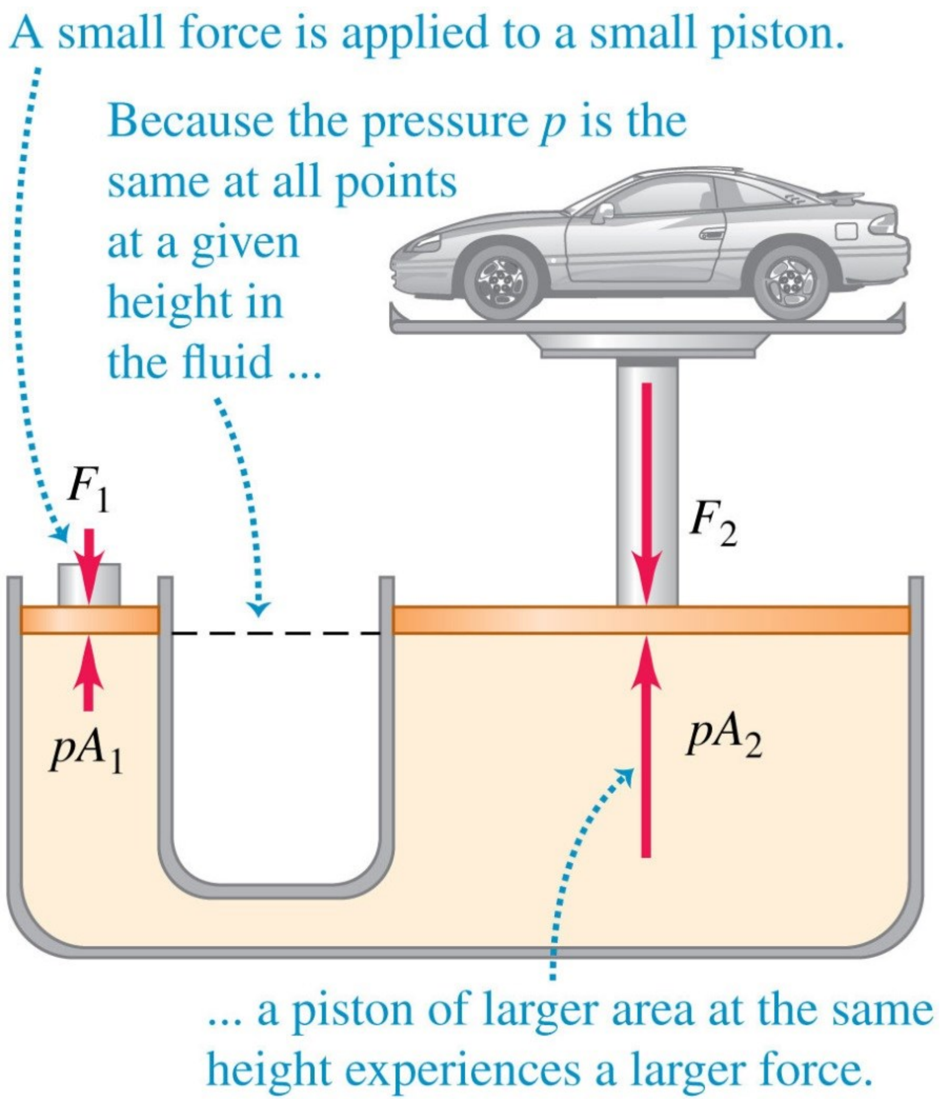


Pascal's Law

- Pressure applied to an enclosed fluid is transmitted undiminished to every portion of the fluid and walls of the containing vessel

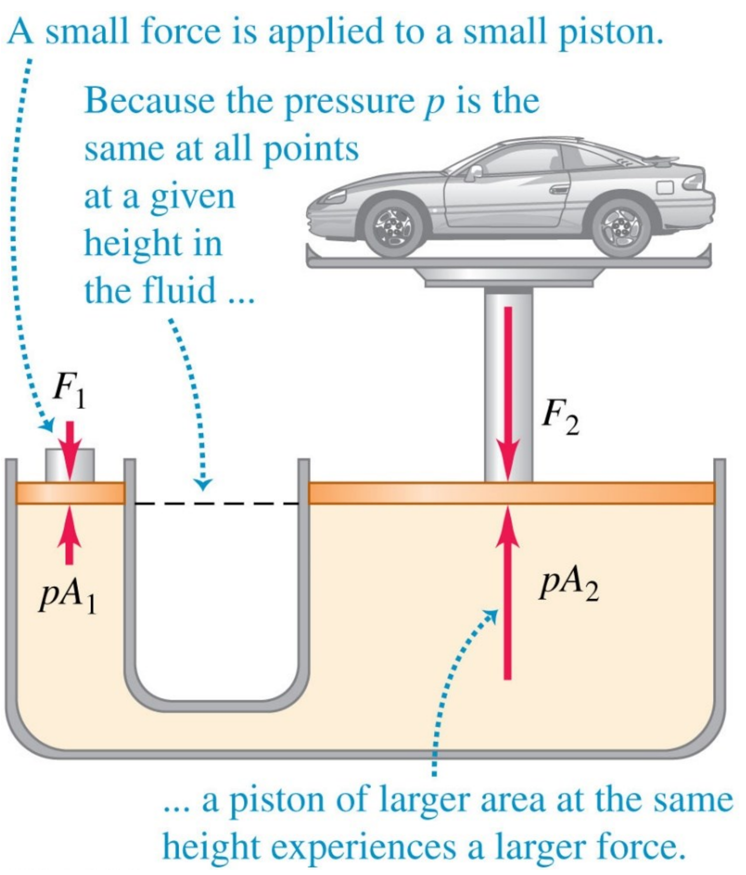
$$p = \frac{F_1}{A_1} = \frac{F_2}{A_2} \qquad\qquad F_2 = \frac{A_2}{A_1} F_1$$

- The hydraulic lift is a force-multiplying device with a multiplication factor equal to the ratio of the areas of the two pistons



Example: Pascal's Law

For hydraulic lift shown in right figure, what must be the ratio of the diameter of the vessel at the car to the diameter of the vessel where the force F_1 is applied so that a 1520-kg car can be lifted with a force F_1 of jut 125 N?



(A) 25.3

(B) 7.3

(C) 10.9 ✓

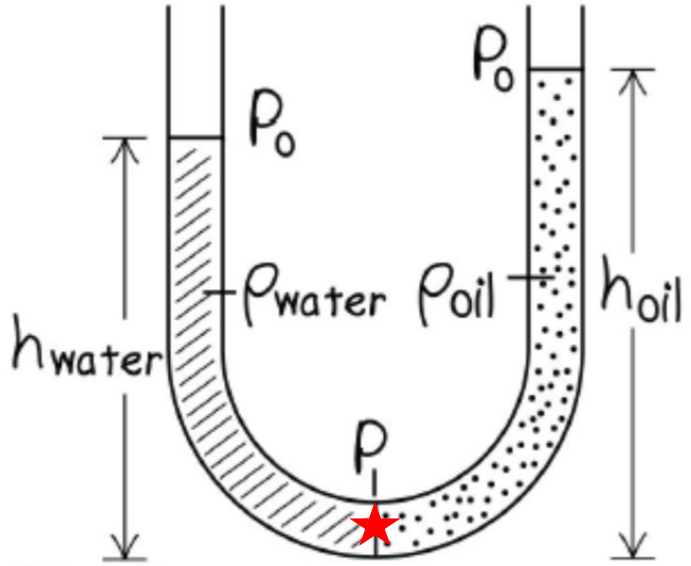
(D) 12.5

$$F_2 = \frac{A_2}{A_1} F_1 = = \frac{\pi D_2^2}{\pi D_1^2} F_1$$

$$(1{,}520\ kg) \times 9.8 = \frac{D_2^2}{D_1^2} (125\ N)$$

Example: two fluid

- A manometer tube is partially filled with water. Oil is poured into the left arm of the tube until the oil-water interface is at the midpoint of the tube as shown. Both arms of the tube are open to the air. Find the relationship between the heights h_{oil} and h_{water}.

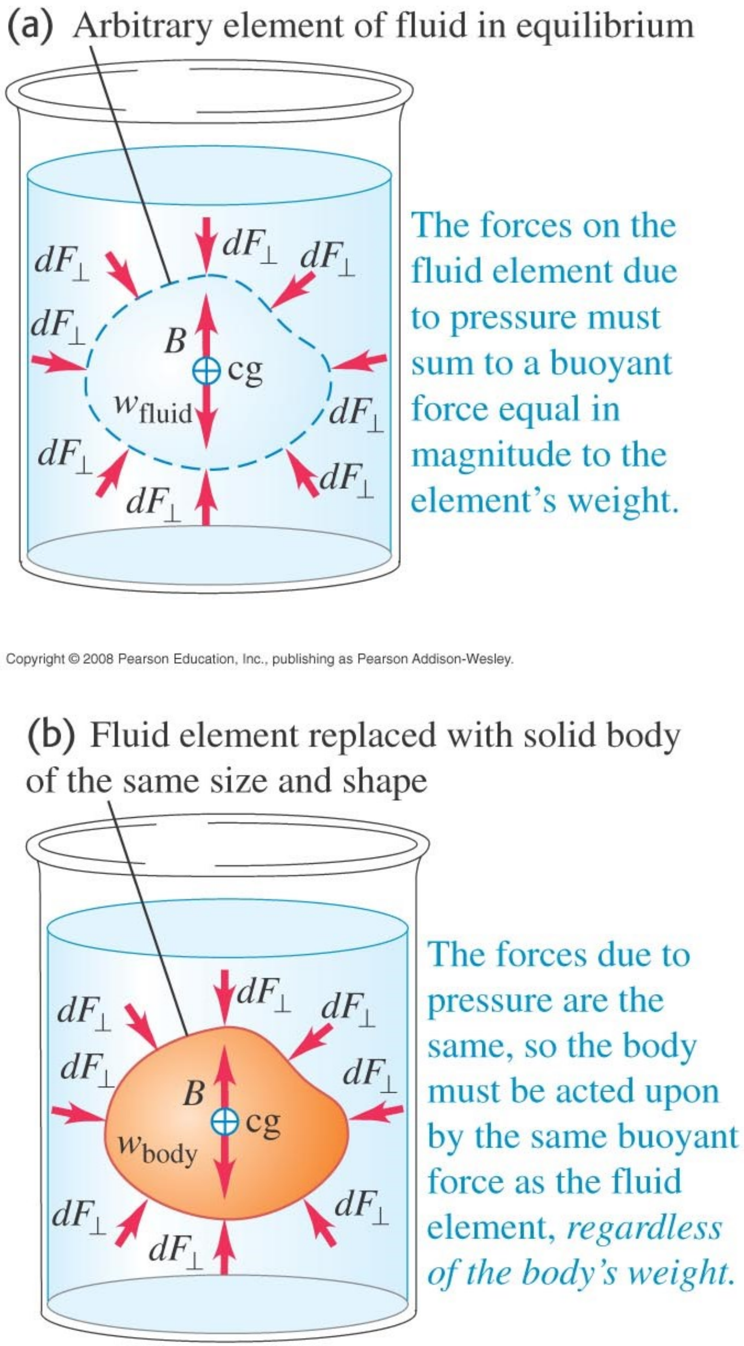


$$p = p_0 + \rho_{water} g h_{water} \qquad p = p_0 + \rho_{oil} g h_{oil}$$

$$h_{oil} = \frac{\rho_{water}}{\rho_{oil}} h_{water}$$

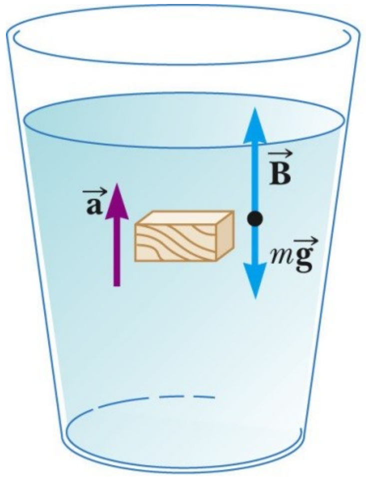
Buoyancy

- **Archimedes's Principle:** When a body is completely or partially immersed in a fluid, the fluid exerts an upward force (the "buoyant force") on the body equal to the weight of the fluid displaced by the body
- Buoyant force $\boldsymbol{B = \rho_{fluid} V g}$ (upward)
- Gravity of the body $w = \rho_{body} V g$ (downward)
- When the body is less dense than the fluid, it floats
- The physical cause of buoyant force is the pressure difference between the top and bottom of the object



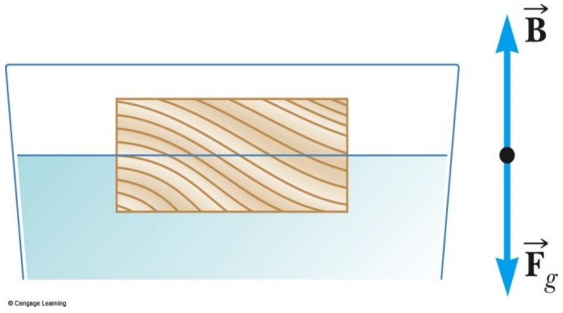
Totally Submerged Object

- The volume of displaced fluid is equal to volume of the object.
- The upward buoyant force is $B = \rho_{fluid} g V_{object}$
- If the object is less dense than the fluid: the object experiences a net upward force
- If the object is denser than the fluid: the net force is downward.



Floating Object

- The object is in static equilibrium ($B = mg$)
- The volume of displaced fluid is equal to volume of the object that is submerged.
- The upward buoyant force is $B = \rho_{fluid}\, g\, V^{object}{}_{sub}$.



Example: Buoyant force

A block of ice (density 920 kg/m^3) and a block of iron (density 7800 kg/m^3) are both completely submerged in a fluid. Both blocks have the same volume. Which block experiences the greater buoyant force?

(A). the block of ice

(B). the block of iron

✓(C). Both experience the same buoyant force.

(D). The answer depends on the density of the fluid.

$$B = \rho_{fluid} V g$$

Example: Buoyancy

An iceberg floating in seawater is extremely dangerous because most of the ice is below the surface. This hidden ice can damage a ship that is still a considerable distance from the visible ice. What fraction of the iceberg lies below the water level?
($\rho_{ice} = 917\ \mathrm{kg/m^3}$, $\rho_{water} = 1030\ \mathrm{kg/m^3}$)

(A). 0.89 ✔
(B). 1.25
(C). 0.78
(D). 1.50

$$\sum \vec{F}_y = B - mg = 0$$

$$\rho_{water} g V_{sub} = \rho_{ice} g V_{tol}$$

$$\frac{V_{sub}}{V_{tol}} = \frac{\rho_{ice}}{\rho_{water}} = \frac{917}{1030}$$