Chapter 11: Fluid Statics

Mass Density:

The mass density ρ is the mass m of a substance divided by its volume V

$$\rho = m / V$$

Unit of Mass Density: kg/m^3

Specific Gravity: (for any substance)

$$\text{Specific gravity} = \frac{\text{Density of substance}}{\text{Density of water at } 4^oC}$$

1000 kg/m^3

Unit of specific gravity: unit-less, number

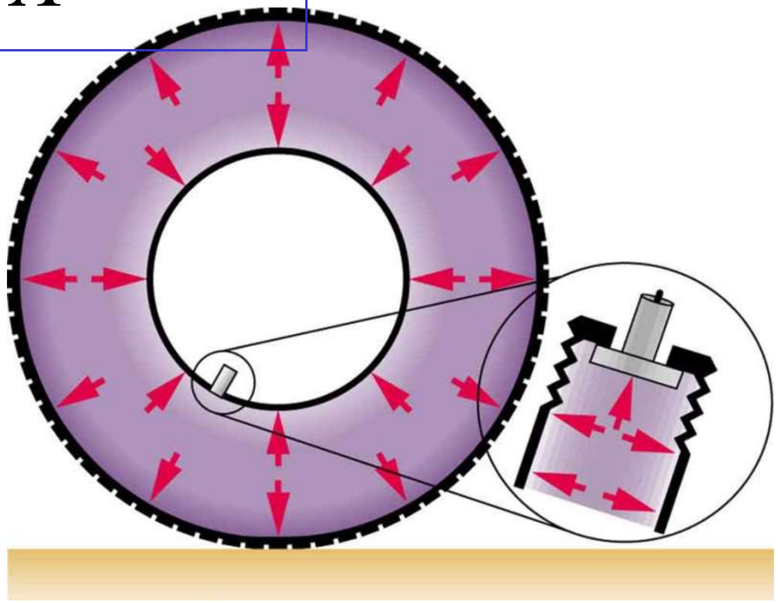
Pressure

The pressure P has a general definition of (normal) force per unit area

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

SI unit: pascal (N/m^2)

In a static liquid (or gas), the pressure is isotropic (non-directional). For a gas (low mass density) the pressure can be regarded as homogeneous (constant throughout space). For liquids (high mass density), the pressure depends on the depth of the liquid.



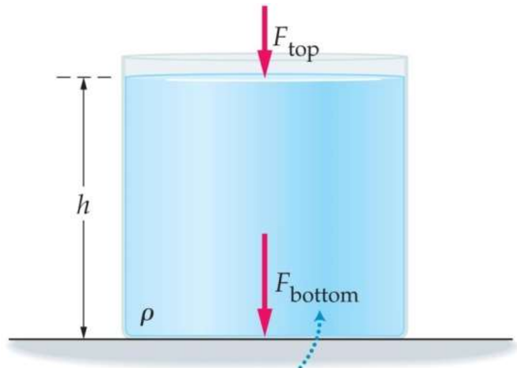
Pressure and Depth in a Static Fluid

$$PA = P_0A + Mg$$

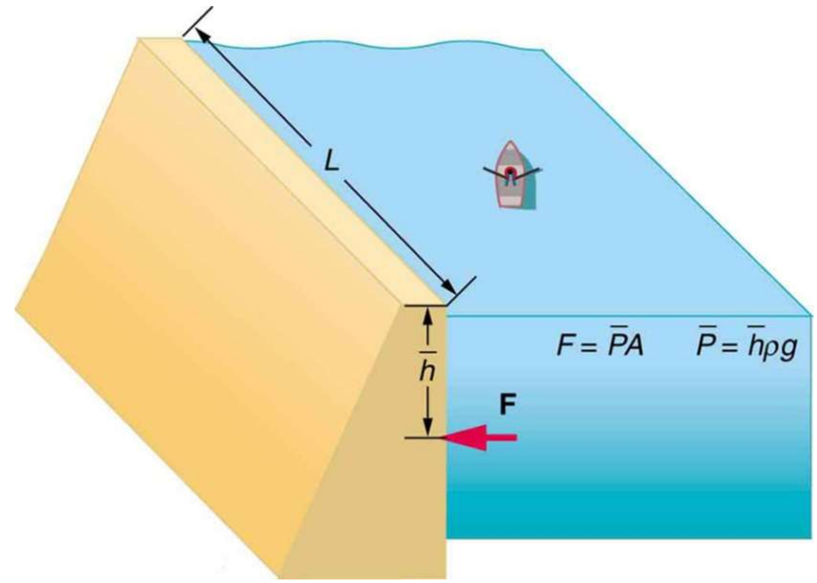
$$PA = P_0A + \rho(hA)\,g$$

$$P = P_0 + \rho g h$$

h: depth below the face of fluid

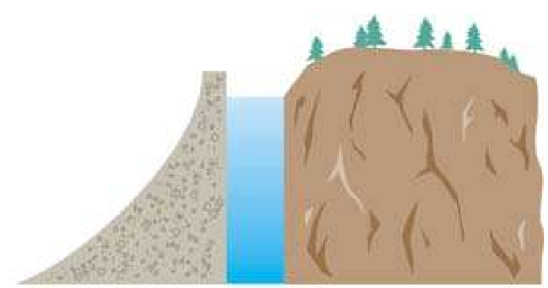


The force on the bottom is equal to the force on the top plus the weight of fluid in the flask.



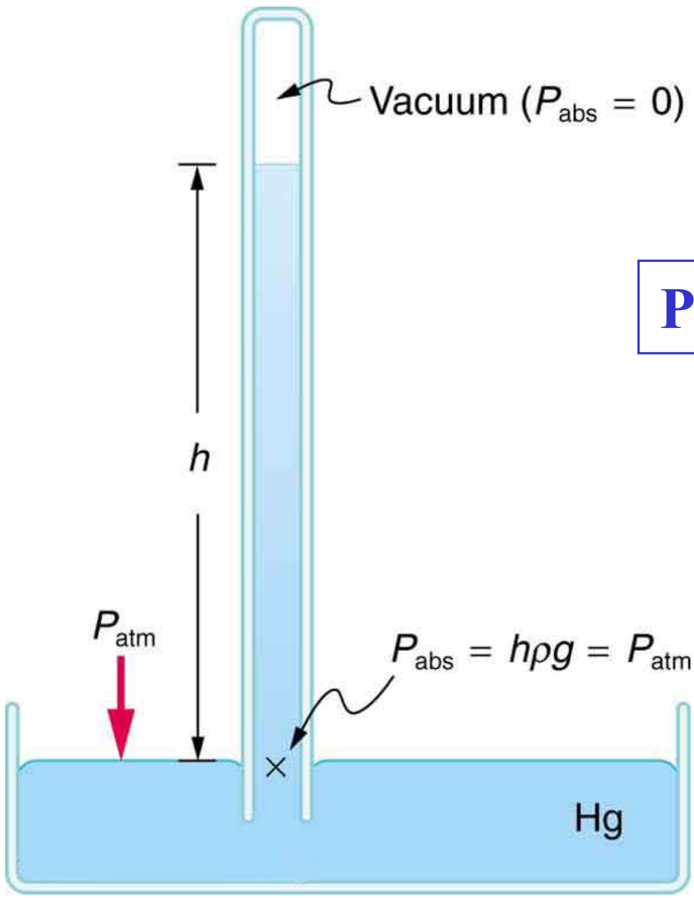
Atmospheric pressure at sea level is

$$P_{at} = 1.01 \times 10^5\,Pa \;\approx\; 14.7\,lb/in^2$$

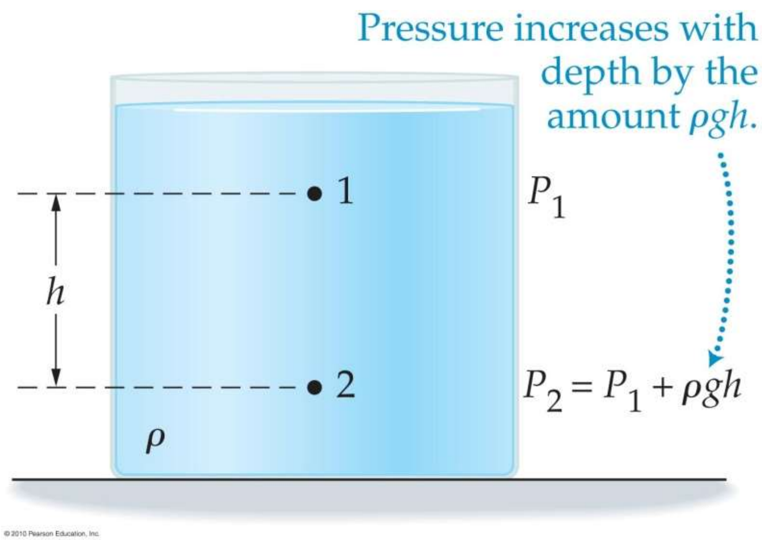


Hoover Dam. Can we use a less massive structure to hold the water if the size (volume) of the reservoir (with same depth) is much narrower?

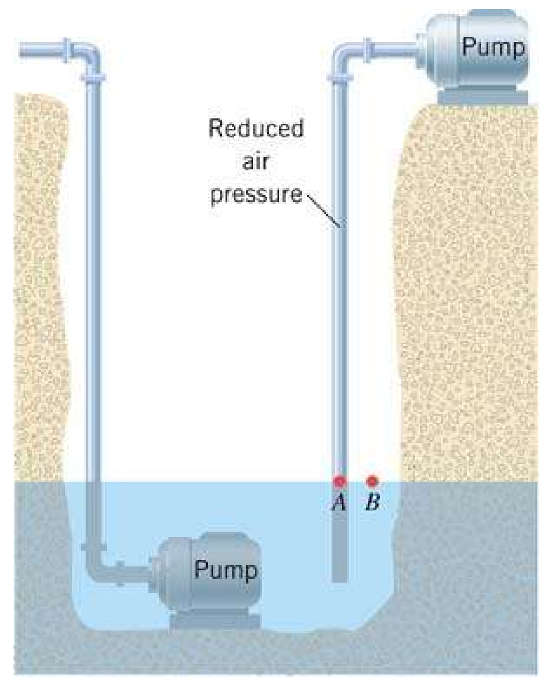
More About Static Fluids



$$P_2 = P_1 + \rho g h$$



absolute pressure



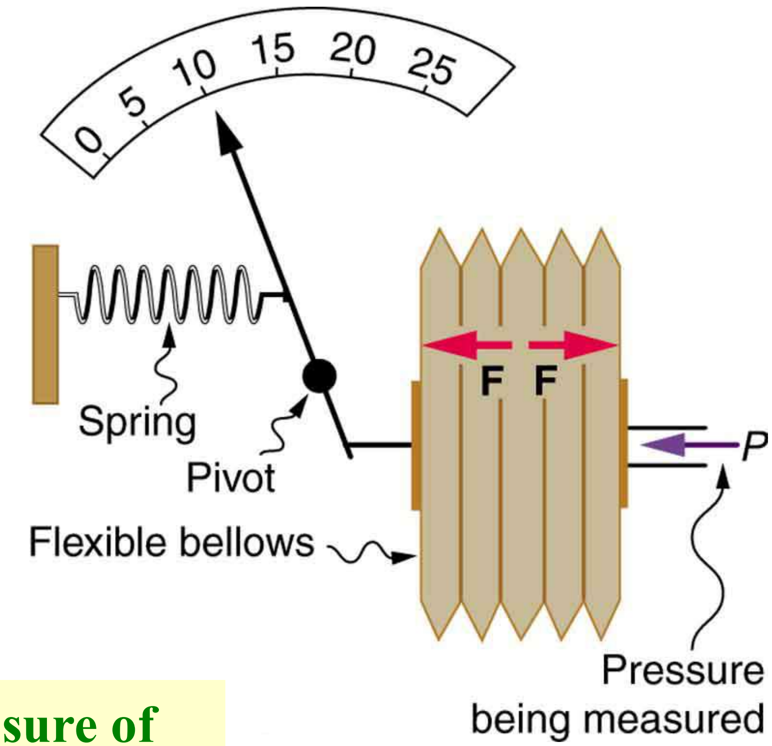
In pumping water up a deep well, does it make a difference whether one puts the pump at the bottom to push to water up or puts the pump at the top to suck the water up?

More About Pressure

Gauge Pressure:

Relative to Atmospheric Pressure

$$P_g = P - P_{at}$$



22. The left side of the heart creates a pressure of 120 mm Hg by exerting a force directly on the blood over an effective area of 15.0 cm^2. What force does it exert to accomplish this?

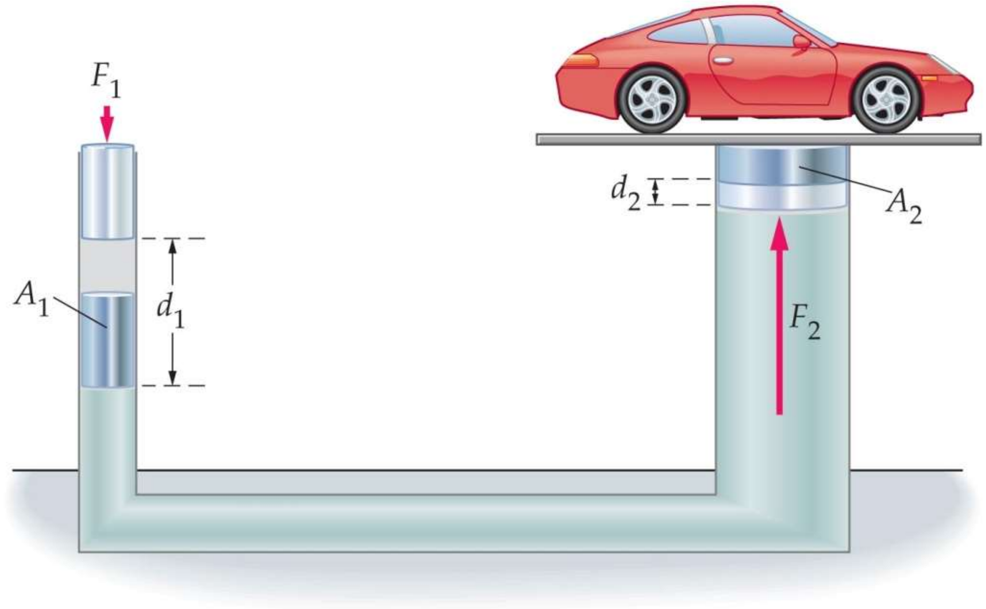
Pascal's Principle

Pascal's Principle

Any change in the pressure applied to a completely enclosed fluid is transmitted undiminished to every point of the fluid and the enclosing walls.

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

$$F_2 = F_1\left(\frac{A_2}{A_1}\right)$$



Can we get something out of nothing?

Of course not!

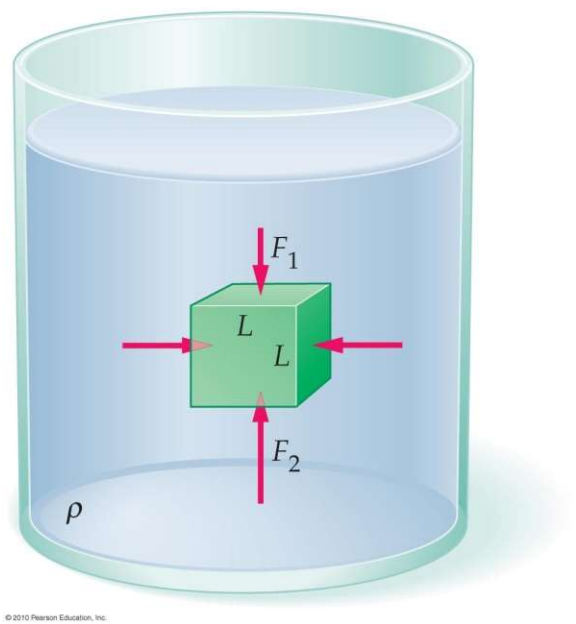
$$A_2 d_2 = A_1 d_1 \qquad F_2 d_2 = F_1 d_1$$

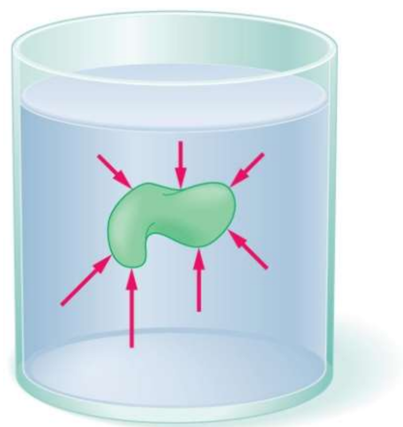
Buoyant Forces and Archimedes' Principle

Magnitude of buoyant force = Weight of displaced fluid

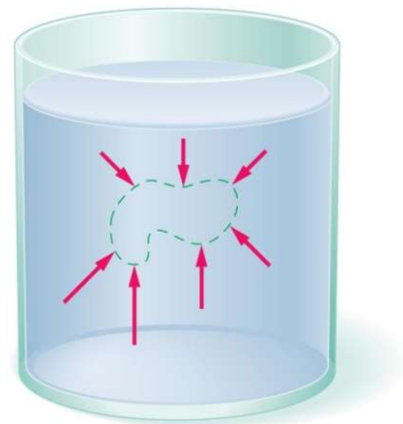
Archimedes' Principle

Buoyant force





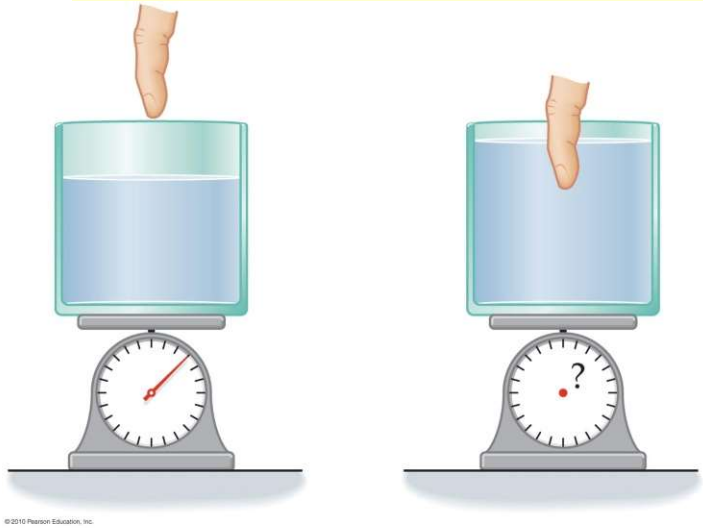
(a) The forces acting on an object surrounded by fluid



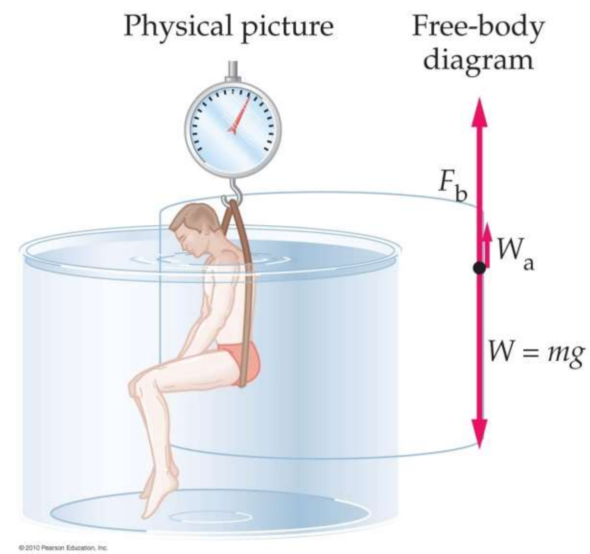
(b) The same forces act when the object is replaced by fluid

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

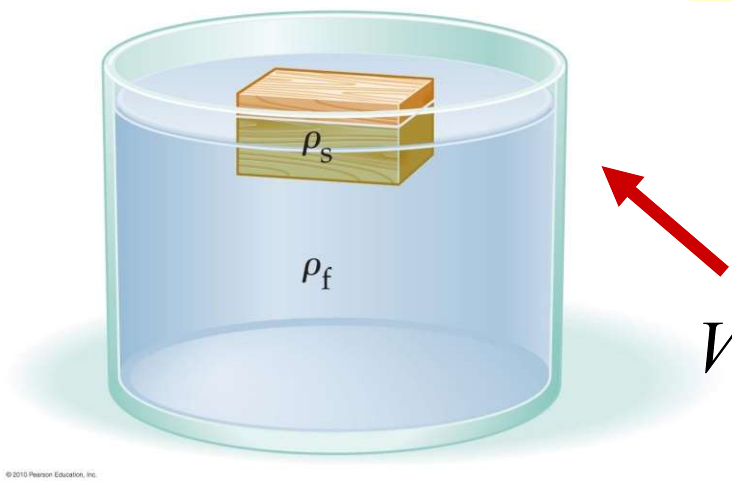
Archimedes' Principle at Work



Measure Body Density?



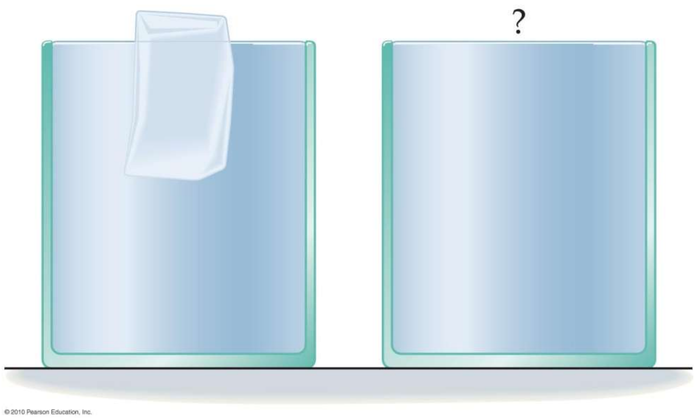
$$F_b = \rho_{fluid}\, g\, V$$

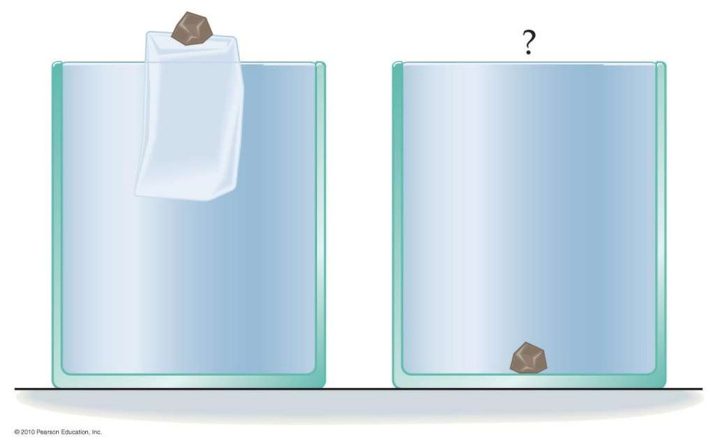


$$V_{sub} = V_{solid} \frac{\rho_{solid}}{\rho_{fluid}}$$

(c) Same block of metal as in (b), but shaped like a bowl to displace more water

Conceptual Check Points





A 300-g chunk of ice floats in a water bucket that is filled to the very top. When the ice melts, how much water spills out or needs to be added to regain full level? Ignore the possible dependence of the density of ice, which is 0.900 g/cm^3, and water, which is 1.000 g/cm^3, on temperature.

A 20.0-g rock, with a volume of 2.00 cm^3, is placed on top of the same piece of ice before water is again filled to the top. When the ice melts and the rock drops to the bottom of the bucket, how much water spills out or needs to be added to maintain full level?

Conceptual Check Points

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

A block of wood floats on water. A layer of oil is now poured on top of the water to a depth that more than covers the block. Is the volume of wood submerged in water greater than, less than, or the same as before?

Problems On Static Fluid

43. In an immersion measurement of a woman's density, she is found to have a mass of 62.0 kg in air and an apparent mass of 0.0850 kg when completely submerged with lungs empty. (a) What mass of water does she displace? (b) What is her volume? (c) Calculate her density. (d) If her lung capacity is 1.75 L, is she able to float without treading water with her lungs filled with air?

Problems On Static Fluid

25. A crass host pours the remnants of several bottles of wine into a jug after a party. He then inserts a cork with a 2.00-cm diameter into the bottle, placing it in direct contact with the wine. He is amazed when he pounds the cork into place and the bottom of the jug (with a 14.0-cm diameter) breaks away. Calculate the extra force exerted against the bottom if he pounds the cork with a 120-N force.

Chapter 11 Summary

- **Density:** $\rho = M/V$
- **Pressure:** $P = F/A$
- **Atmospheric pressure:** $P_{at} = 1.01 \times 10^5 \text{ N/m}^2 \approx 14.7 \text{ lb/in}^2$
- **Gauge pressure:** $P_g = P - P_{at}$
- **Pressure with depth:** $P_2 = P_1 + \rho g h$
- **Archimedes' principle.** $F_b = \rho_{fluid} g V$
- **Volume of submerged part of object:** $V_{sub} = V_s(\rho_s/\rho_f)$