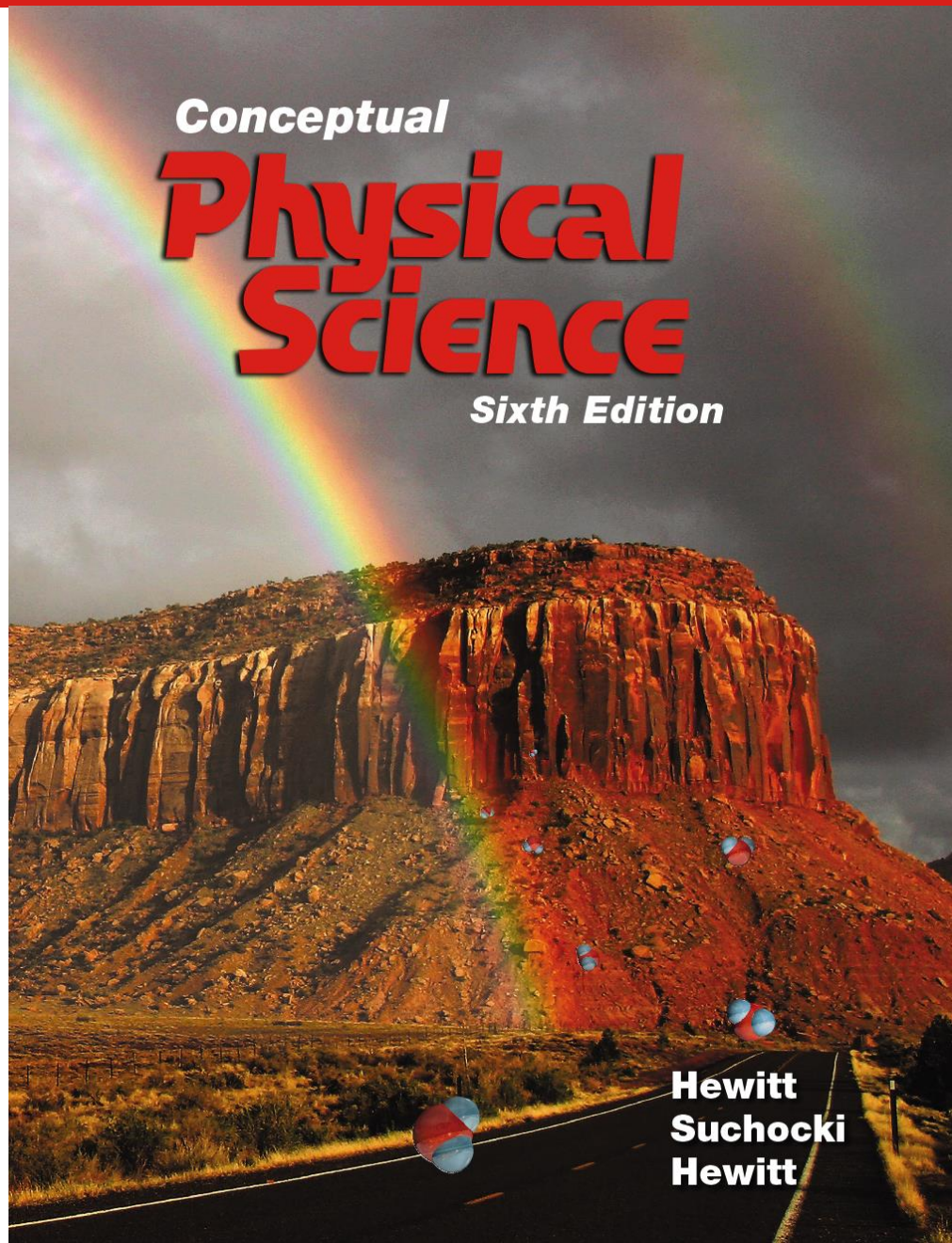
# Chapter 6: Fluid Mechanics

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# This lecture will help you understand:

- Density
- Pressure
- Pressure in a Liquid
- Pressure in a Gas
- Atmospheric Pressure
- Barometers

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# Density

- Density
  - Important property of materials (solids, liquids, gases)
  - Measure of compactness of how much mass an object occupies
  - "lightness" or "heaviness" of materials of the same size

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# Density

- Equation:

$$density = \frac{mass}{volume}$$

- Units of:
  - mass in grams or kilograms
  - volume in $cm^3$ or $m^3$
  - density in $kg/m^3$ or $g/cm^3$

- Example:
  - The density of mercury is 13.6 $g/cm^3$, so mercury has 13.6 times as much mass as an equal volume of water (density 1 $g/cm^3$).

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# Pressure

- Force per unit area that one object exerts on another
- Equation:

$$pressure = \frac{force}{area}$$

- Depends on area over which force is distributed
- Units in $lb/ft^2$, $N/m^2$, or Pa (Pascals)

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# Pressure in a Liquid

- Force per unit area that a liquid exerts on something
- Depth dependent and not volume dependent

- Example:
  - Swim twice as deep and the pressure due to the weight of water above you is twice as much. (For total pressure, add to this the atmospheric pressure acting on the water surface.)

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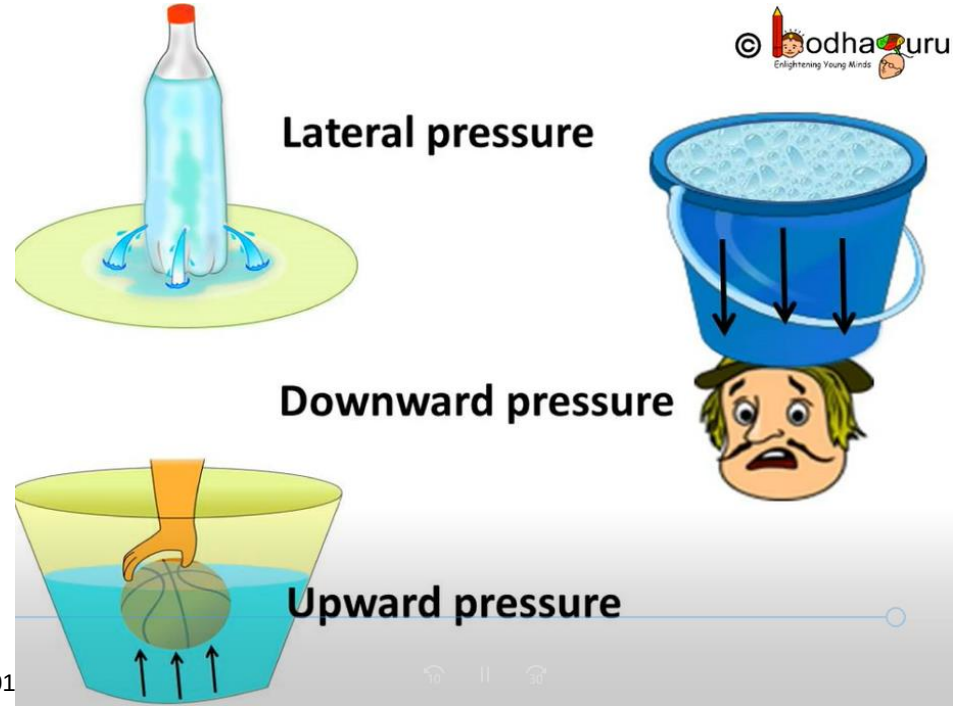
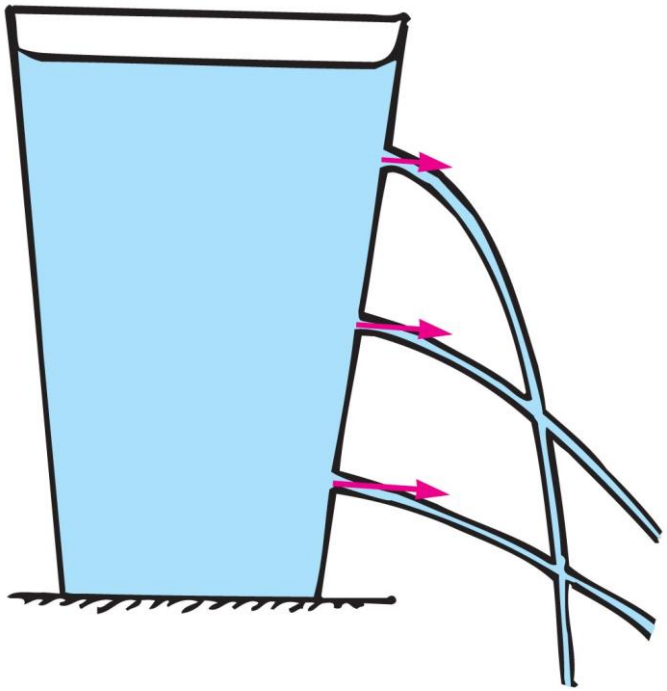
# Pressure in a Liquid

- Effects of water pressure
- acts perpendicular to surfaces  of a container
  - liquid spurts at right angles from a hole in the surface curving downward
    - The greater the depth, the greater the exiting speed



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# Pressure in a Liquid

- Acts equally in all directions
- Examples:
  - your ears feel the same amount of pressure under water no matter how you tip your head
  - bottom of a boat is pushed upward by water pressure
  - pressure acts upward when pushing a beach ball under water

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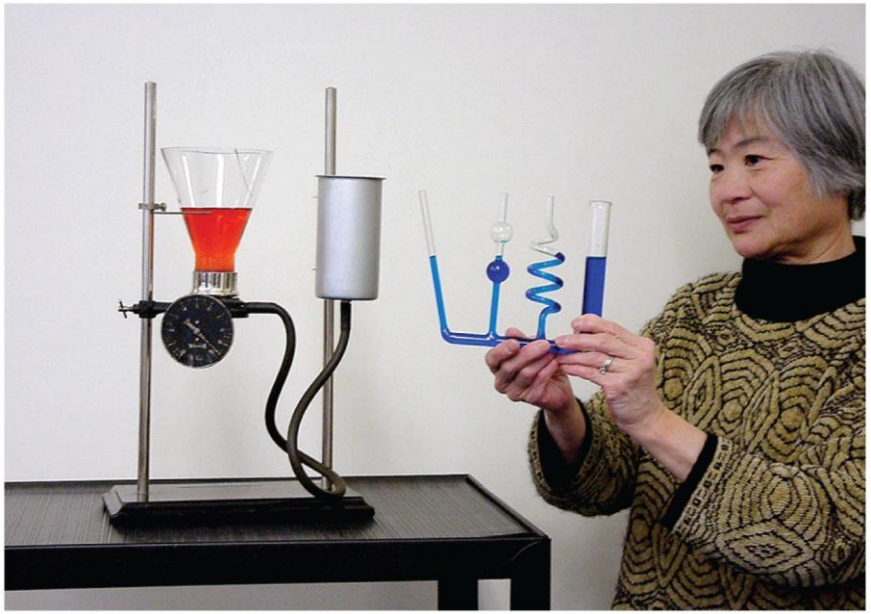
# Pressure in a Liquid

- Independent of shape of container
  - whatever the shape of a container, pressure at any particular depth is the same
- Equation:

$$\textit{liquid pressure} = \textit{weight density} \times \textit{depth}$$



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# Pressure
# CHECK YOUR NEIGHBOR

Does a 3-meter deep lake or a 6-meter deep small pond exert more pressure on a dam?

A. The three-meter deep lake.
B. The six-meter deep small pond.
C. Same amount of pressure is exerted (atmospheric) so same force.
D. Not enough information given in the question.

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# Pressure
# CHECK YOUR ANSWER

Does a 3-meter deep lake or a 6-meter deep small pond exert more pressure on a dam?

A. The three-meter deep lake.

**B. The six-meter deep small pond.**

C. Same amount of pressure is exerted (atmospheric) so same force.

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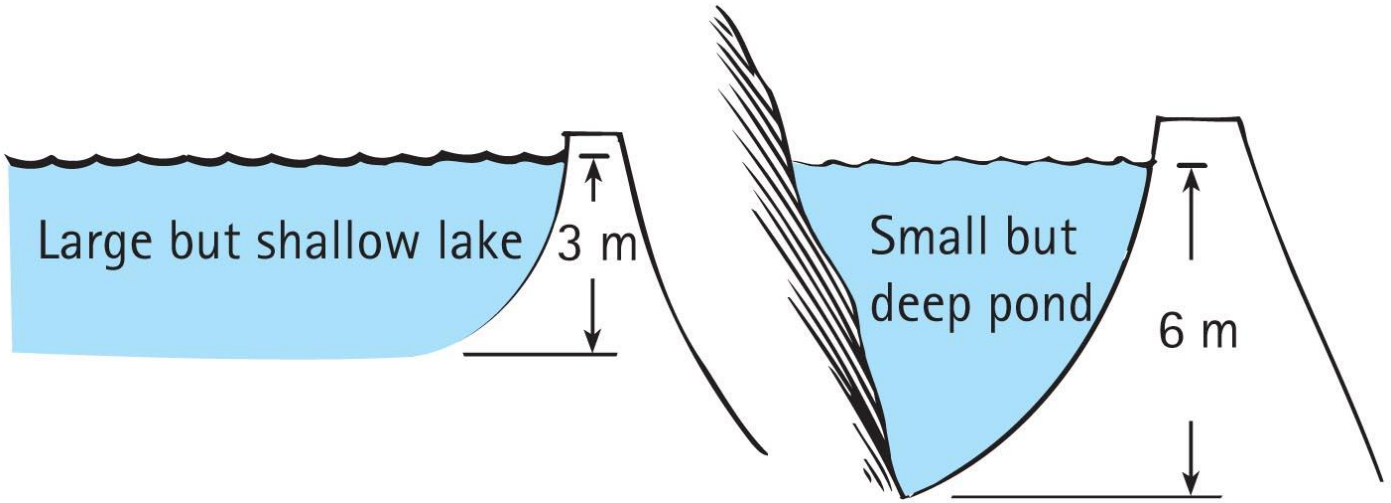


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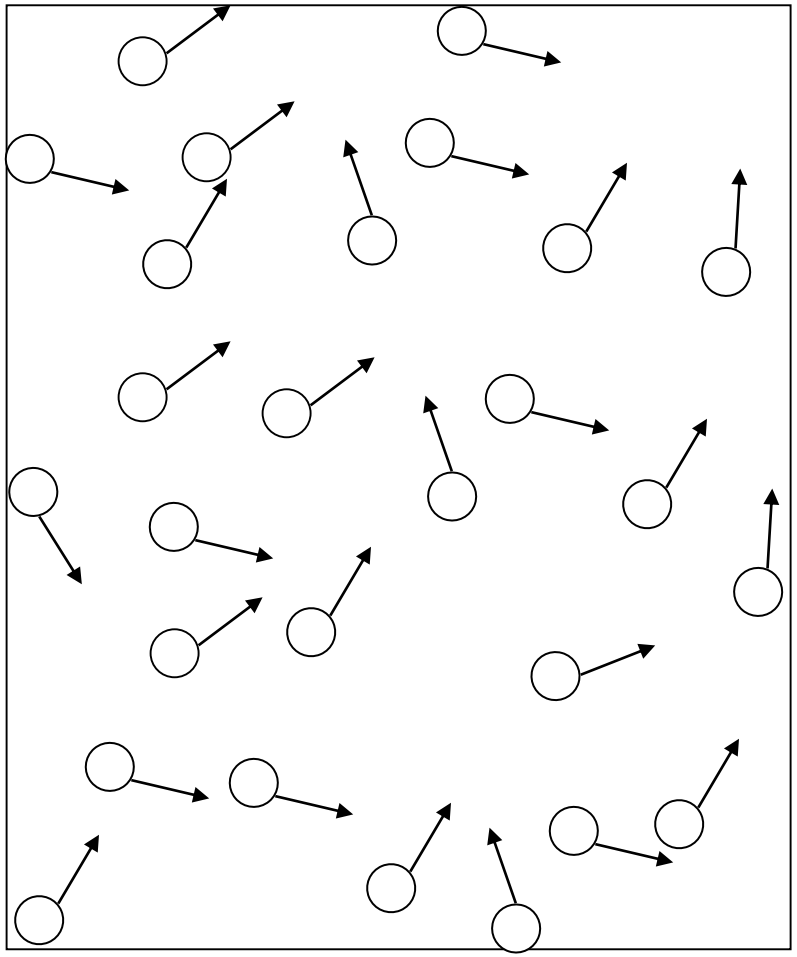
# Pressure in a Gas

- Gas pressure is a measure of the amount of force per area that a gas exerts against containing walls.
- Here, the force is exerted by the motion of molecules bouncing around.
- Temperature is a measure of the KE per molecules of the gas.



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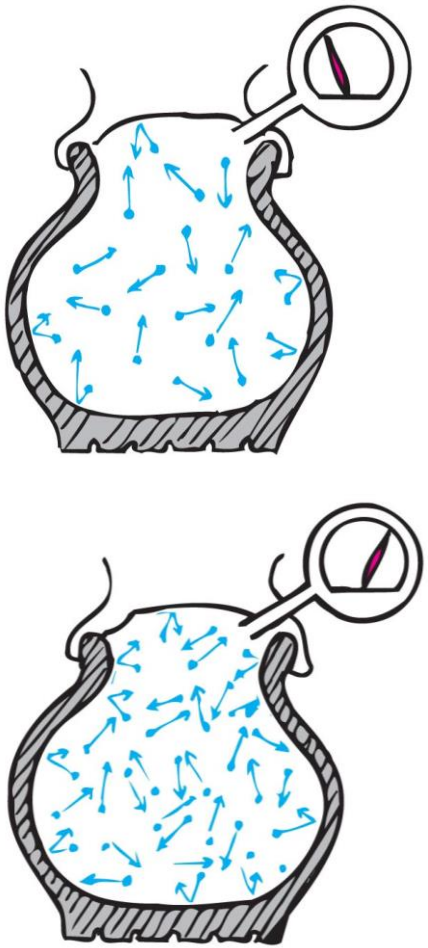
# Pressure in a Gas

- Relationship between pressure and density
  - Gas pressure is proportional to density

    Example:
    - Air pressure and air density inside an inflated tire are greater than the atmospheric pressure and density outside
    - Twice as many molecules in the same volume $\Rightarrow$ air density doubled
    - For molecules moving at the same speed (same temperature), collisions are doubled $\Rightarrow$ pressure doubled



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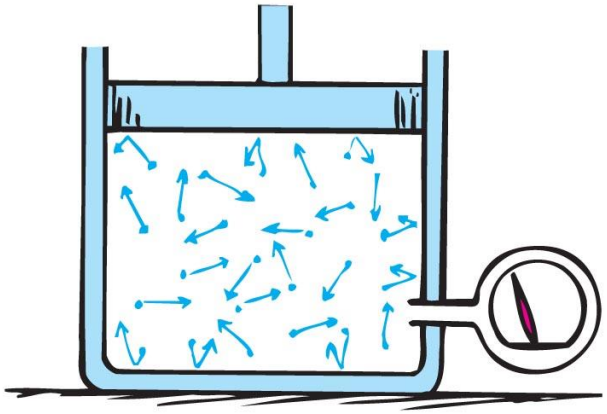
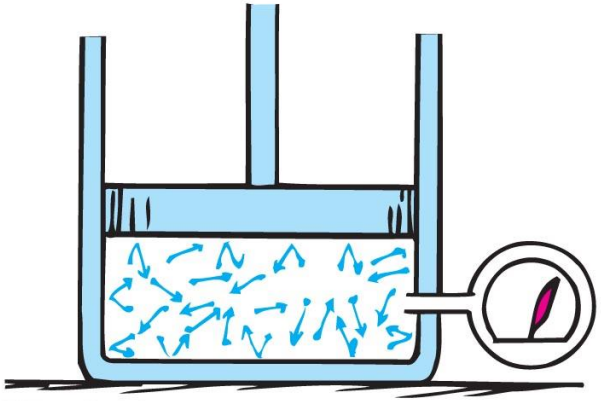
# Pressure in a Gas

- Double density of air by
  - Doubling the amount of air
  - Decreasing the volume to half





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# Pressure in a Gas

- Boyle's law
  - Relationship between pressure and volume for ideal gases
  - An ideal gas is one in which intermolecular forces play no role
  - States that pressure × volume is a constant for a given mass of confined gas regardless of changes in pressure or volume (with temperature remaining unchanged)
  - pressure × volume = constant means that $P_1V_1 = P_2V_2$

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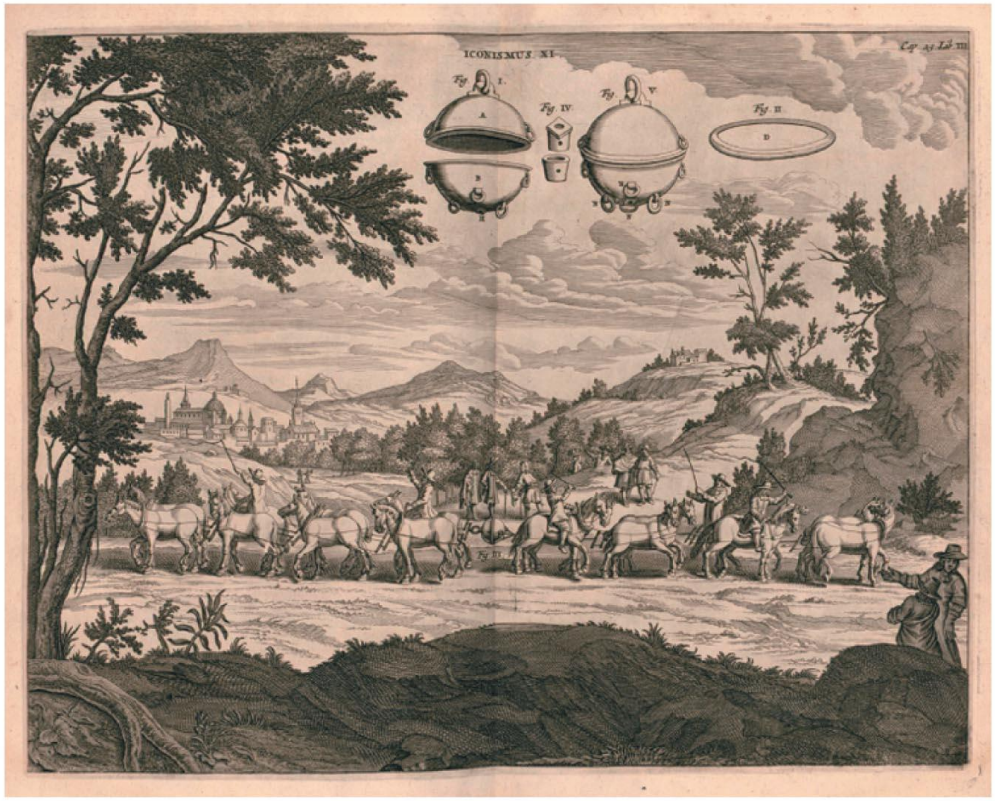
# Earth's Atmosphere



- Atmosphere
  - ocean of air
  - exerts pressure
- **The Magdeburg-hemispheres demonstration in 1654 by Otto von Guericke showed the large magnitude of atmosphere's pressure.**

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# Atmospheric Pressure

- Atmospheric pressure
  - Caused by weight of air
  - Varies from one locality to another
  - Not uniform
  - Measurements are used to predict weather conditions

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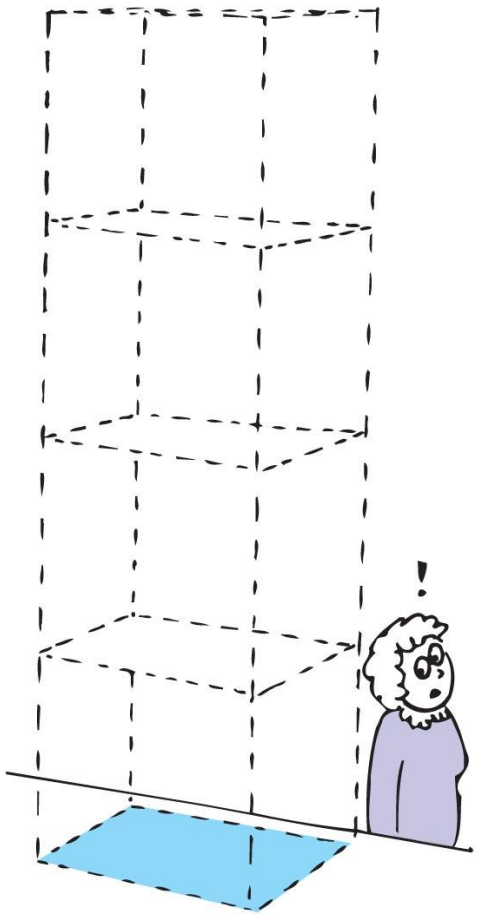
# Atmospheric Pressure

- Pressure exerted against bodies immersed in the atmosphere result from the weight of air pressing from above
- At sea level is 101 kilopascals (101 kPa)
- Weight of air pressing down on 1 $m^2$ at sea level ~ 100,000 N, so atmospheric pressure is ~ $10^5$ $N/m^2$



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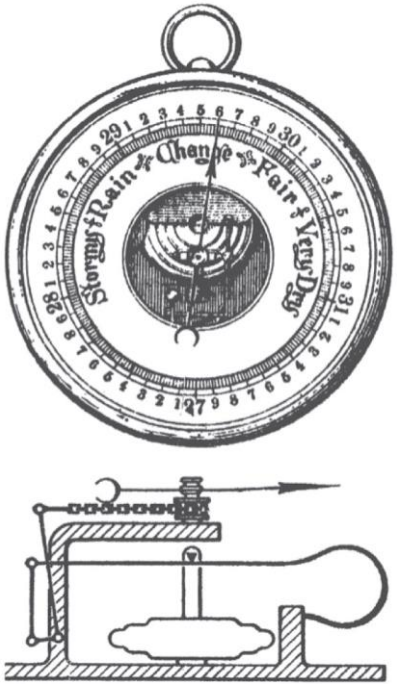
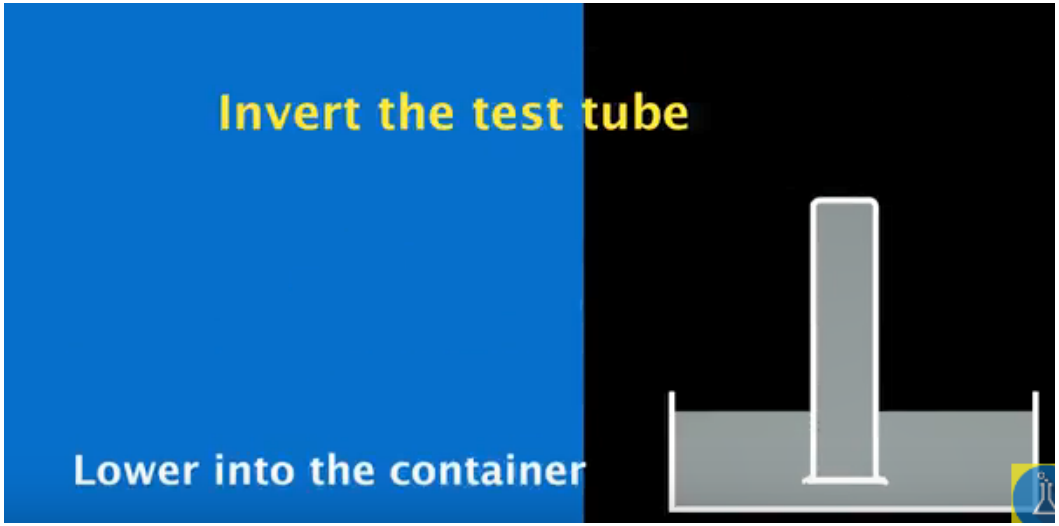
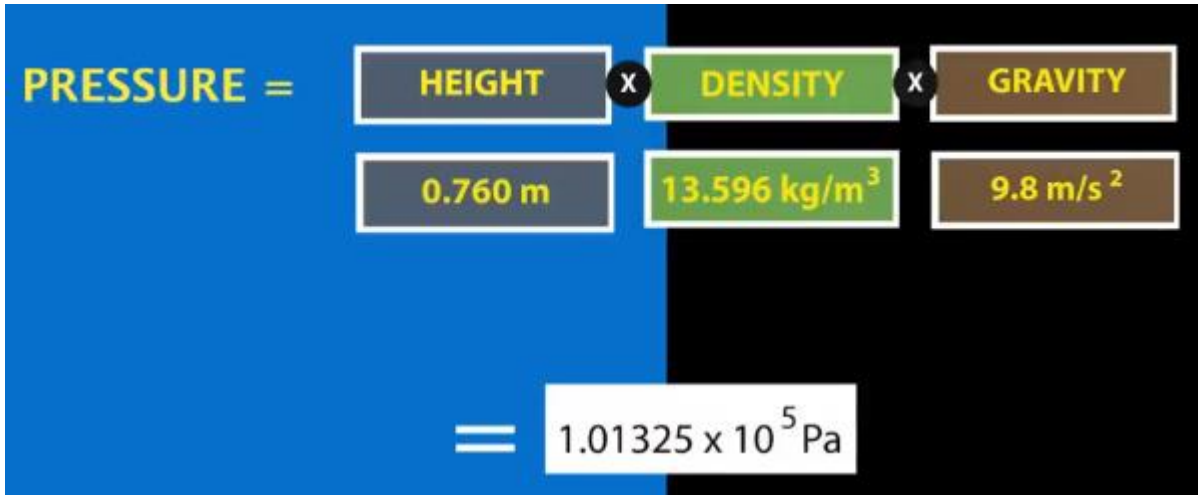
# Barometers




- Barometer
  - Device to measure atmospheric pressure
  - Also determines elevation

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# Atmospheric Pressure

- Pressure at the bottom of a column of air reaching to the top of the atmosphere is the same as the pressure at the bottom of a column of water 10.3 m high.
- Consequence: the highest the atmosphere can push water up into a vacuum pump is 10.3 m

- Mechanical pumps that don't depend on atmospheric pressure don't have the 10.3-m limit

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