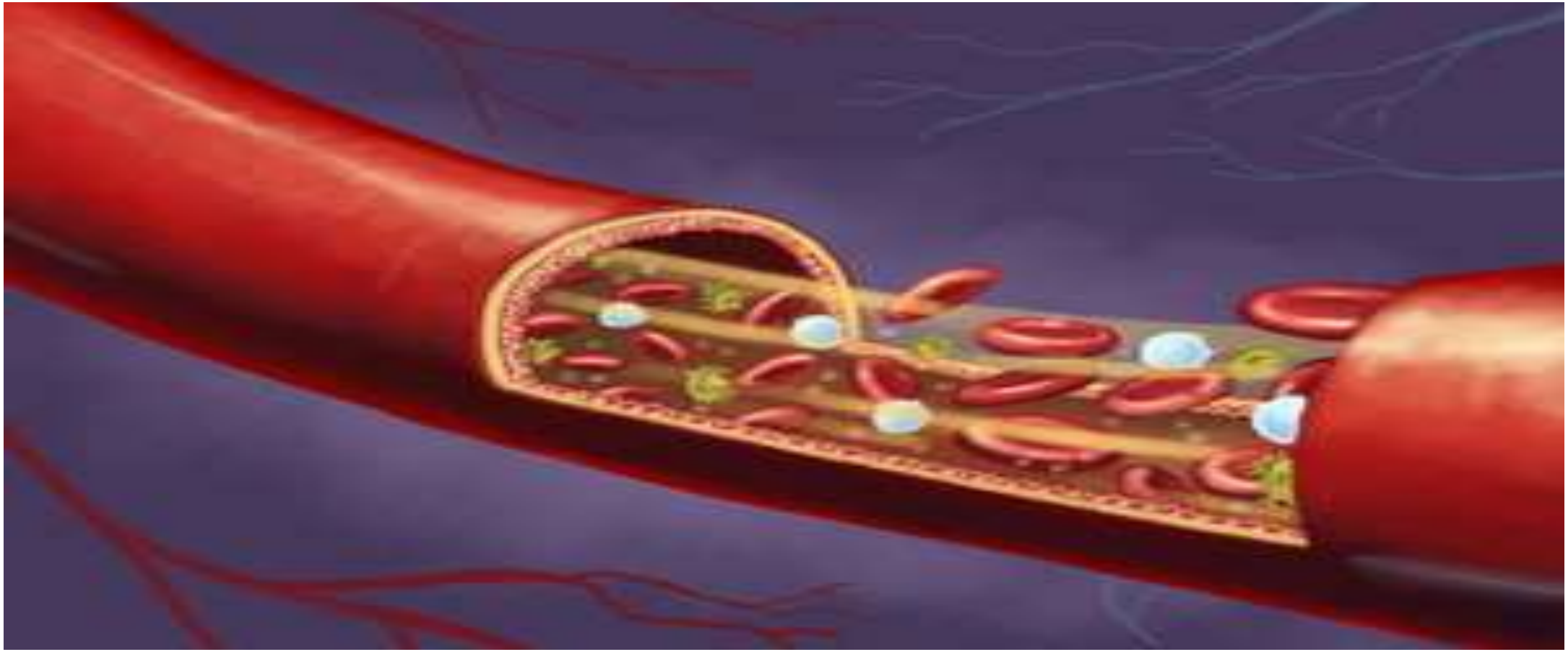
Basic Physics



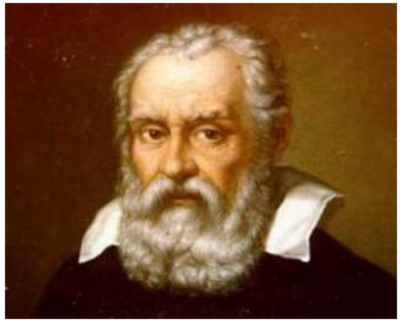
รวบรวมและเรียบเรียงโดย
อ. วรรณพงษ์ เตรียมโพธิ์
ภาควิชาฟิสิกส์ คณะวิทยาศาสตร์ ม. มหิดล

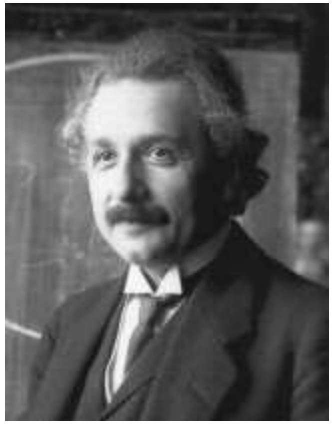
Lecture 4: Fluid

Many of the following figures or pictures are copied from open sources at the Web or Else. I do not claim any intellectual property for the following materials.

Topics

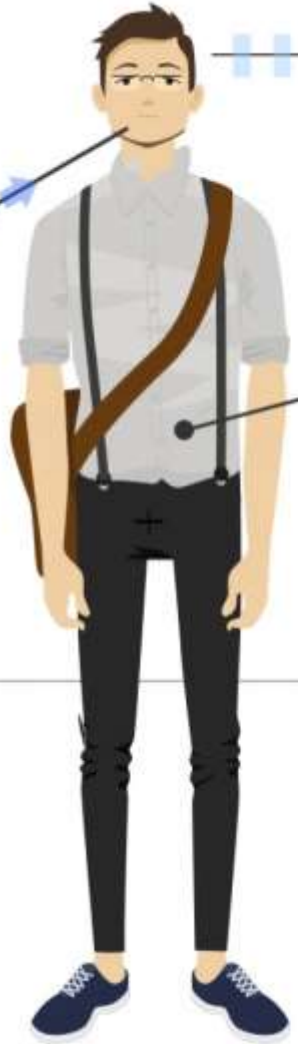
0. Nature of Science and physics
1. Mechanics
2. Temperature and Heat
3. Fluid
4. Waves
5. Sound and hearing
6. Optics and visualization
7. basic electromagnetism
8. basic quantum mechanics
9. atomic physics
10. basic nuclear physics and radioactivity






WATER BALANCE

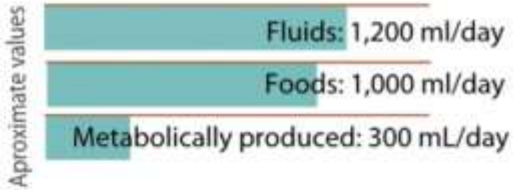
The balance between intake and excretion of fluids.



Am I in Water Balance?

When the body is in water balance
the input and output of water are equal

WATER INTAKE FROM:



WATER OUTPUT FROM:

2,500 ml/day ◄——► 2,500 ml/day

THIRST

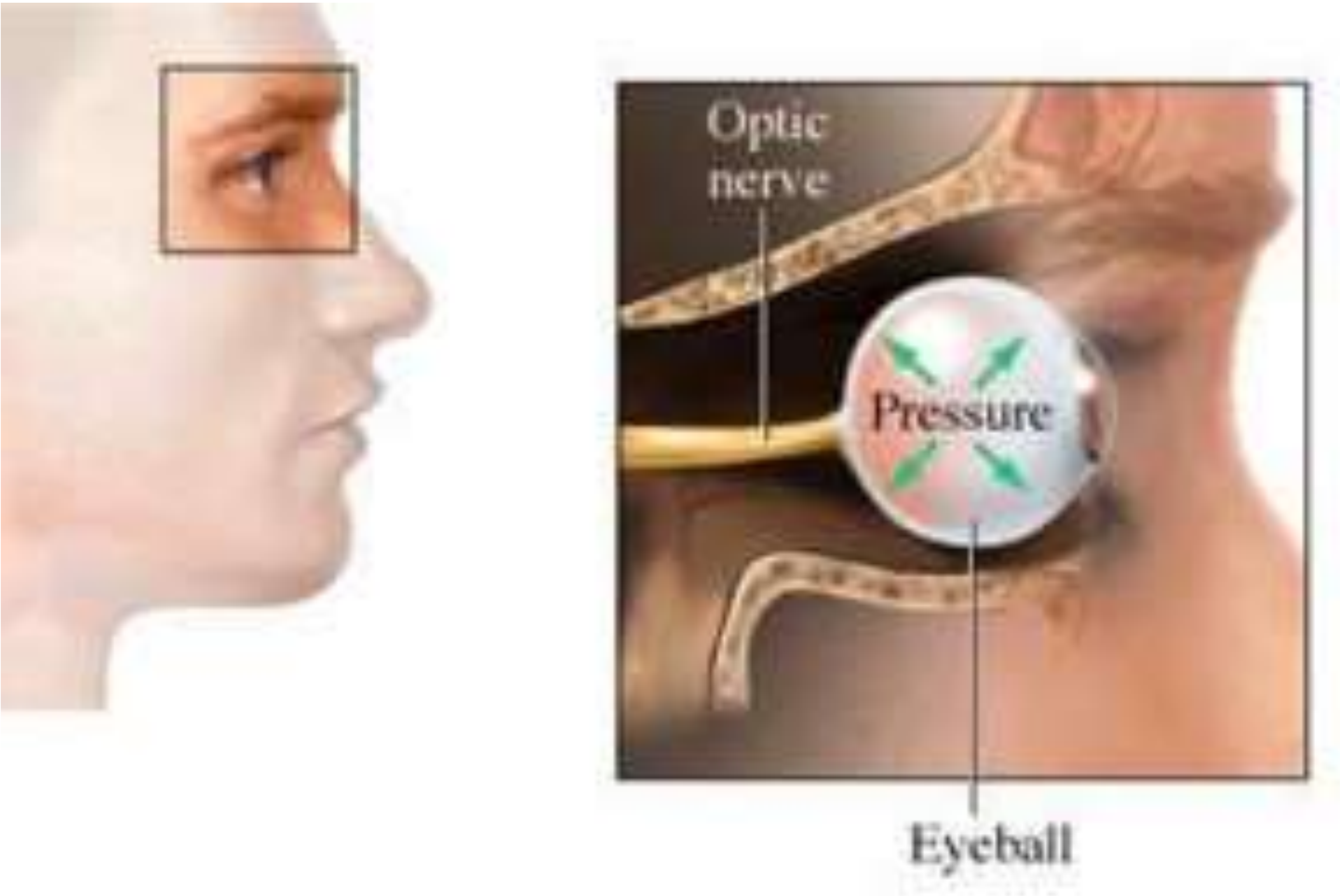
Thirst is "the physiological urge to drink water"

The 4 major stimuli to thirst are:

Hypertonicity: Cellular dehydration acts via an osmoreceptor mechanism in the hypothalamus
Hypovolaemia: Low volume is sensed via the low pressure baroreceptors in the great veins and right atrium
Hypotension: The high pressure baroreceptors in carotid sinus & aorta provide the sensors for this input
Angiotensin II: This is produced consequent to the release of renin by the kidney (eg in response to renal hypotension

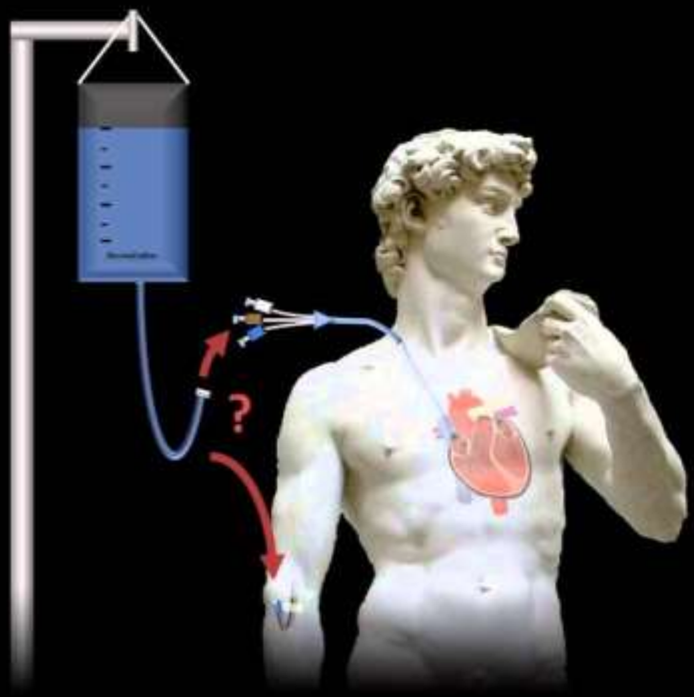
legroj.org

Simplicity is the major feature needed in physiological basic concepts.


Optic
nerve
Pressure
Eyeball

Viscosity and Poiseuille's Law

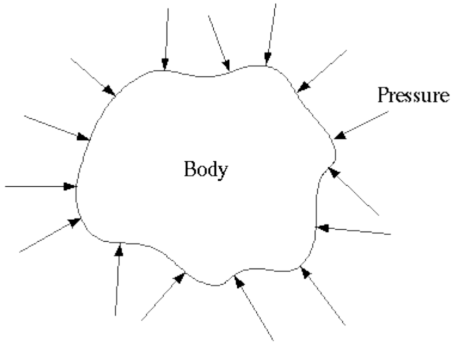
A hypotensive patient requires immediate infusion of intravenous saline. If the goal is to infuse the saline as fast as possible, which is the preferred route of administration: a standard triple lumen central line (length 20cm, radius of each lumen 0.84mm), or a standard 16 gauge peripheral IV (length 4cm, radius 1.2mm)?

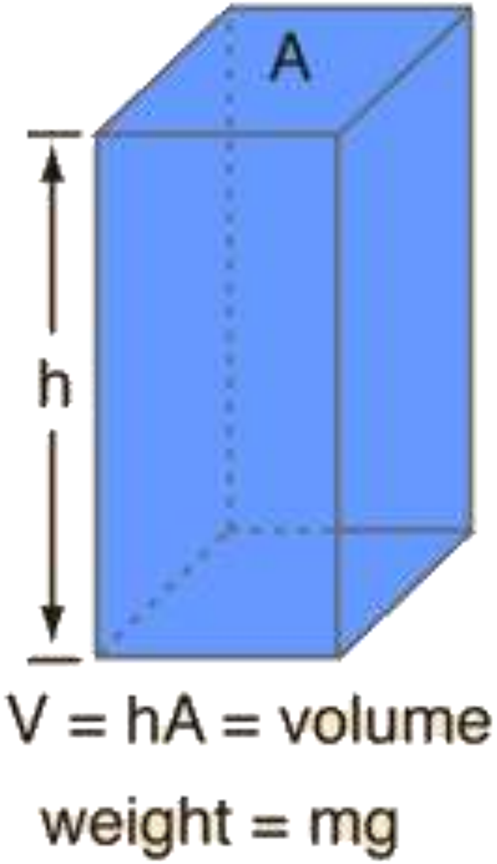


$$R = \frac{8 \cdot \mu \cdot L}{\pi\, r^4}$$

$$\frac{R_{CL}}{R_{IV}} = \frac{\dfrac{\cancel{8} \cdot \cancel{\mu} \cdot L_{CL}}{\cancel{\pi}\, r_{CL}^{4}}}{\dfrac{\cancel{8} \cdot \cancel{\mu} \cdot L_{IV}}{\cancel{\pi}\, r_{IV}^{4}}} = \frac{\dfrac{(20\text{cm})}{(0.84\text{mm})^4}}{\dfrac{(4\text{cm})}{(1.2\text{mm})^4}}$$

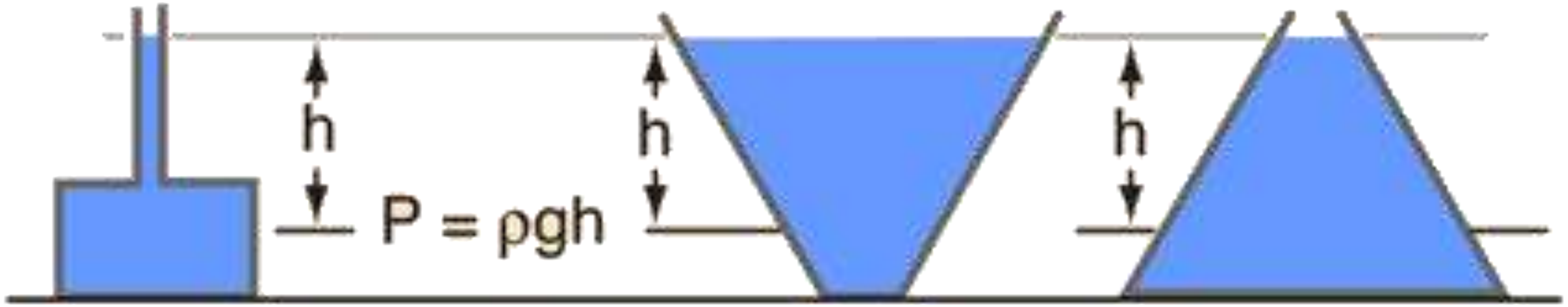
Pressure



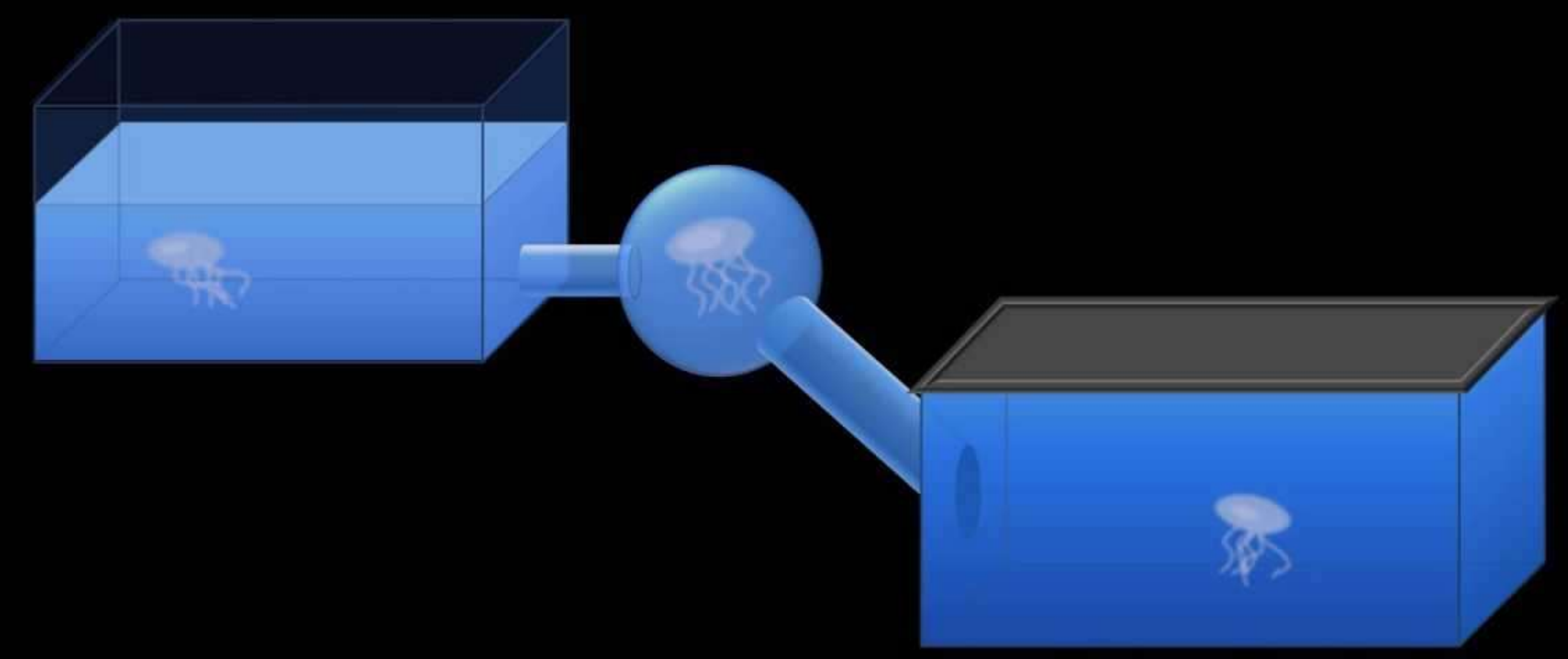


Static fluid pressure does not depend on the shape, total mass, or surface area of the liquid.

$$\text{Pressure} = \frac{\text{weight}}{\text{area}} = \frac{mg}{A} = \frac{\rho V g}{A} = \rho g h$$

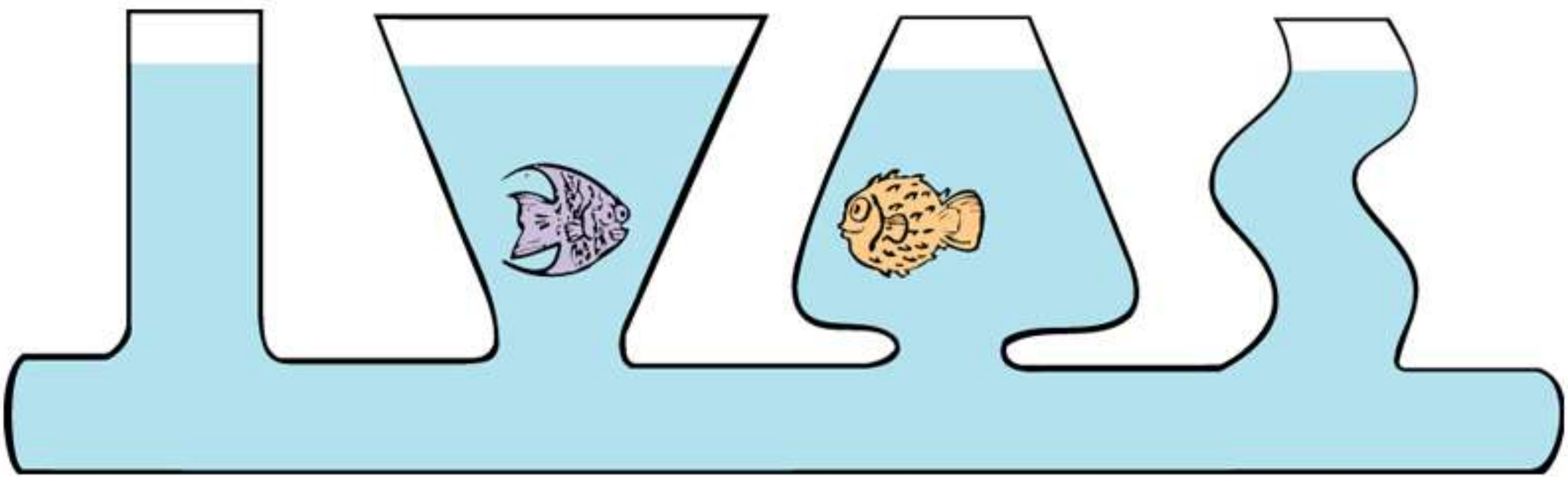


Hydrostatic Pressure



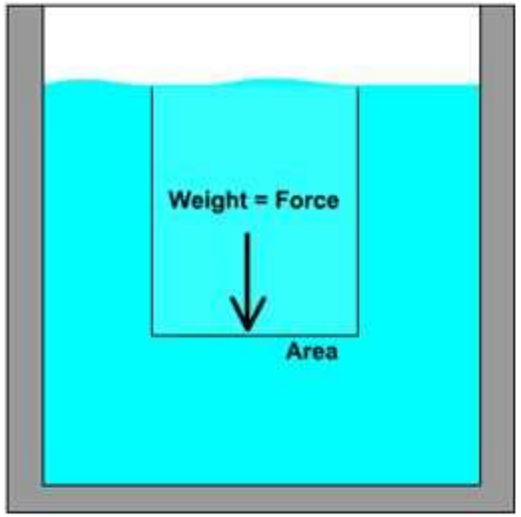
$$\Delta P = \rho \cdot g \cdot (\Delta h)$$

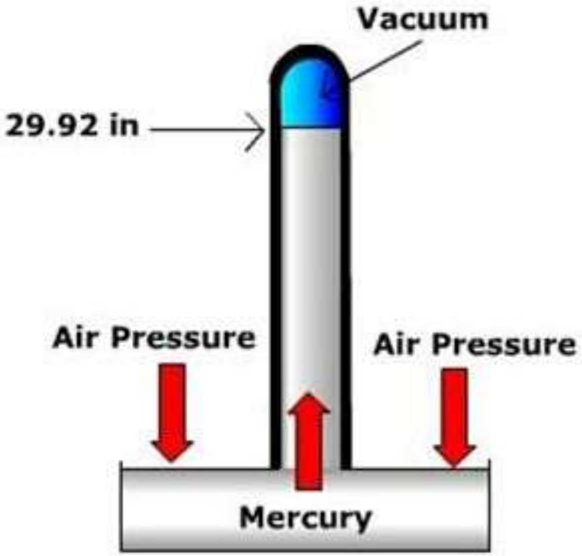
Pressure of liquid is same at any given depth below surface regardless of shape of container.

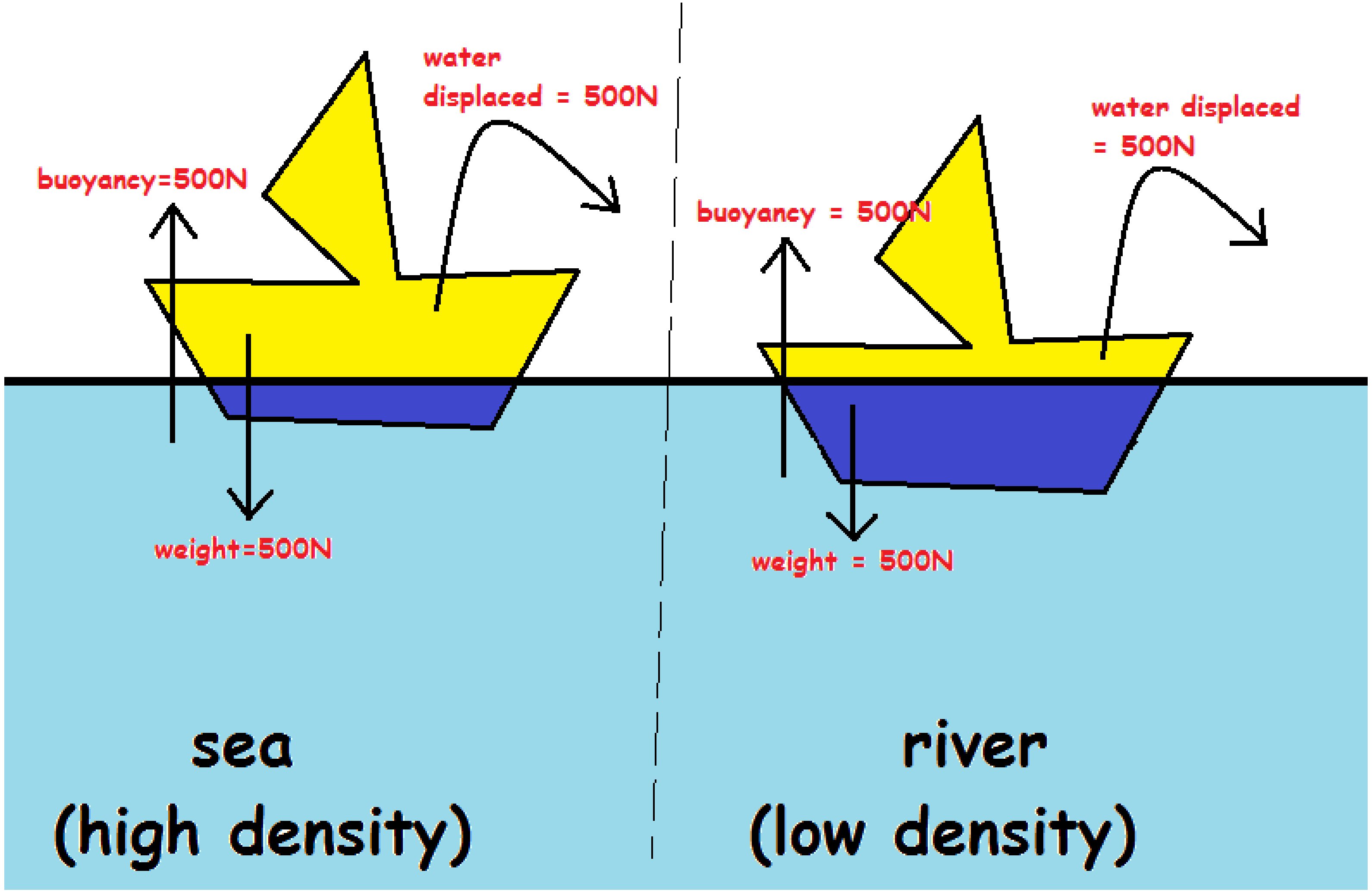


Calculate Fluid Pressure

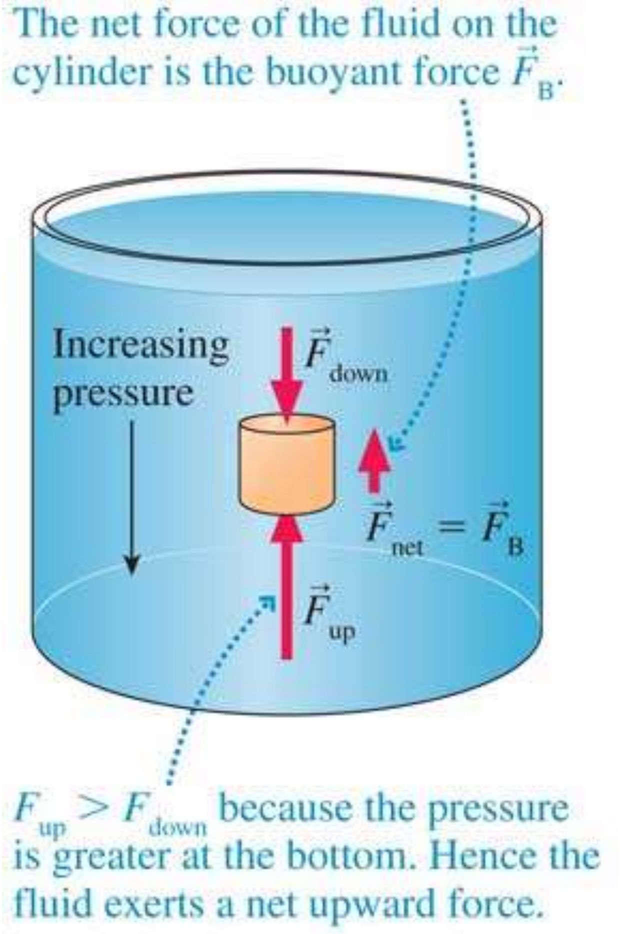
- $P = \rho \cdot g \cdot h$ Units: N/m^2 or Pa
- Air pressure at sea level is 14.7 psi = 760 mm Hg = 101 kPa = 1 atm.
- ρ of H_2O is 1000 kg/m^3



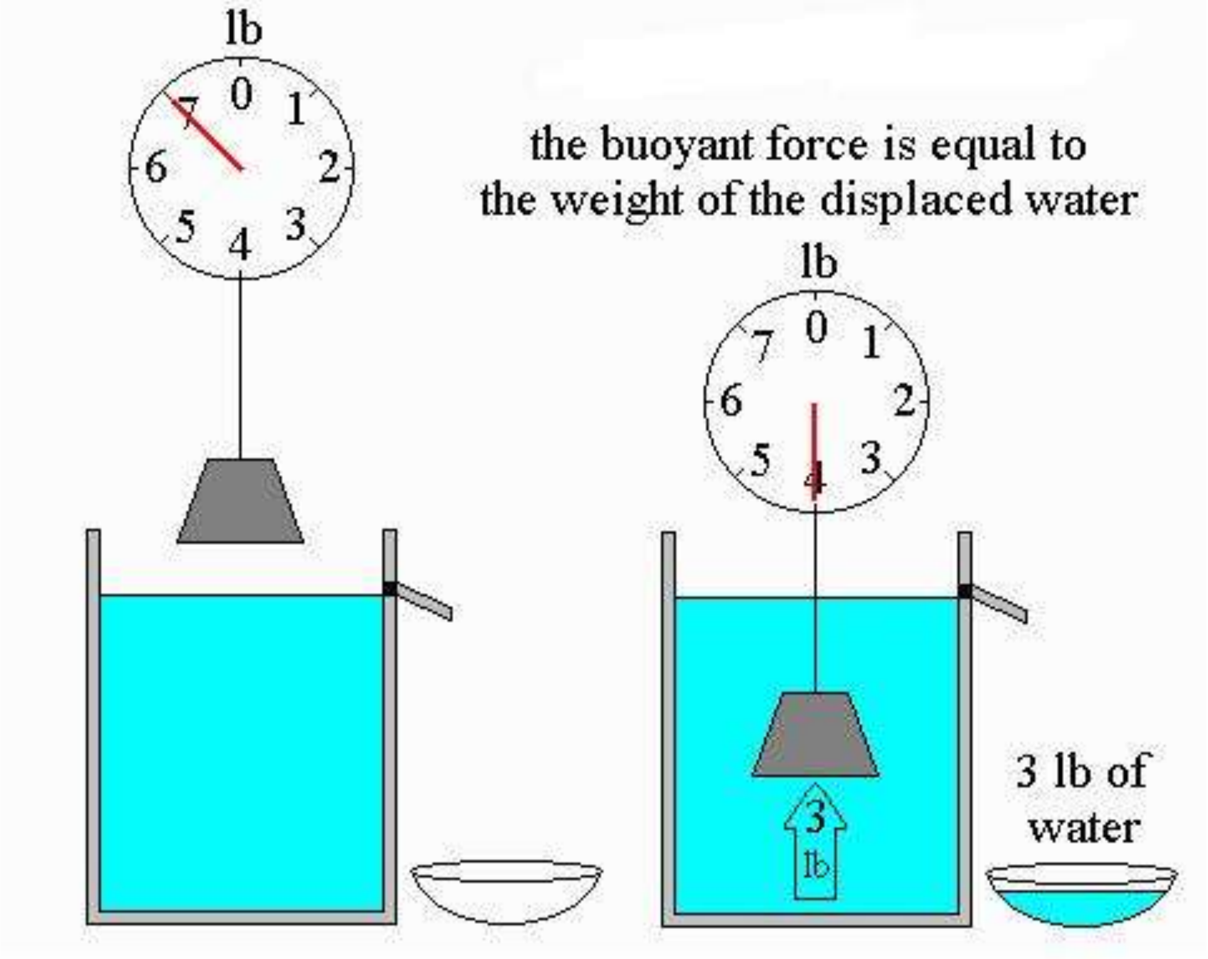



water
displaced = 500N
buoyancy=500N
weight=500N
sea
(high density)
water displaced
= 500N
buoyancy = 500N
weight = 500N
river
(low density)

Archimedes principle indicates that the upward bouyant force that is exerted on a body immersed in a fluid, whether fully or partially submerged, is equal to the weight of the fluid that the body displaces. Archimedes' principle is a law of physics fundamental to fluid mechanies. Archimedes Syeacuse formulated this principle, which bears his name.



The net force of the fluid on the cylinder is the buoyant force $\vec{F}_B$.
Increasing pressure
$\vec{F}_{down}$
$\vec{F}_{net} = \vec{F}_B$
$\vec{F}_{up}$
$F_{up} > F_{down}$ because the pressure is greater at the bottom. Hence the fluid exerts a net upward force.

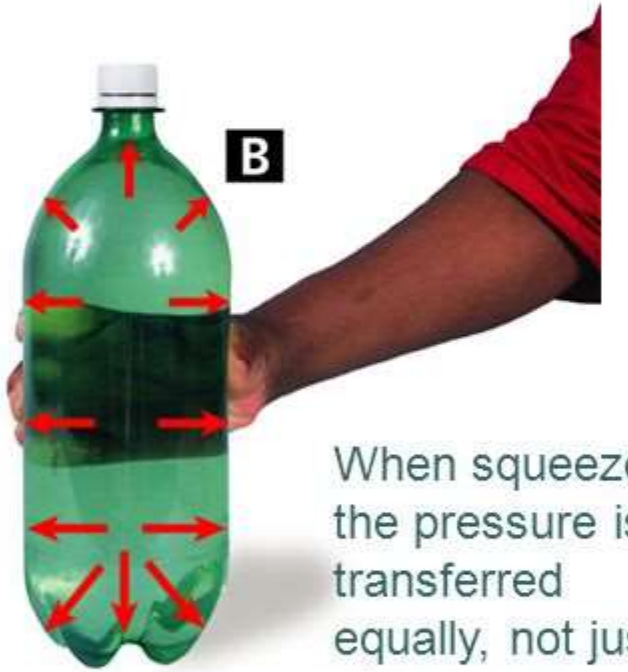


lb
0 1 2 3 4 5 6 7
the buoyant force is equal to the weight of the displaced water
lb
0 1 2 3 4 5 6 7
3 lb
3 lb of water

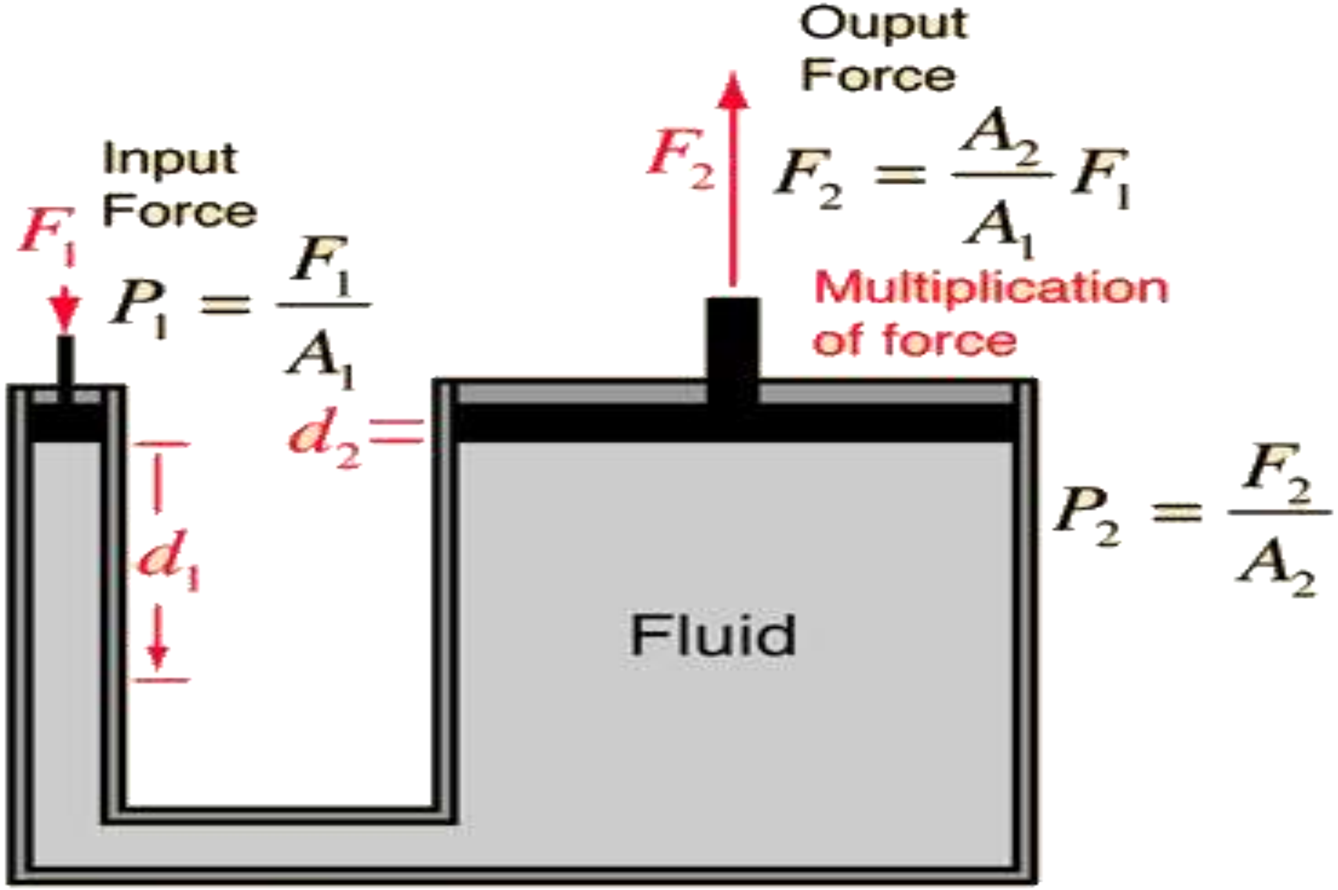
Pascal's Principal

The forces on the walls in bottle A is equal at any given depth

Pascal's Principal:
A change in pressure at any point in a fluid is transmitted equally in all directions



When squeezed, the pressure is transferred equally, not just where you squeeze

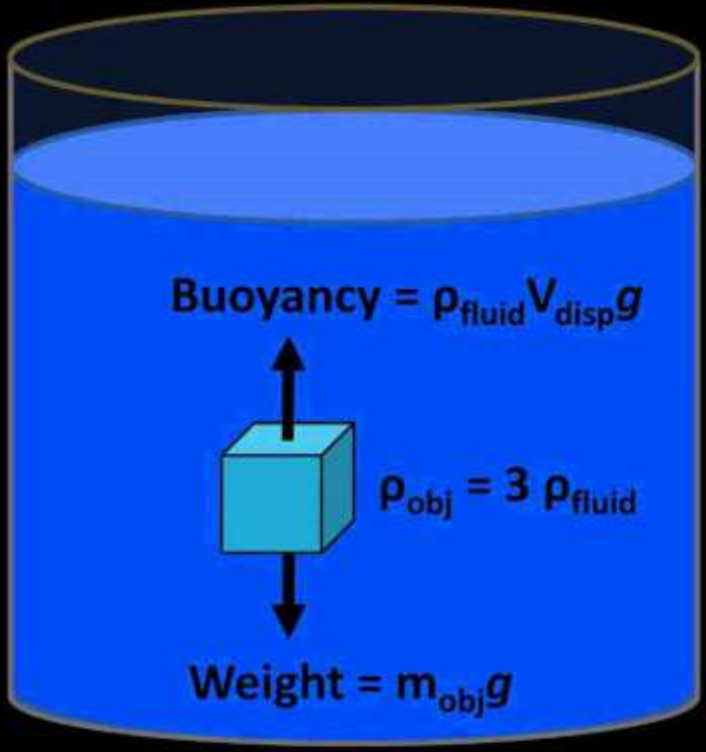


$$F_1 d_1 = F_2 d_2$$

$$d_1 = \frac{F_2}{F_1} d_2 = \frac{A_2}{A_1} d_2$$

You have to pay for the multiplied output force by exerting the smaller input force through a larger distance.

Archimedes' Principle and Buoyancy



What acceleration will a completely submerged object experience if its density is three times that of the fluid in which it is submerged?

$$\Sigma F = m\,a$$

$$F_{weight} - F_{buoyancy} = m_{obj}\,a_{obj}$$

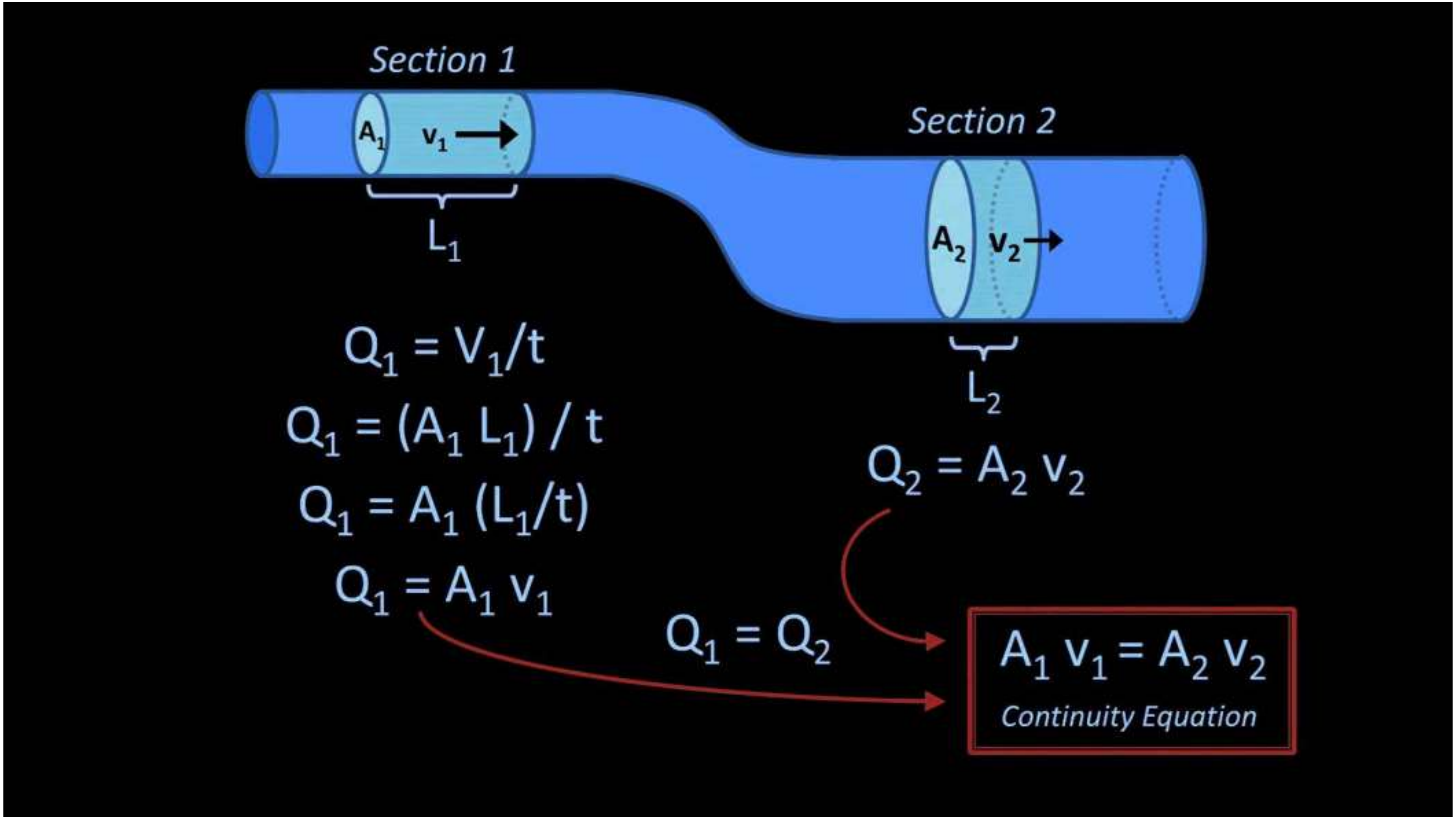
$$(m_{obj}g) - (\rho_{fluid}V_{obj}g) = m_{obj}\,a_{obj}$$

$$(3\cancel{\rho}_{fluid}\cancel{V}_{obj}g) - (\cancel{\rho}_{fluid}\cancel{V}_{obj}g) = (3\cancel{\rho}_{fluid}\cancel{V}_{obj})\,a_{obj}$$

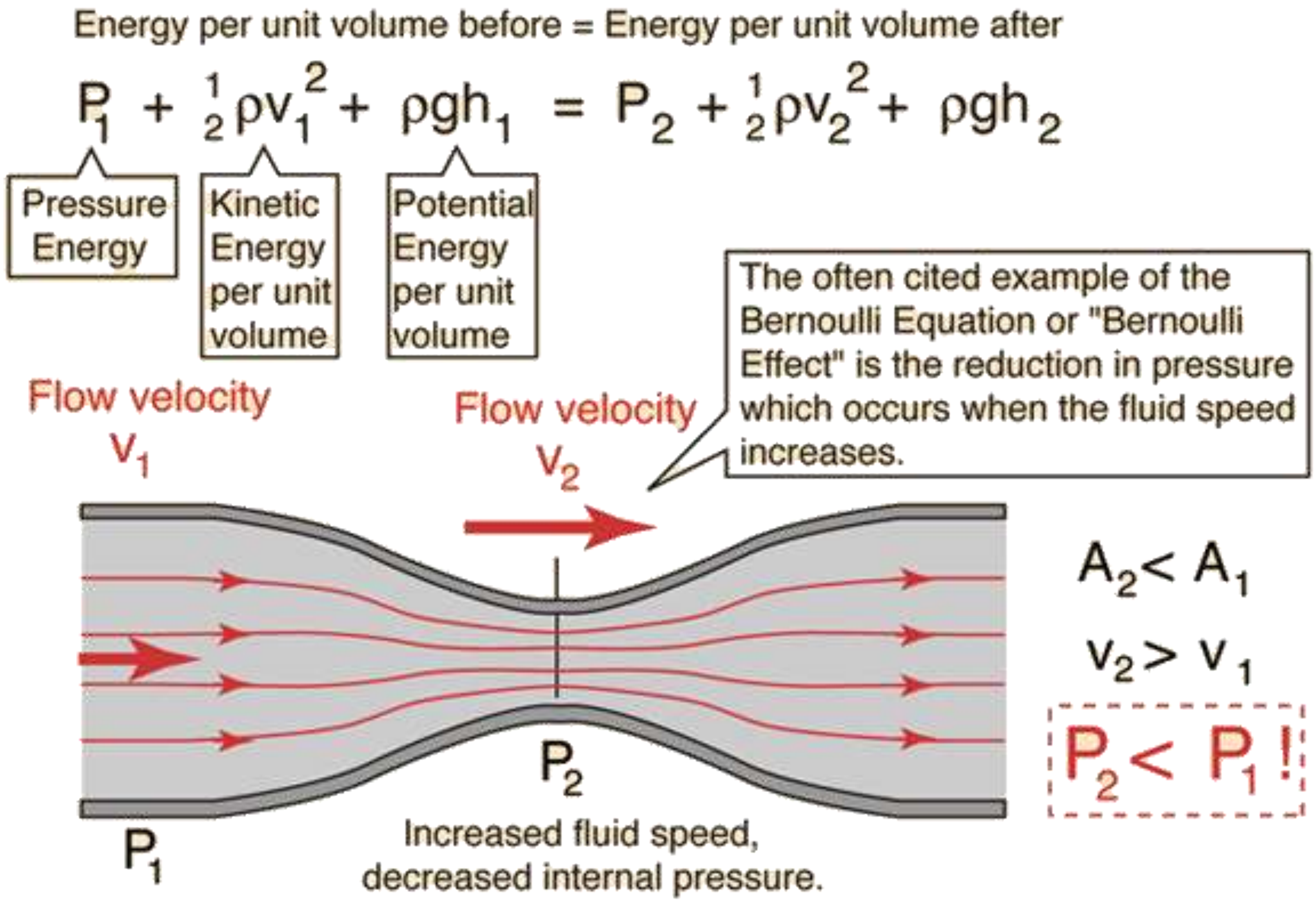
$$3g - g = 3a_{obj}$$

$$a_{obj} = \tfrac{2}{3}g = \tfrac{2}{3}(9.8\ \text{m/s}^2) = 6.5\ \text{m/s}^2$$

The Continuity Equation



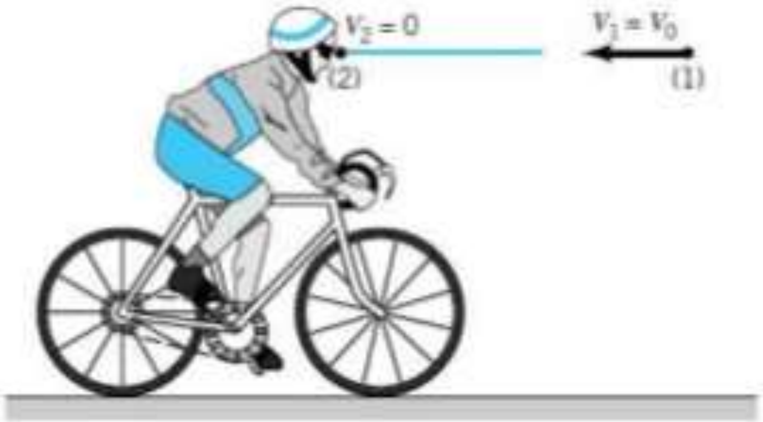
Steady-state flow caveat: While the Bernoulli equation is stated in terms of universally valid ideas like conservation of energy and the ideas of pressure, ...



Bernoulli Equation

➢ Example ☺1

Consider the flow of air around a bicyclist moving through still air with velocity as is shown in Fig. Determine the difference in the pressure between points 1 and 2.



$$p_1 + \frac{1}{2}\rho V_1^{\,2} + \gamma z_1 = p_2 + \frac{1}{2}\rho V_2^{\,2} + \gamma z_2$$

$$slout ion: p_2 - p_1 = \frac{1}{2}\rho V_1^2$$

Viscous fluid

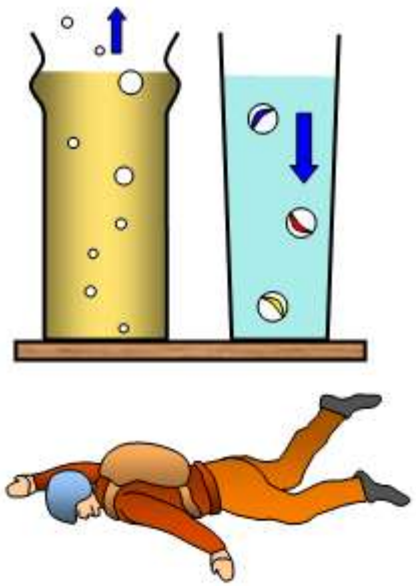


Figure 1

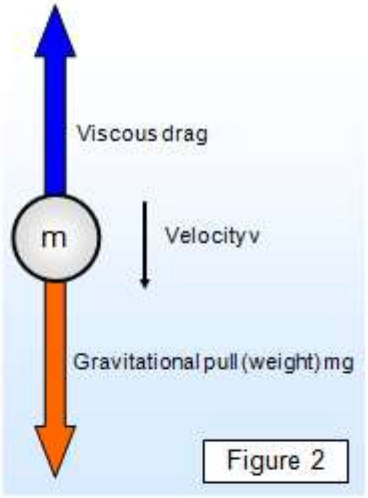
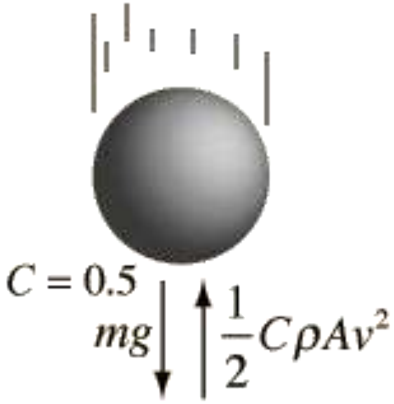
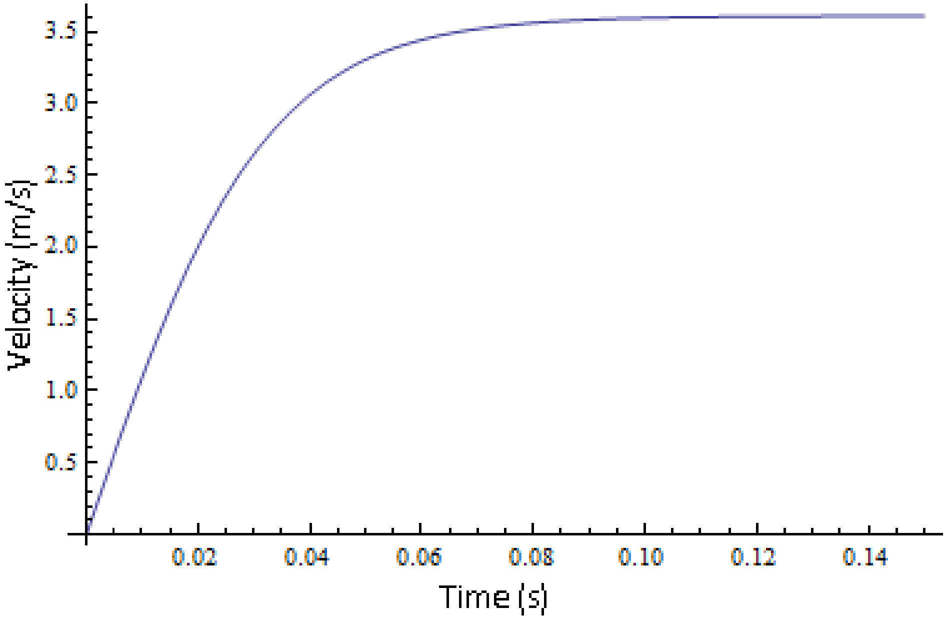


Figure 2

$$v_{terminal} = \sqrt{\frac{2mg}{C\rho_{air}A}}$$



$$\rho_{air} = 1.29 kg/m^3$$



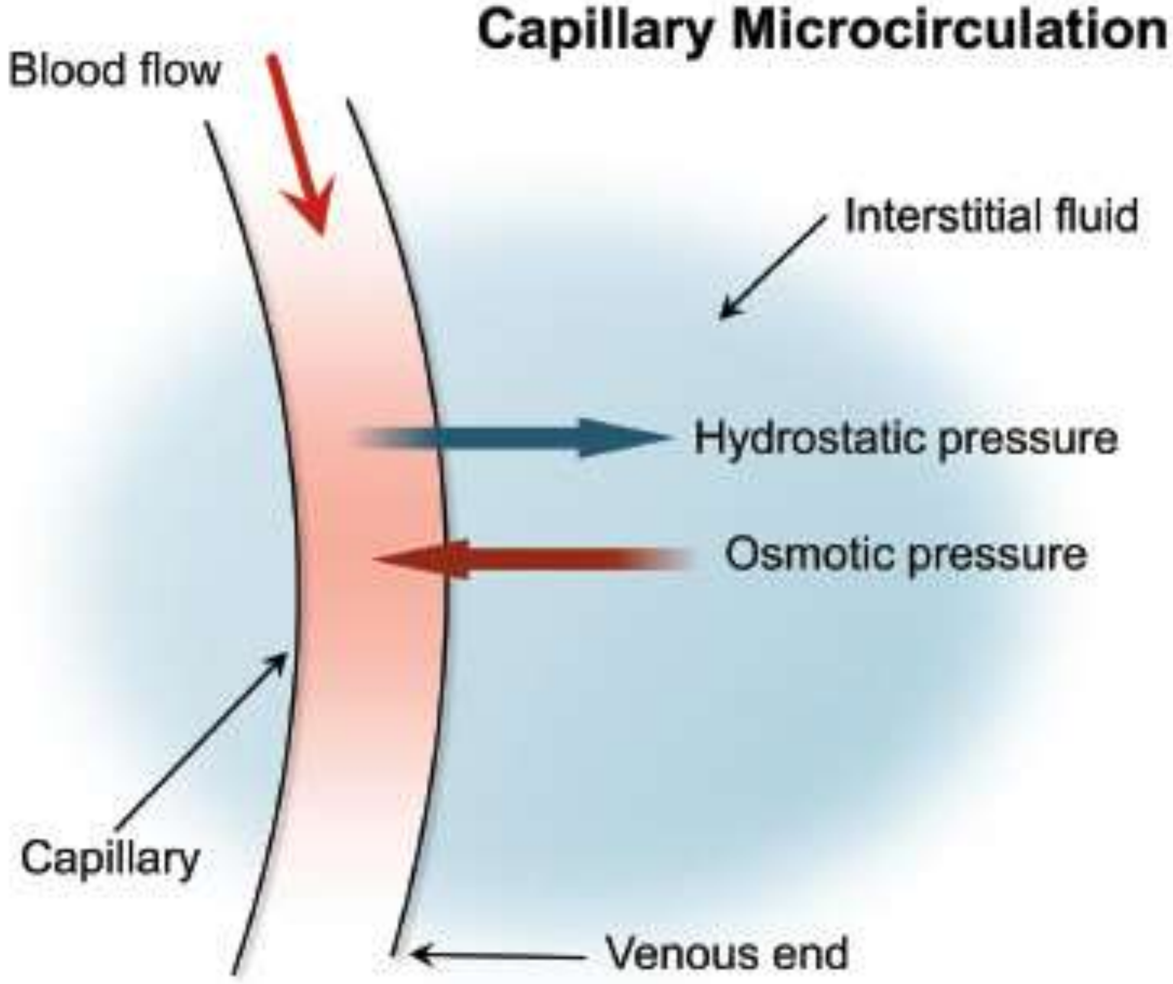
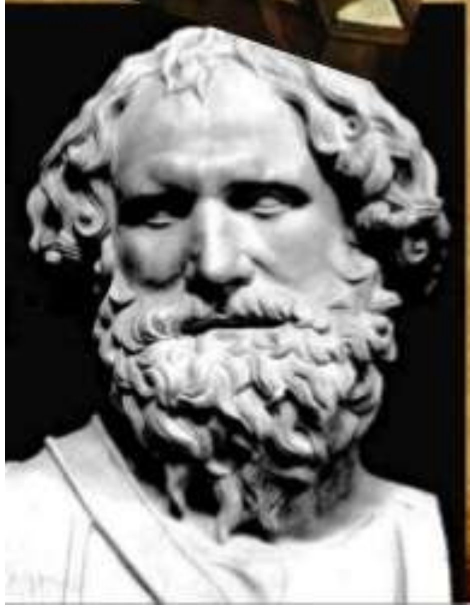


Figure 2. *Fluid exchange occurs across capillaries according to hydrostatic and colloid osmotic pressures maintained between the extracellular and intravascular compartments.*



ARCHIMEDES

The Ancient World's Genius