FLUIDS and MATERIALS

What do you think?

- Order the drink with the greatest density.
- What do you drink?
  - Orange Drink
  - Milkshake

Density

- Mass / Volume
  - g/cm^3
    - water = $1 g/cm^3$
  - kg/m^3
    - water = $1000 \ kg/m^3$

$$\rho = \frac{m}{V}$$

- NOT the same as how "thick" something is

Sample Problem

- Calculate the density
  - Diameter = 4 cm
  - Height = 15 cm
  - Mass = 625 g
  - $V = \pi r^2 h$
  - $V = 188.4\ cm^3$
  - $\rho = 3.31\ g/cm^3$

What do you think?

Which one applies the greatest force to the ground below?

Pressure

- Force / Area
  - PSI
  - N/m^2 = Pascal (Pa)
  - ATM
  - mmHg = Torr

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

1 ATM =	14.7 PSI
	101.3 kPa
	760 Torr

Sample Problem

- Calculate the pressure under a steel block 15 x 20 x 3 cm.
  - (when resting on its largest face)
  - Density = 7.86 g/cm^3

Sample

- Density = 7.86 g/cm^3
- Volume= 15 x 20 x 3 = 900 cm^3 *(match units)*
- Mass = ρ x V = 7.86 g/cm^3 x 900 cm^3 = 7,074 g
- Weight = 7.074kg x 9.8 = 69.33 N
- Area = 0.15m x 0.2m = 0.03 m^2 *(match units)*
- Pressure = 2,310 Pa = 2.31 kPa

What do you think?

- Greater pressure?

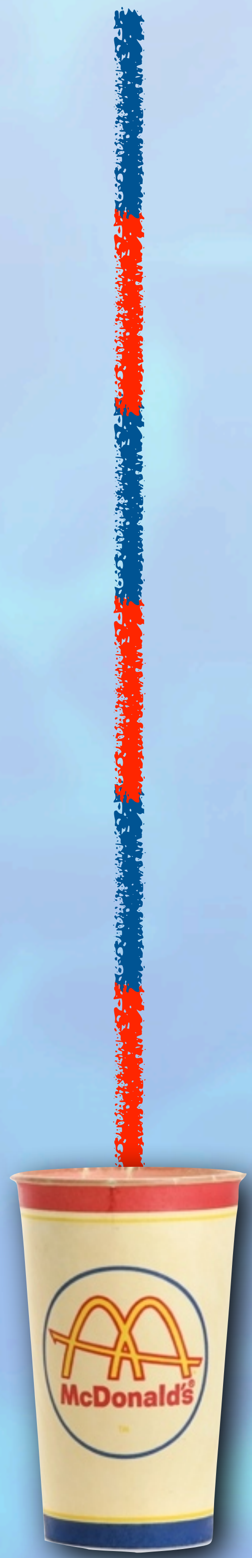
  - 5 feet underwater in a pool
  - pressure on the table
  - or pressure on the swimmer
  - would it matter if the pool were replaced by a large lake?

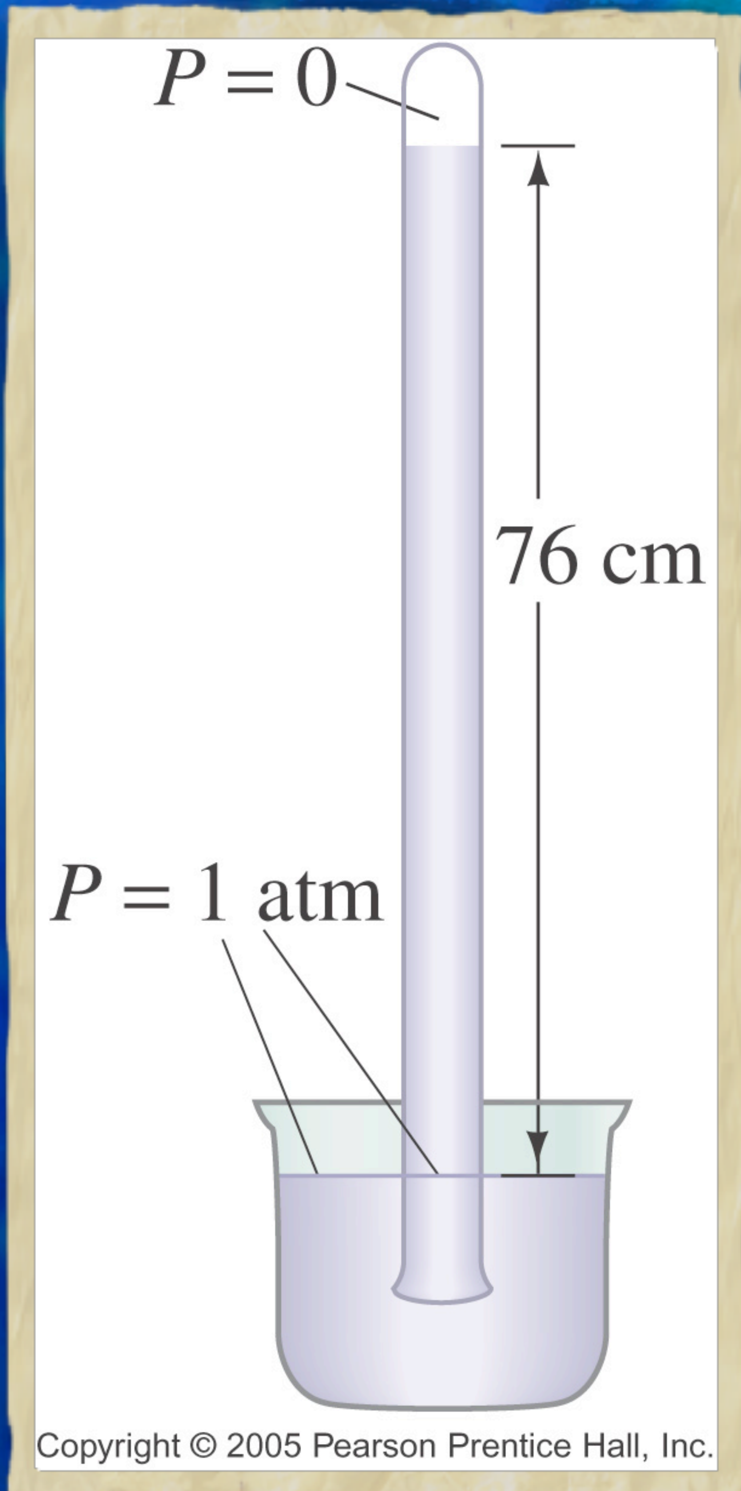
What do you think?

- How Many Straws?

What do you think?

- How Many Straws?





Barometer

Pressure at a Depth

$$P = \rho g h$$

Pressure caused by the weight of the fluid above an area

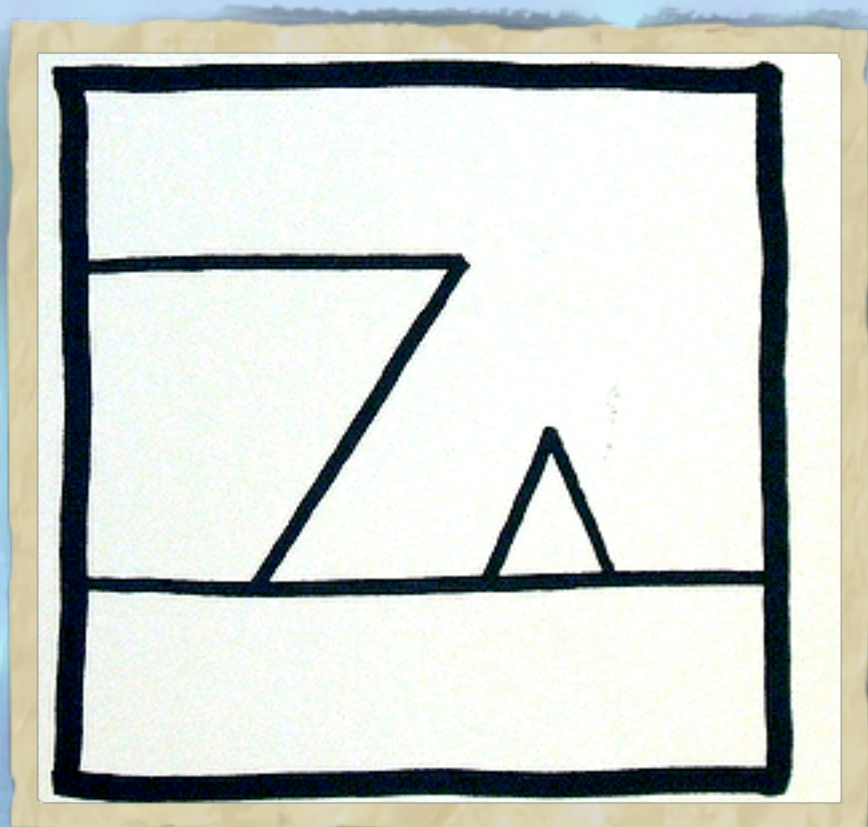
Which Pressure?

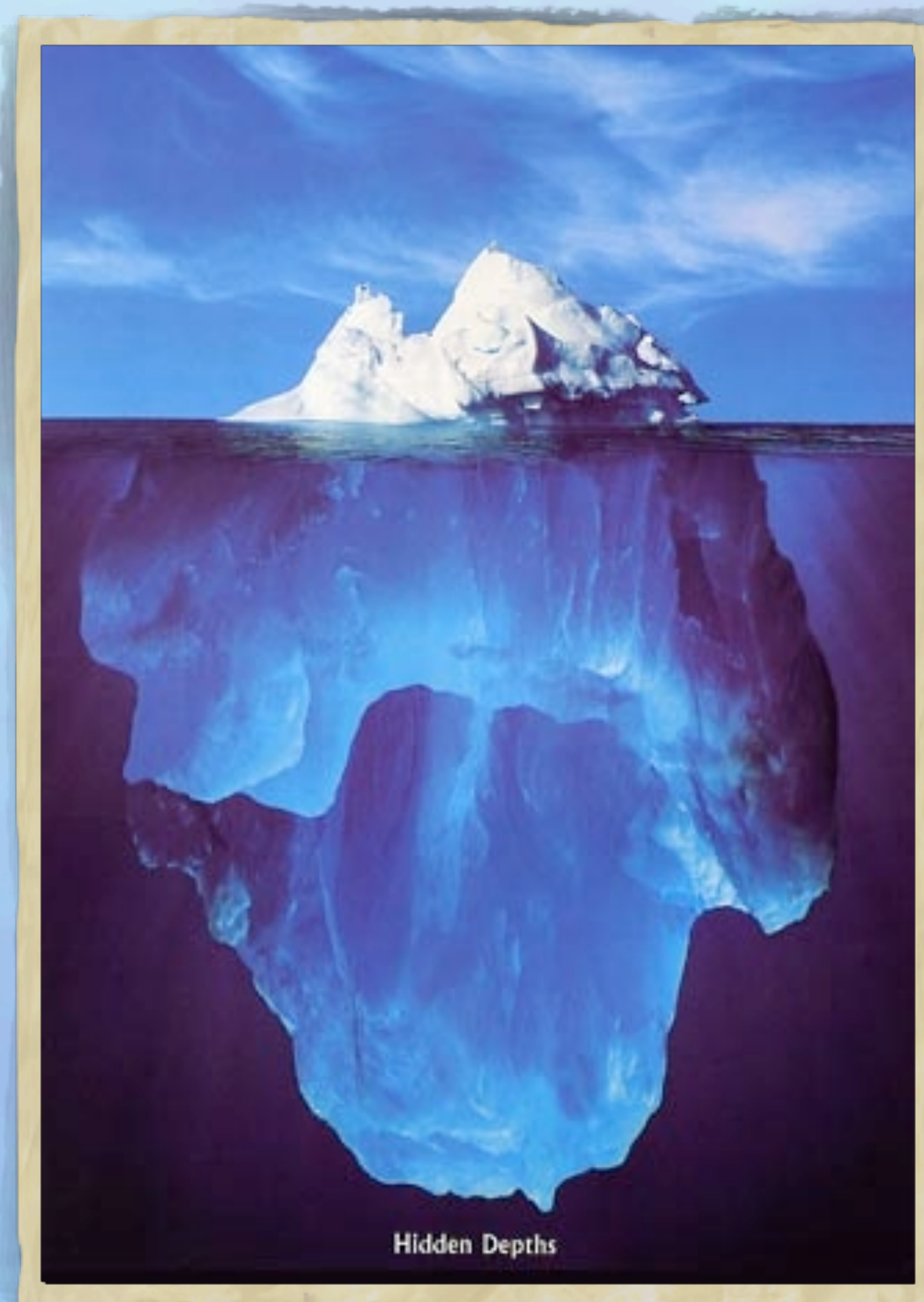
- Atmospheric
  - from the air above
- Gauge
  - the applied pressure
- Absolute
  - the total pressure

Sample

- 3 meters underwater… what is the
  - Gauge Pressure
    - $(1000 kg/m^3)(9.8 m/s^2)(3 m)$
    - 29,400 Pa = 29.4 kPa
  - Atmospheric = 101 kPa
  - Absolute pressure = 130.4 kPa

What do you think?

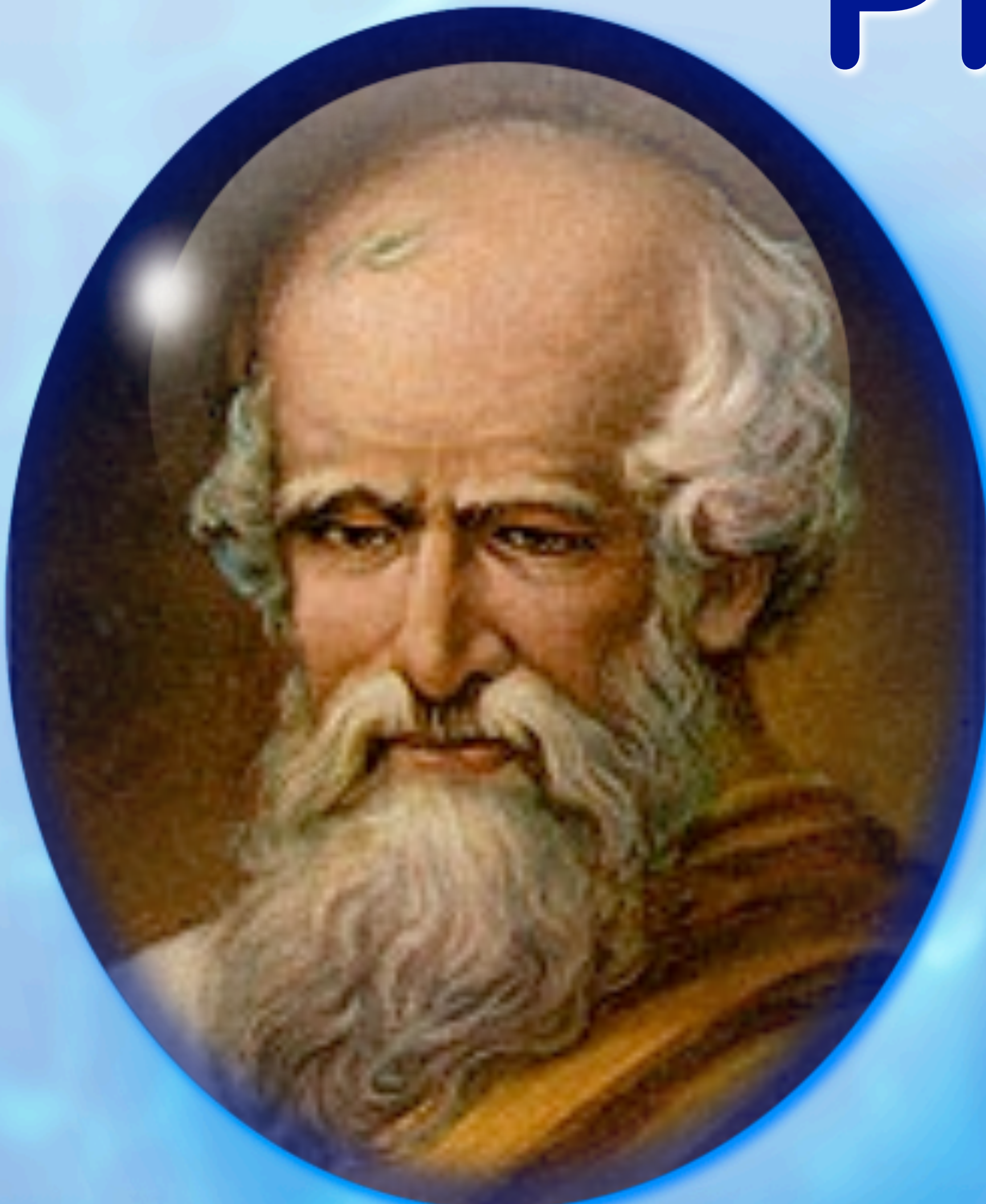




What do you think?

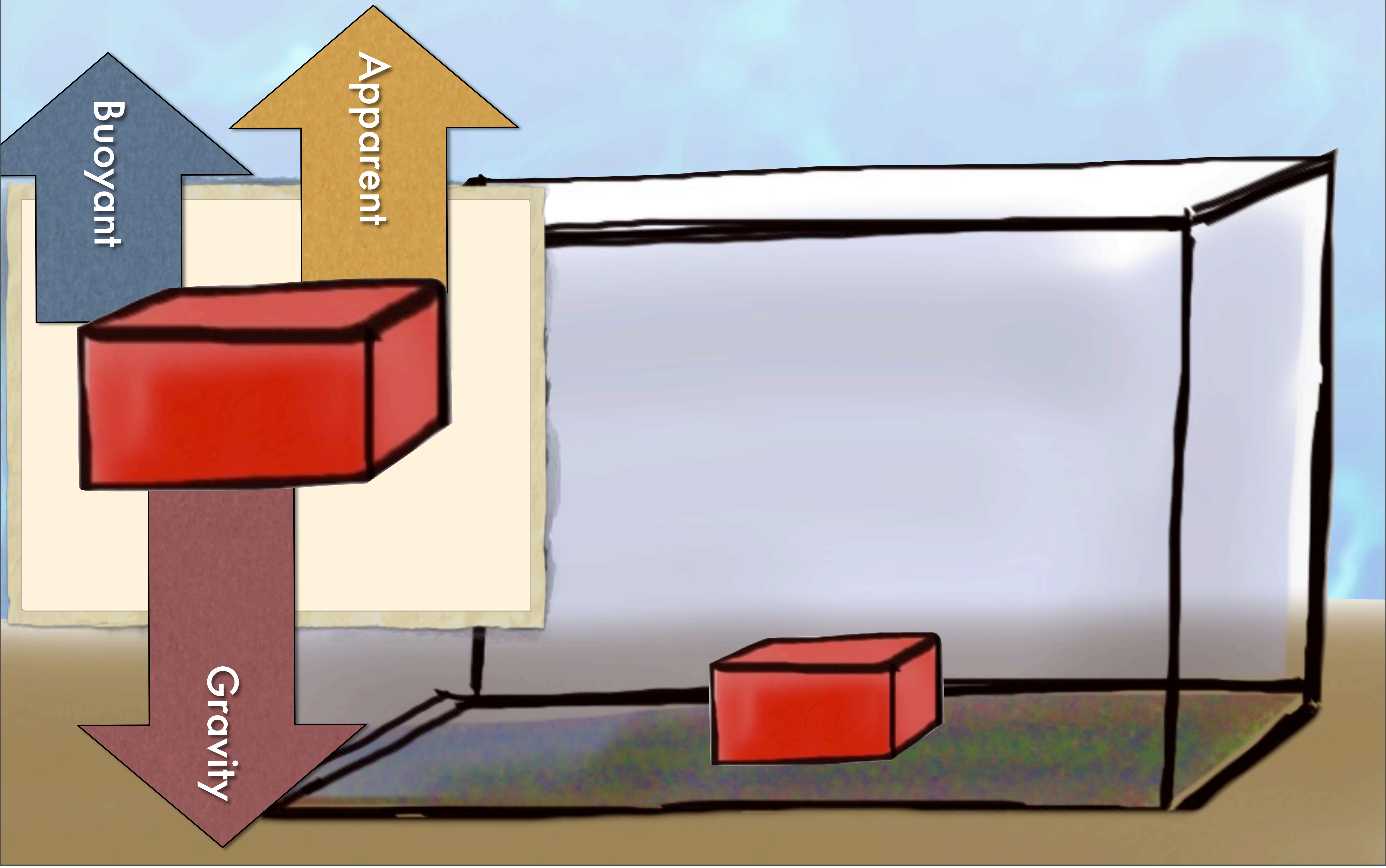
Why wouldn’t a metal boat sink?

Archimedes Principle

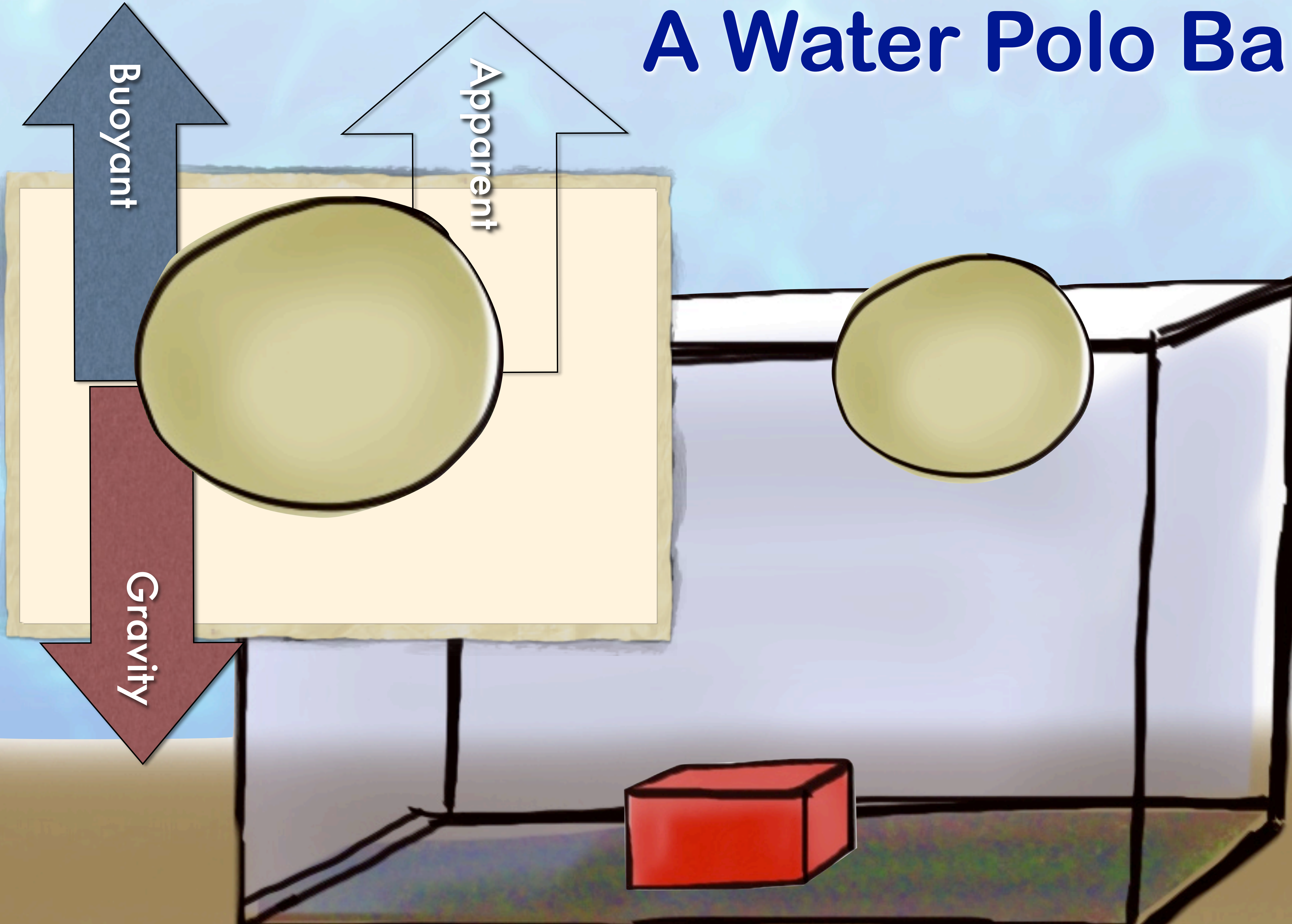


- There exists, on any object immersed in a fluid, a buoyant force upward equal to the weight of the fluid displaced

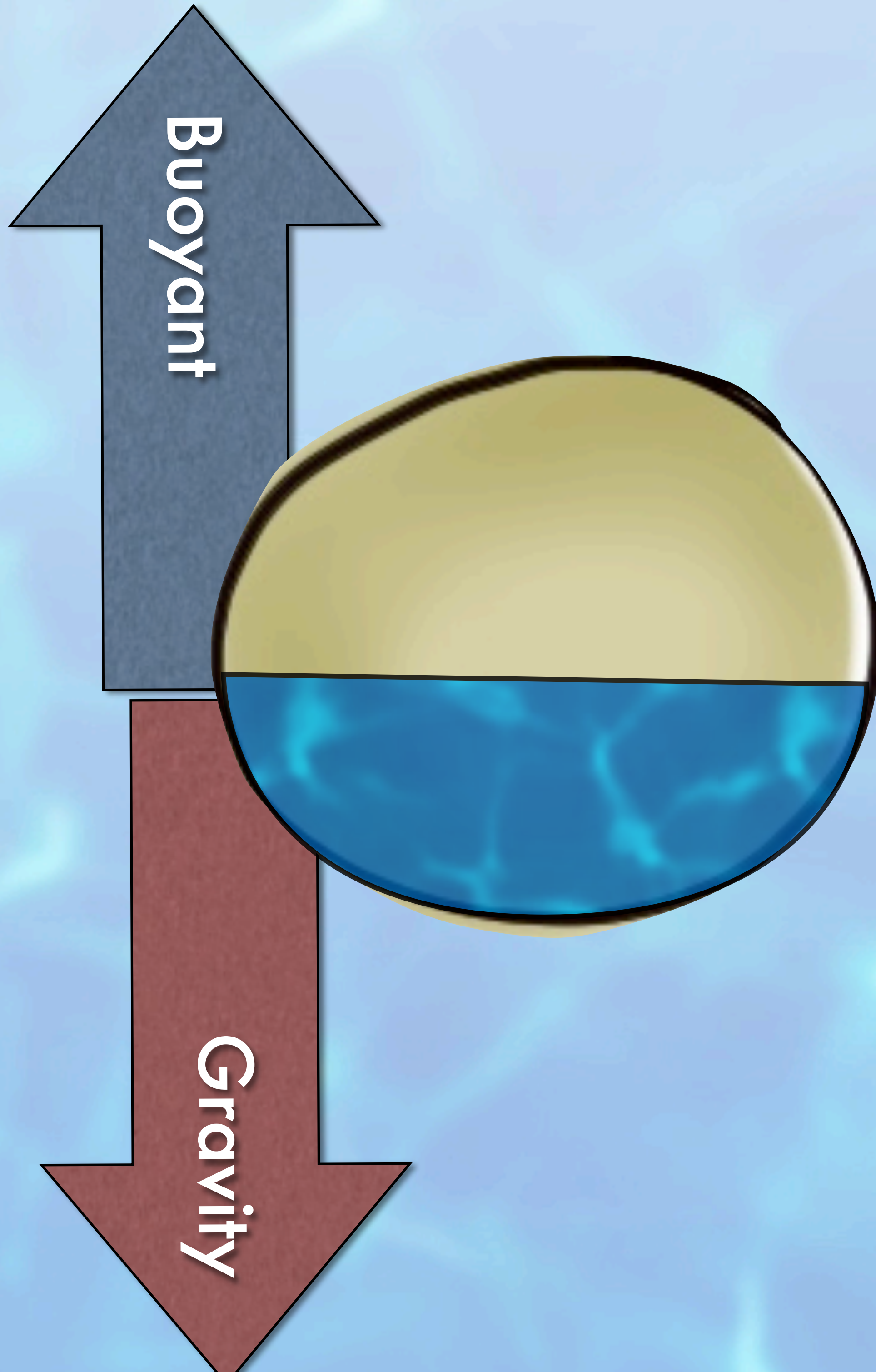
A Brick on the bottom



A Water Polo Ball



Equal Weight



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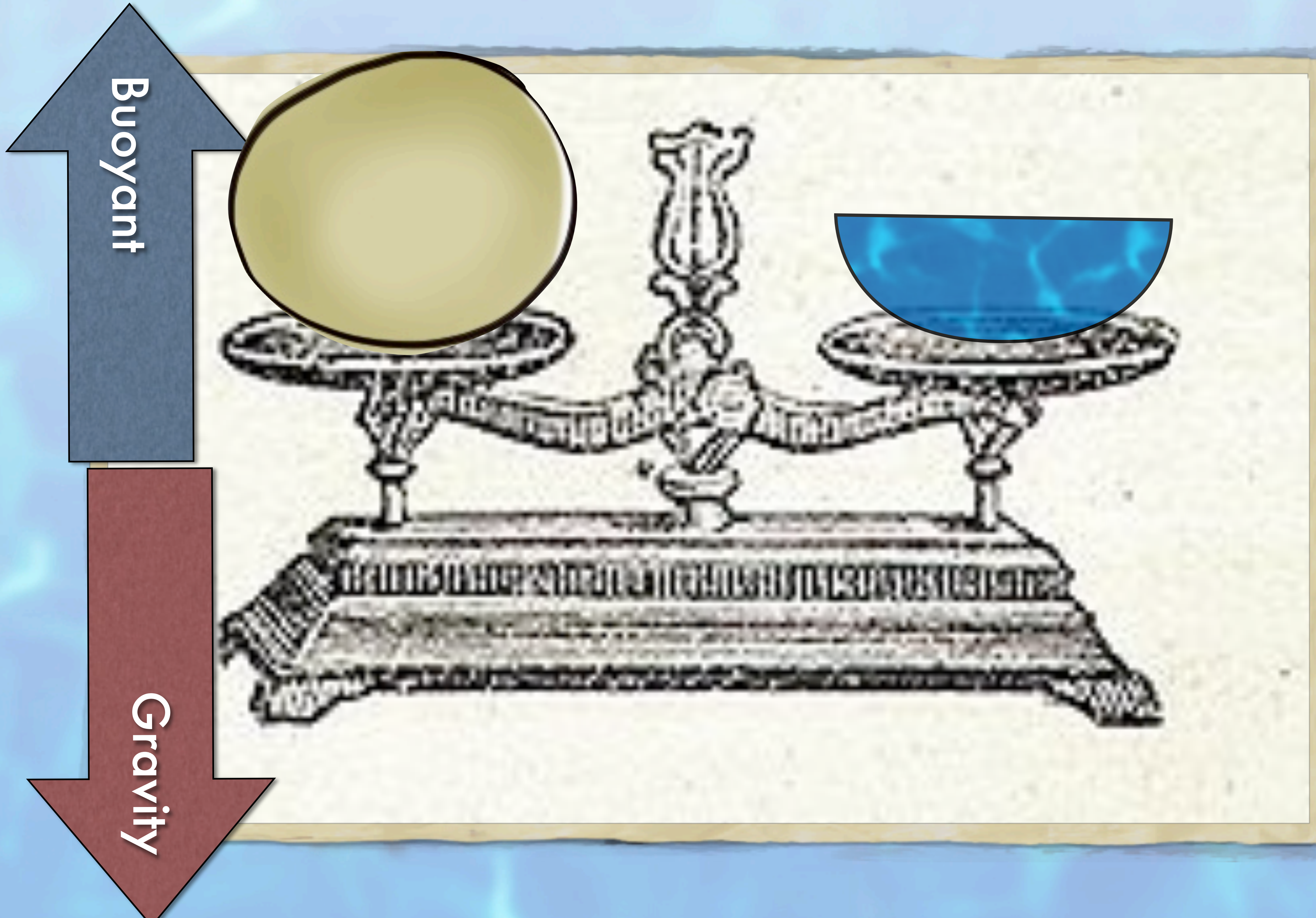
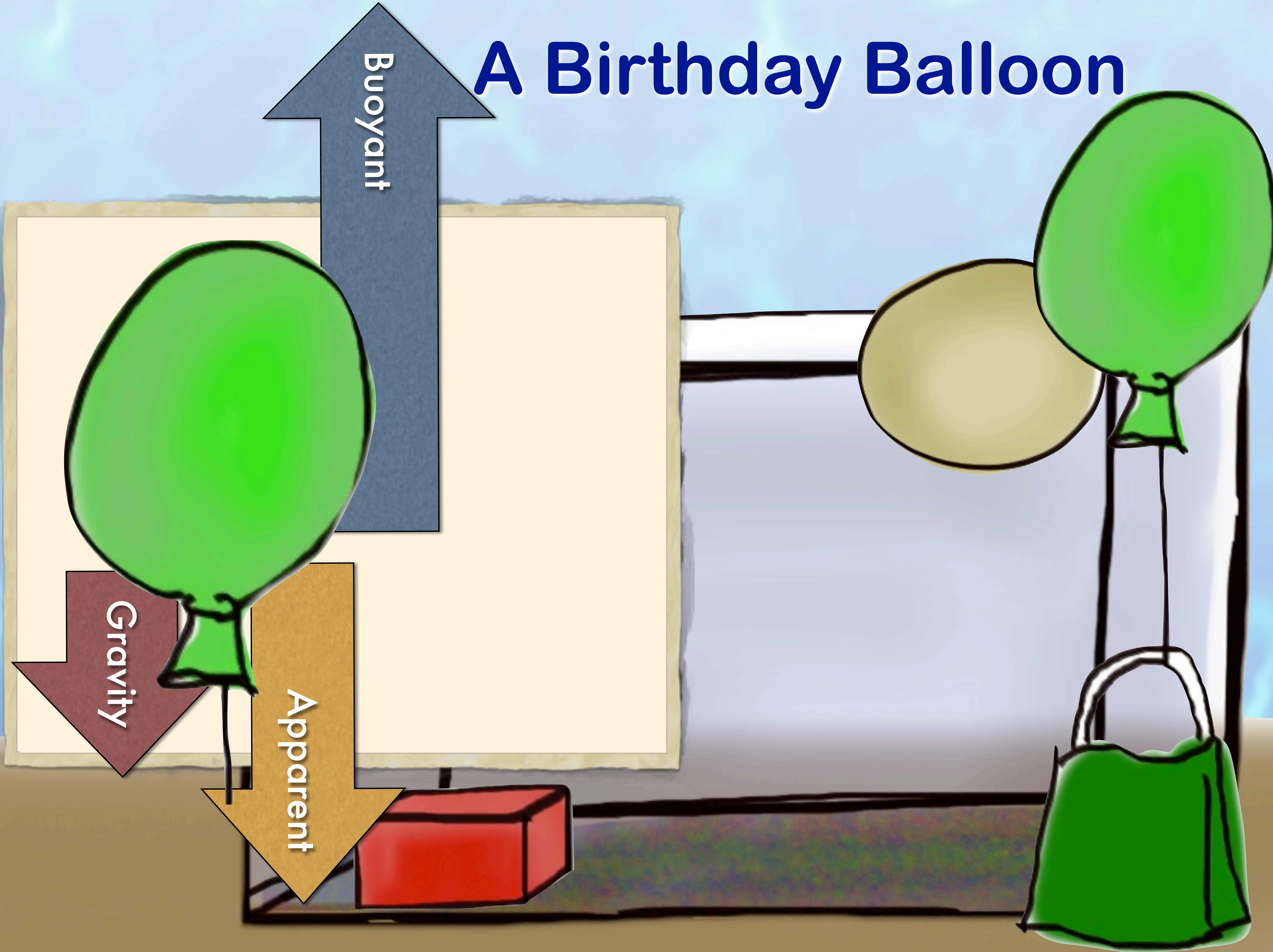


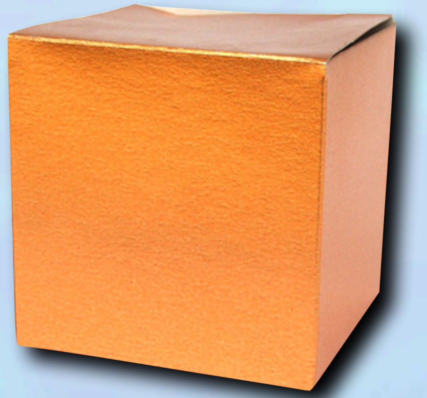
A Birthday Balloon



Sample Problem

- What is the apparent weight of a small block of Copper at the bottom of a tank of water?
- Copper $\rho = 8.96\ g/cm^3$
- $4 \times 5 \times 8$ cm

Apparent Weight



Copper

$\rho = 8.96\ g/cm^3$

4 x 5 x 8 cm

$v = 160\ cm^3$

$m = \rho\, v = 1433.6g$

$w = 1.43 \times 9.8 = 14.05\ N$

Water

$\rho = 1.0\ g/cm^3$

4 x 5 x 8 cm

$v = 160\ cm^3$

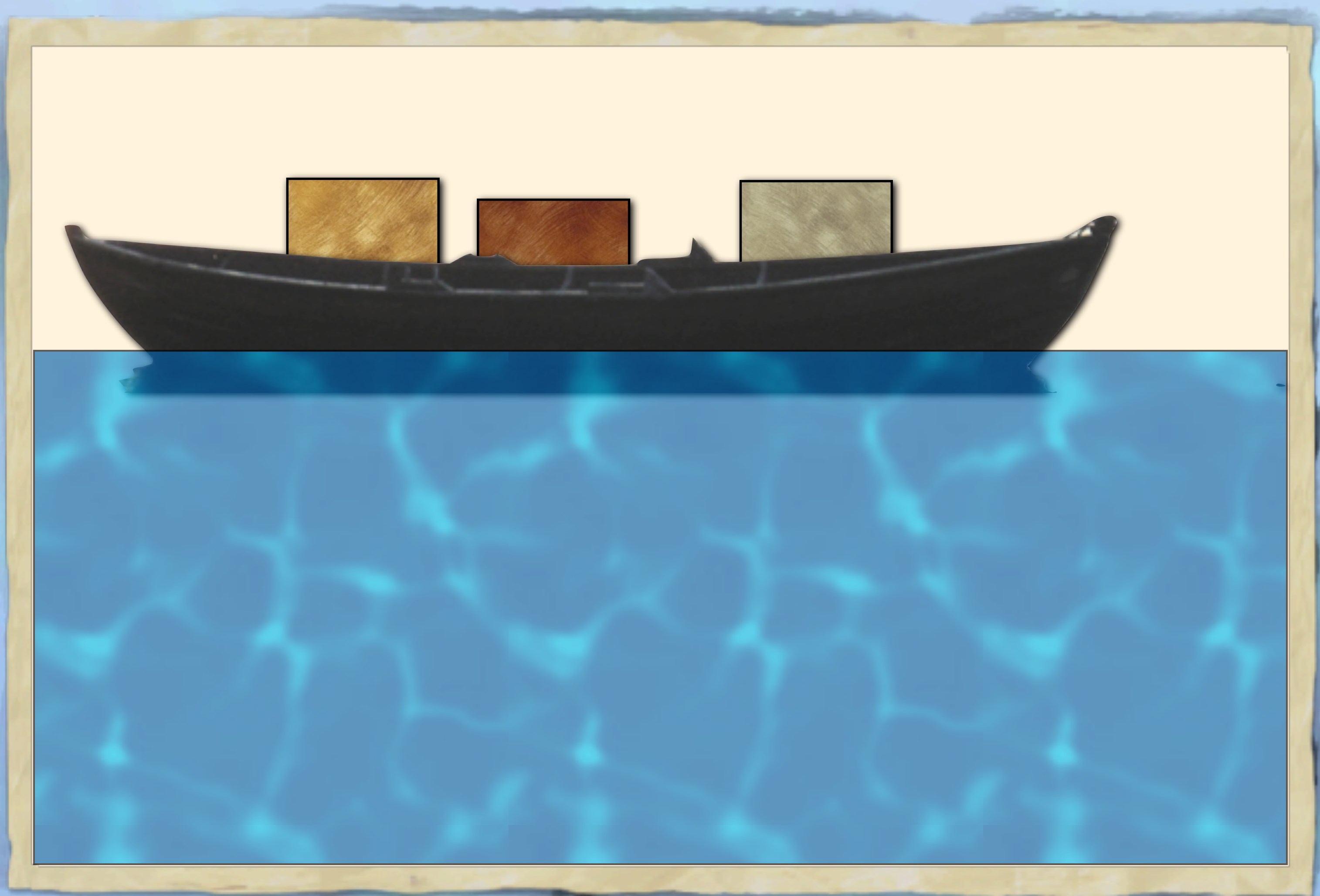
$m = \rho\, v = 160\ g$

$w = 0.16 \times 9.8 = 1.57\ N$

$$W_a = W_g - F_b$$
$$= 14.05 - 1.57$$
$$= 12.48\ N$$

What would happen...

...to the water level in the pool if the metal blocks inside the boat were thrown overboard?



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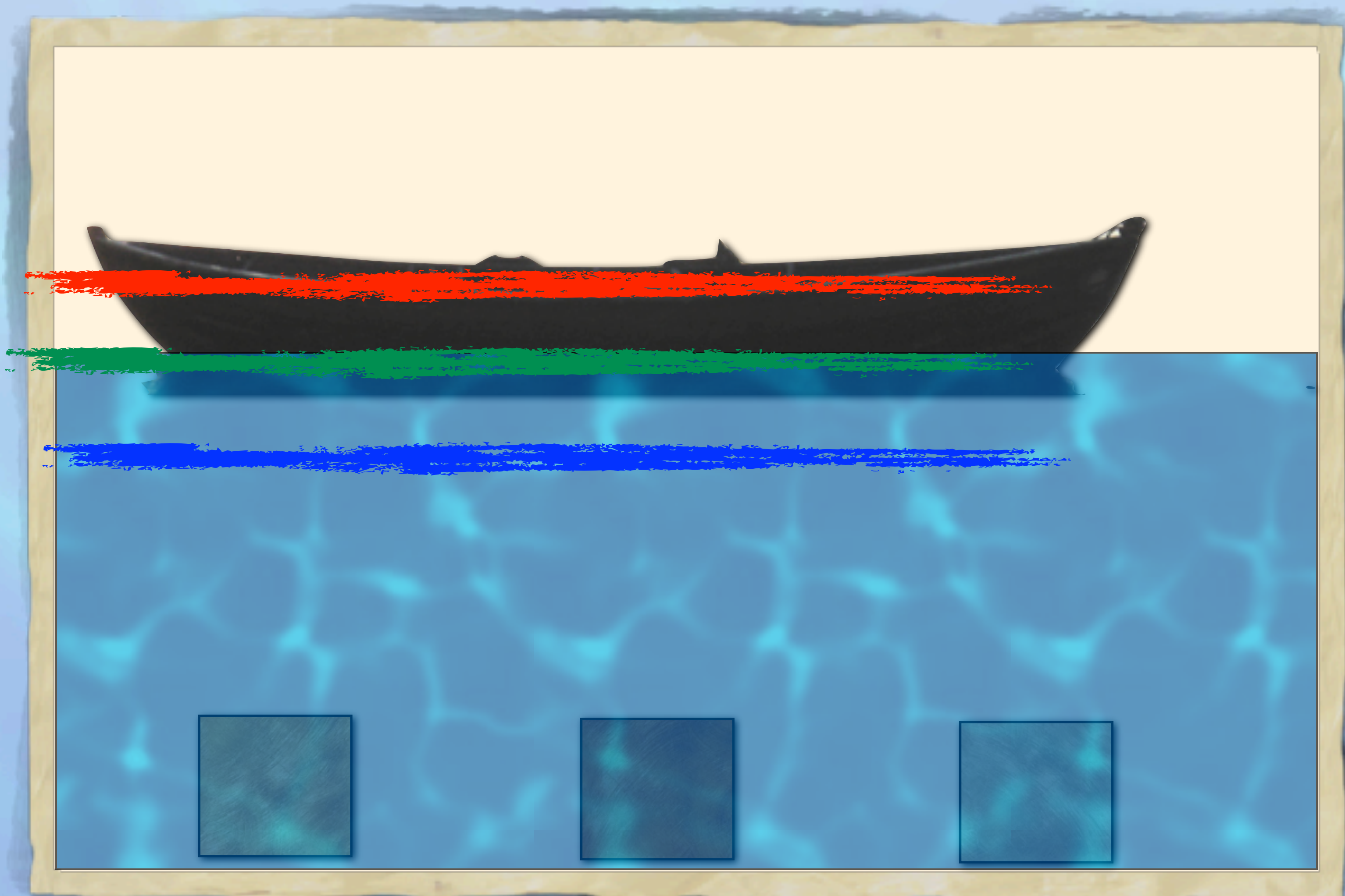
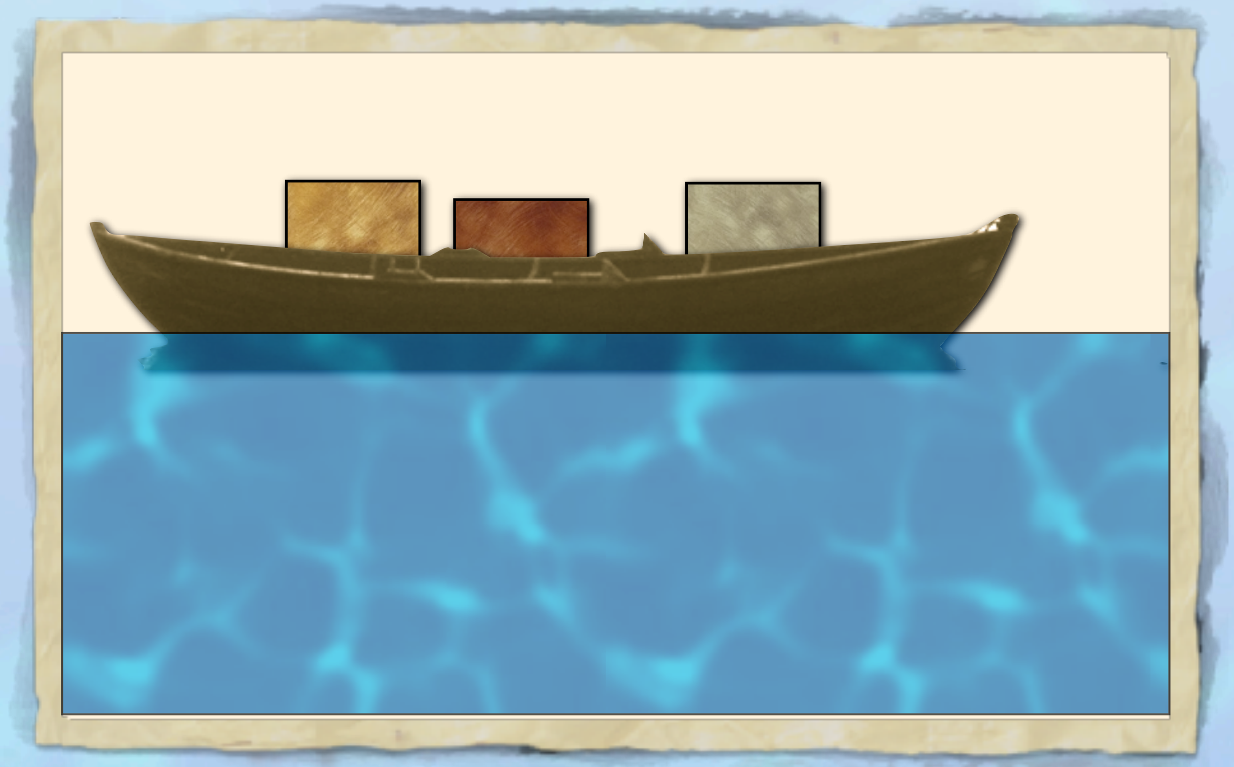


- a - the water level would rise?
- b - the water level would fall?
- c- the water level would stay the same

Think about the displaced water

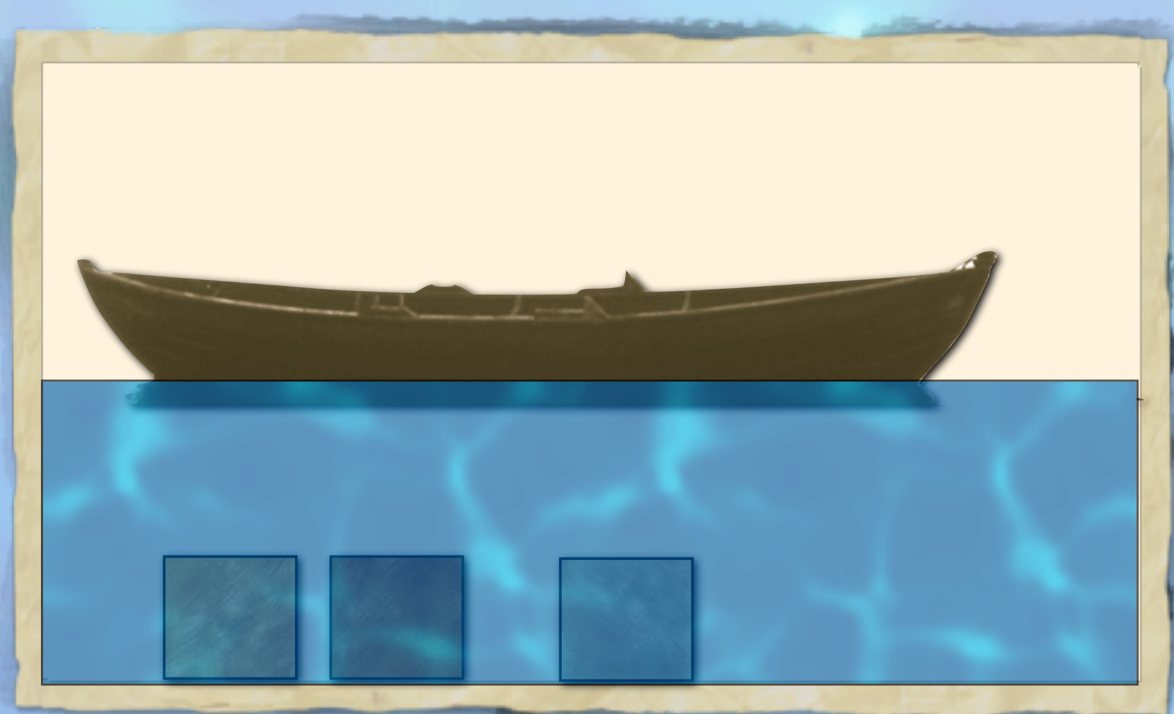


Enough water to support:

300N boat + 60N metal

360 N water

above the “regular” level
of the pool



Enough water to support:

300N boat

<u>less than</u> the 60N metal
maybe 320 N water

the water level falls
the boat rises in the water

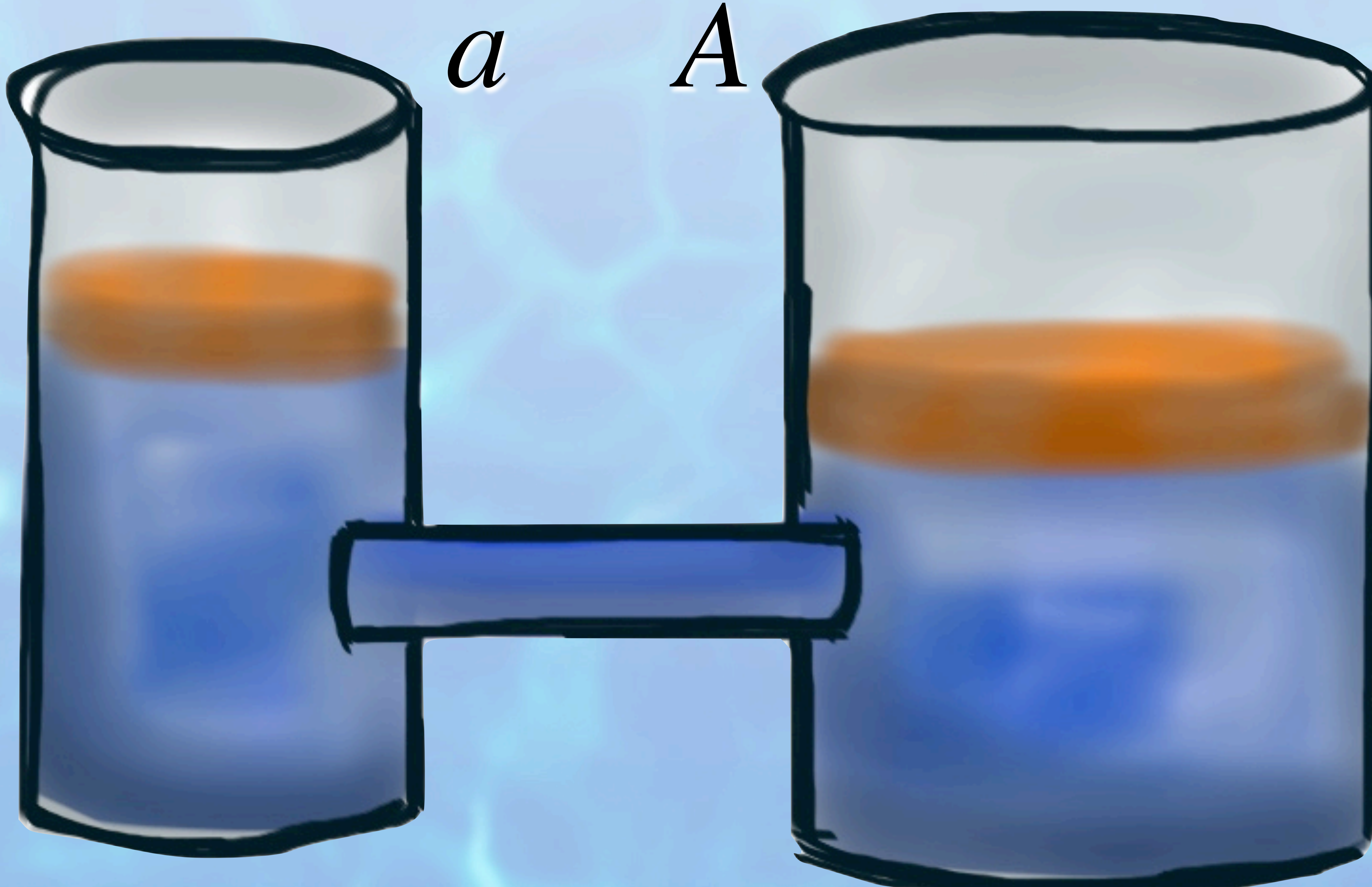
What do you think?

Pascal's Principle

- Pressure applied to an enclosed fluid is transmitted undiminished to every part of the fluid, as well as to the walls of the container.

Another Machine

$$\frac{f}{a} = \frac{F}{A}$$



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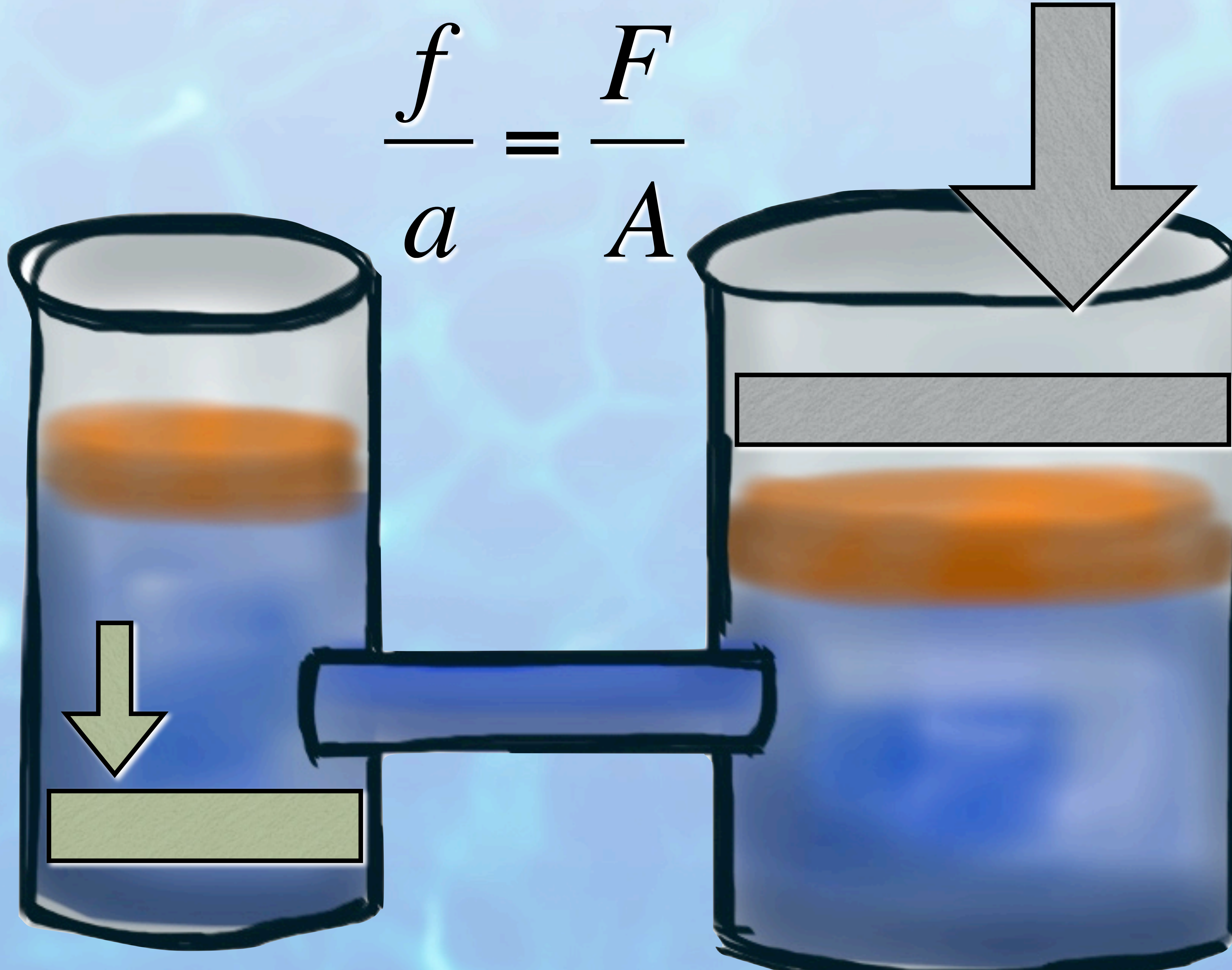

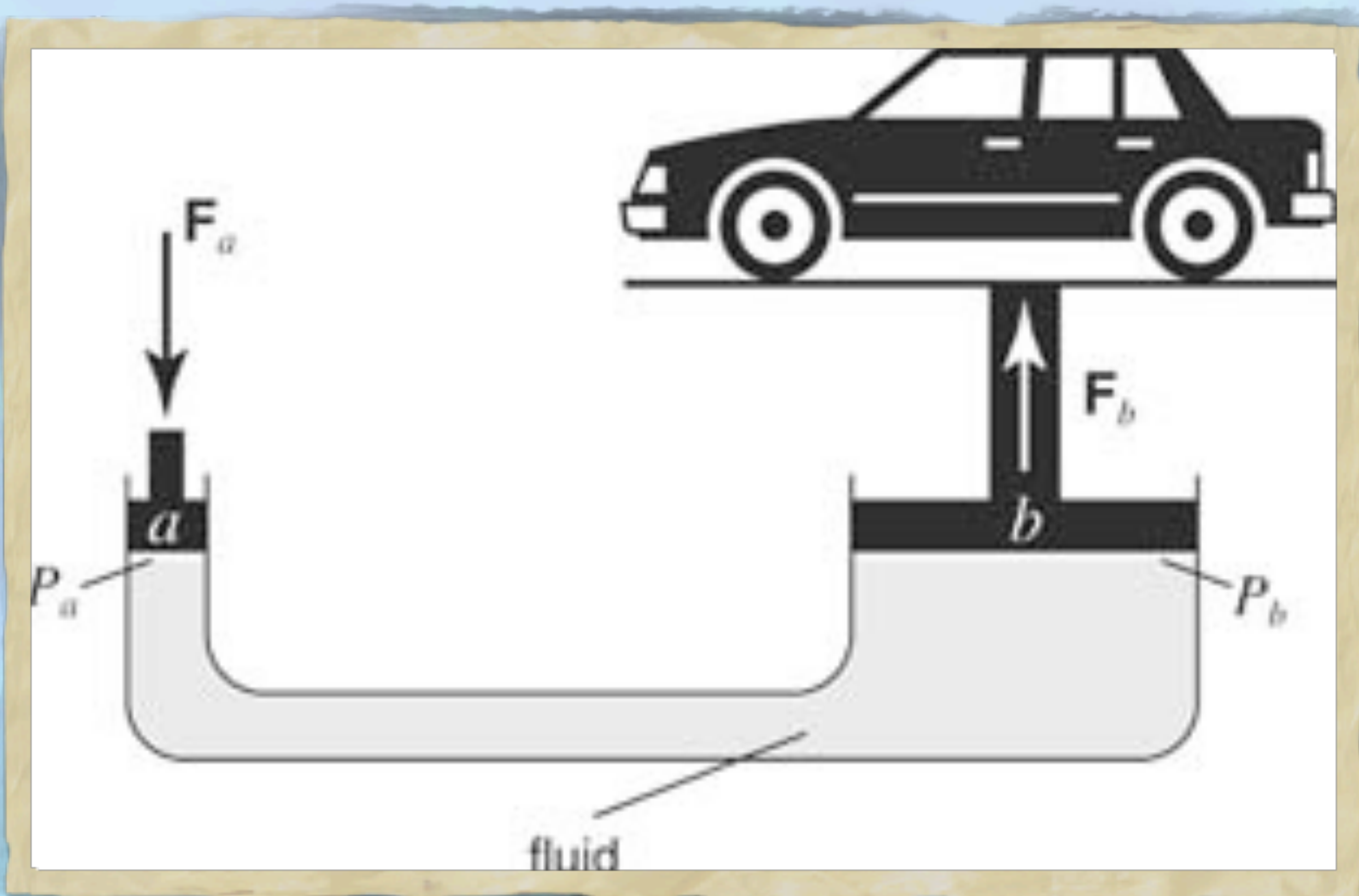

Sample

- A car weighs 540 N, and sits on the larger piston of a hydraulic lift. The diameter of the larger side is 1.5 m, the smaller is 0.5 m.
- How much force is required to lift the car?

Sample Problem

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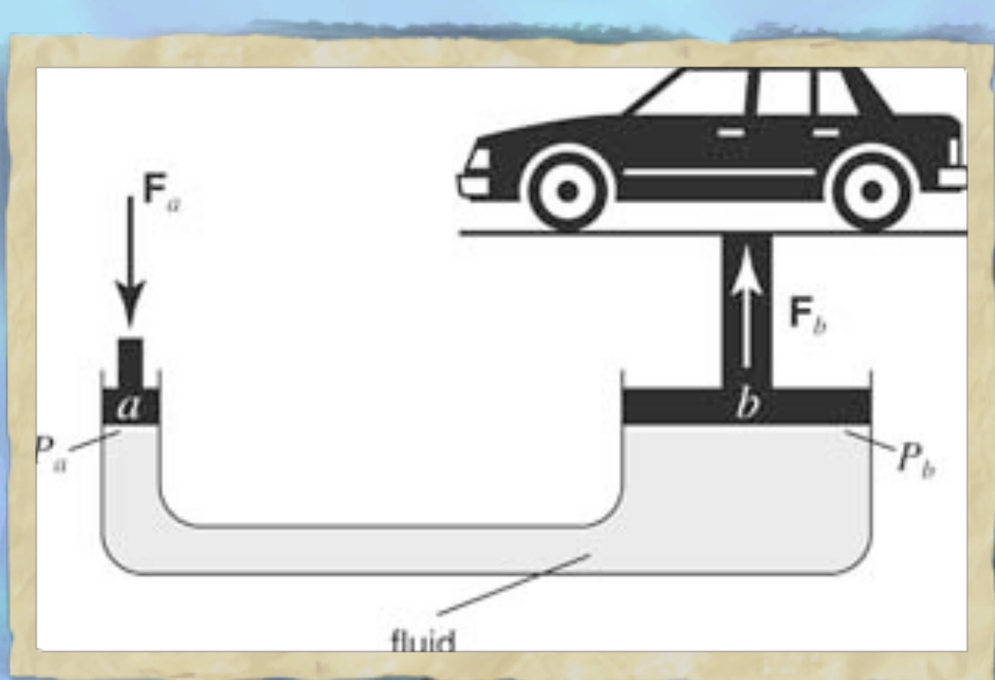
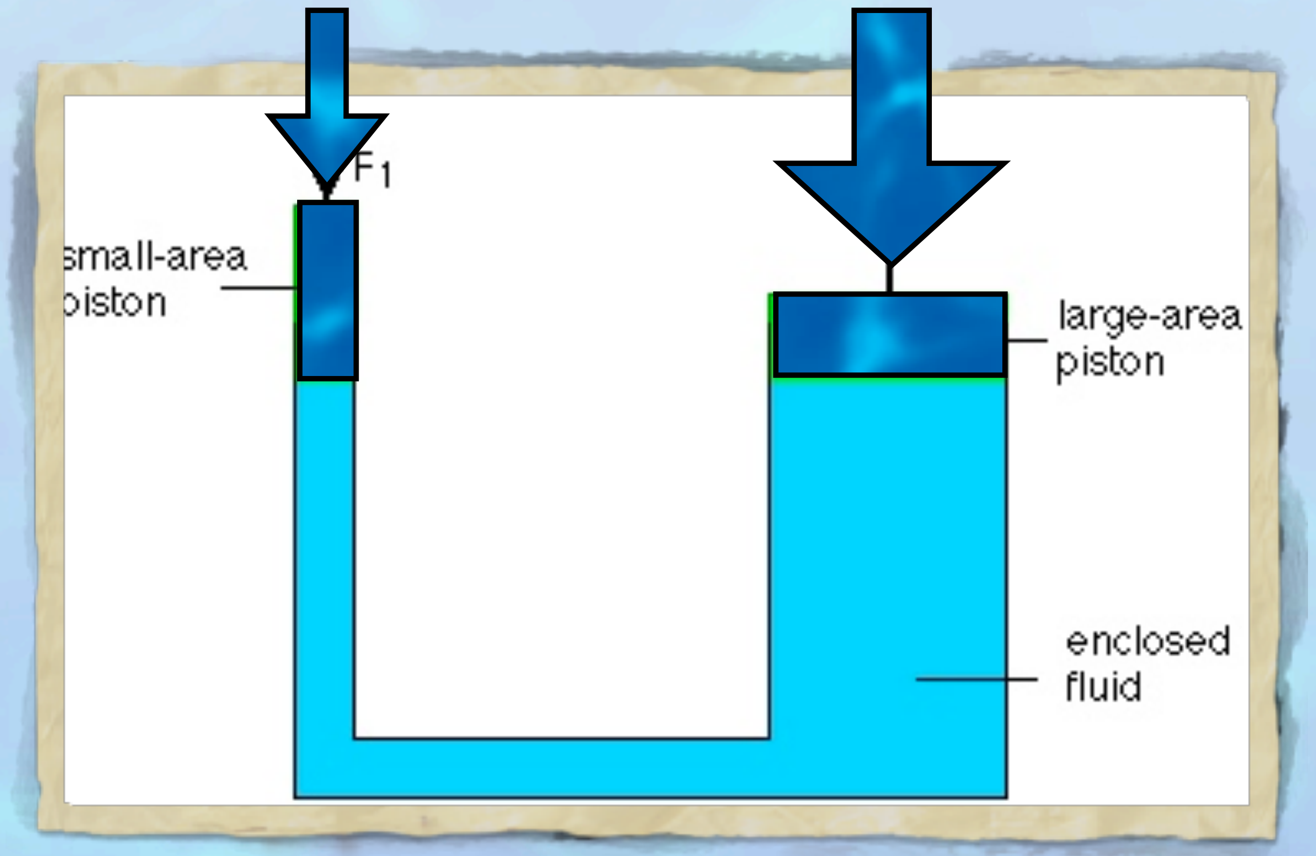
$$\frac{F}{A} = \frac{f}{a}$$

$$\frac{540}{\pi(.75)^2} = \frac{f}{\pi(.25)^2}$$



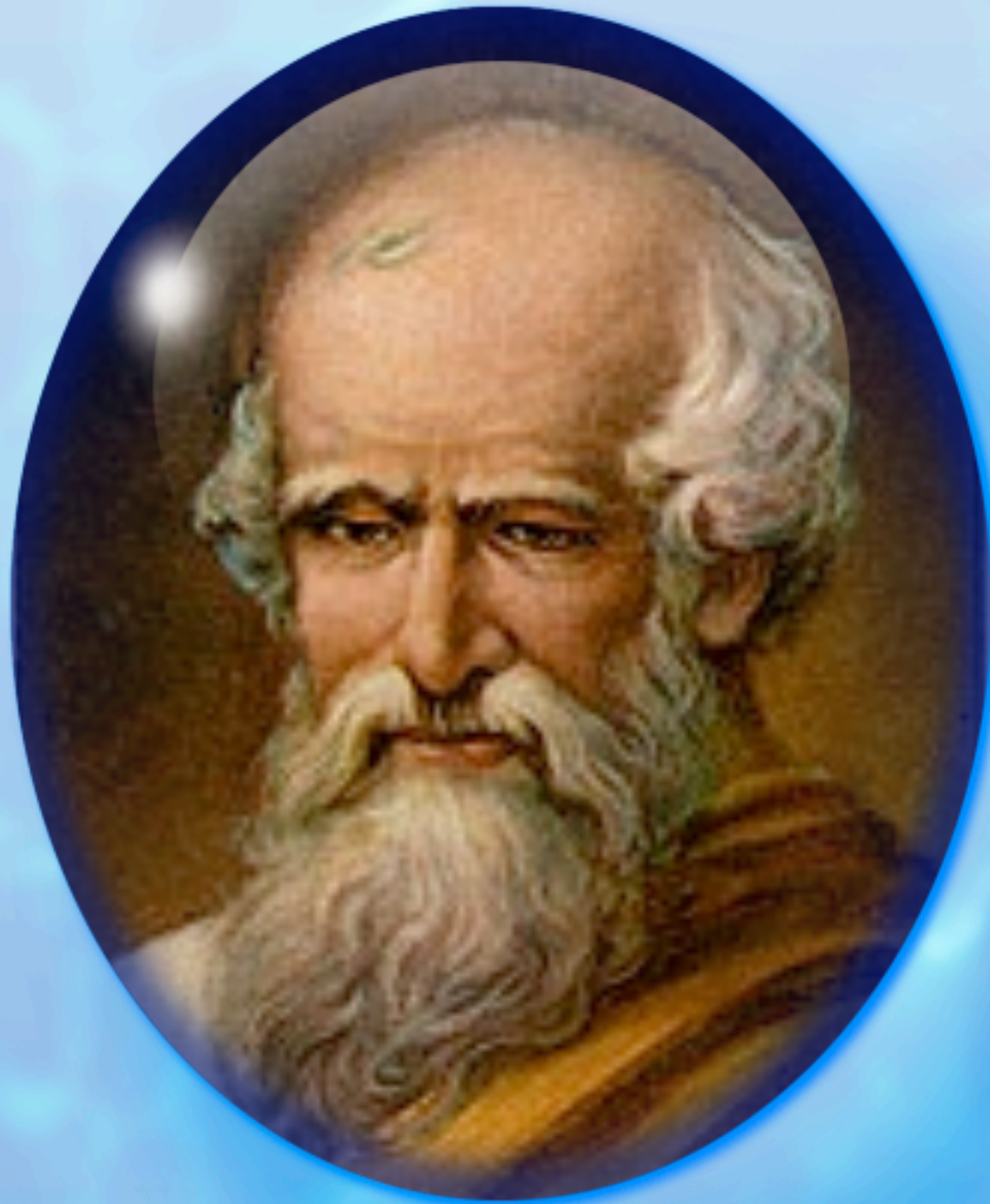
- f = 60 N
- 1/9 of the Force
- 1/3 of the radius

Remember Machines



- Can't be more than 100% efficient
- Greater force ⇒ smaller distance
- ratio of areas
- constant volume

Archimedes Principle



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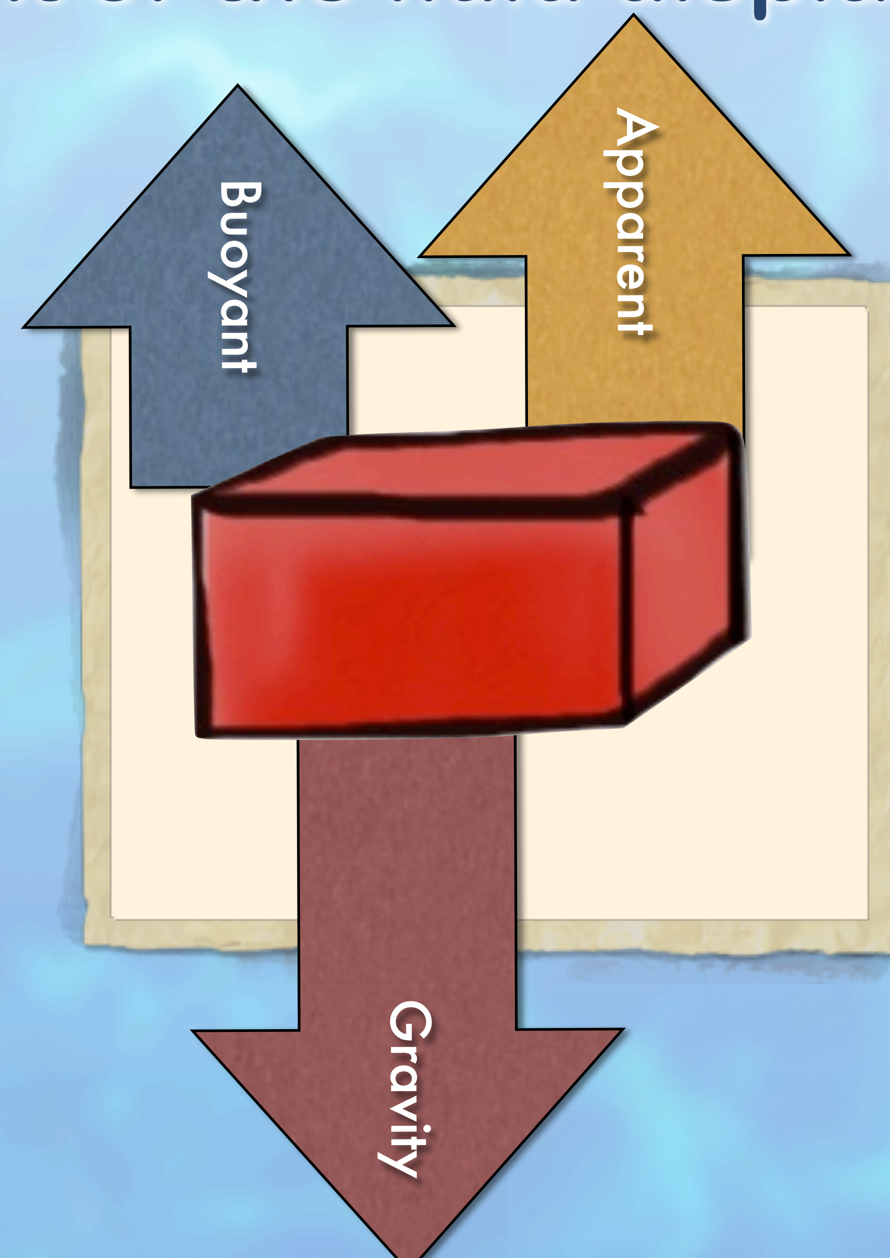

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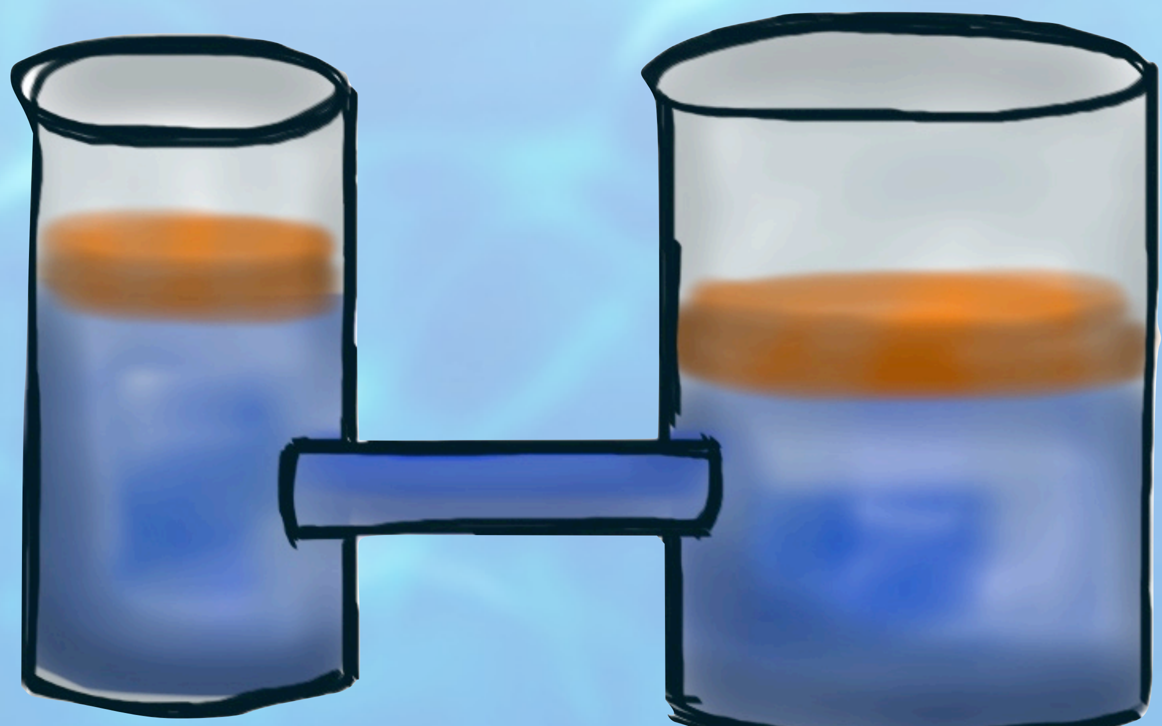
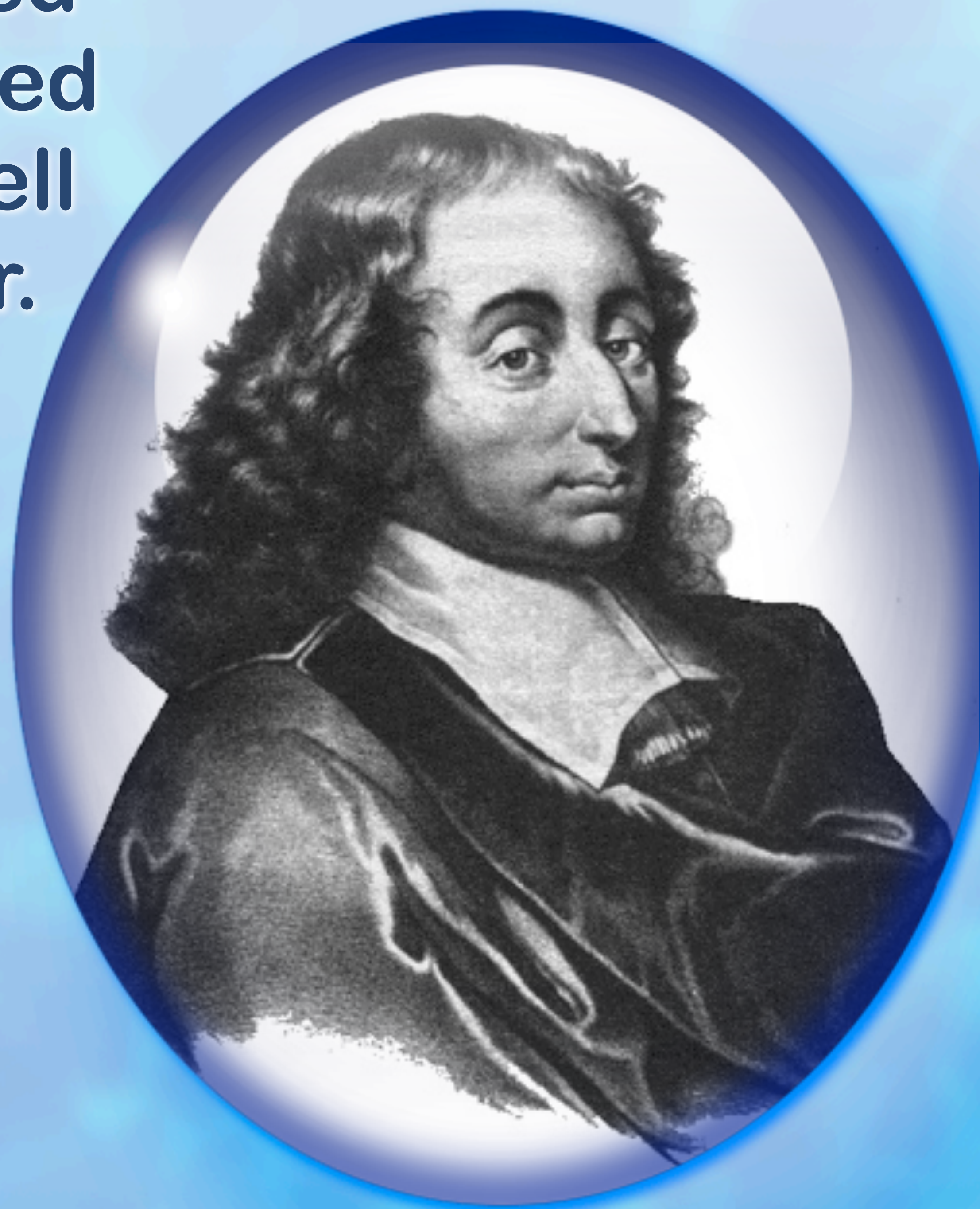




Water Pressure from a Tank

- How fast would the water come out from the bottom?

Bernoulli's Theorem

A fluid exerts a lower pressure at higher velocities

Sum of 3 types of pressure remains constant

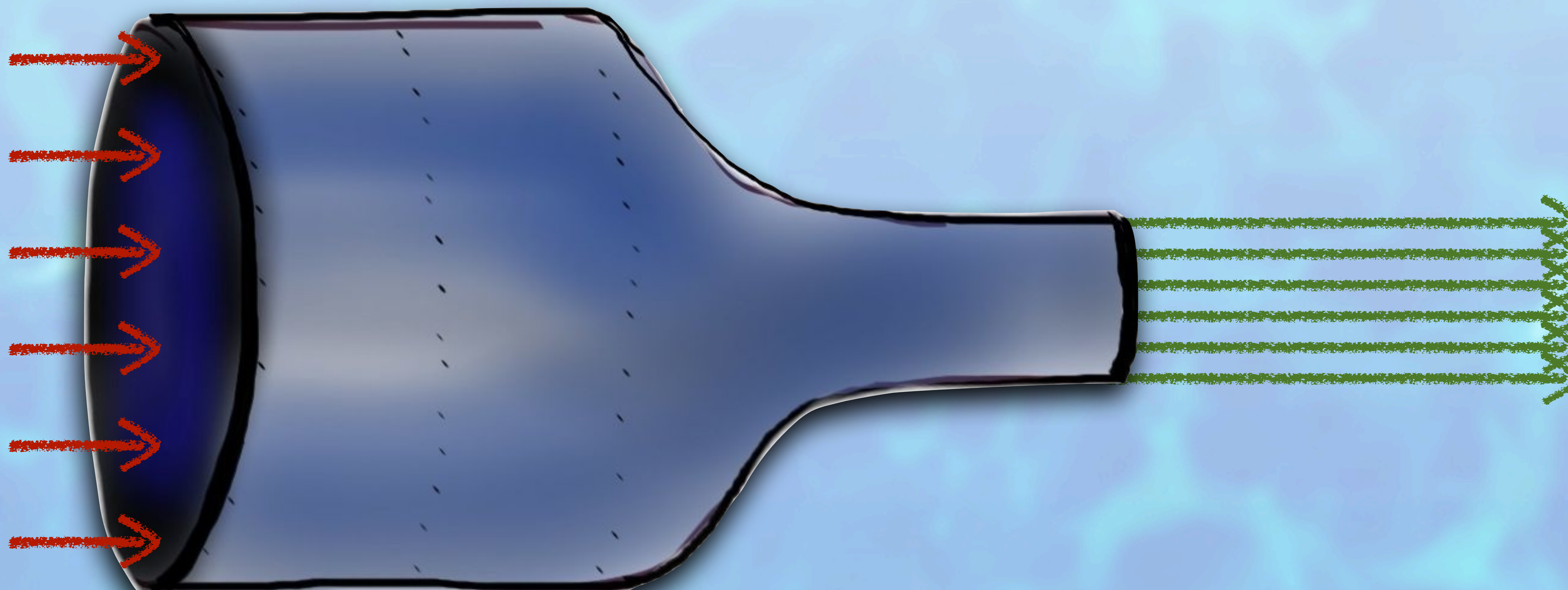
P (think applied)

ρgh (think potential)

$\frac{1}{2}\rho v^2$ (think kinetic)

Equation of Continuity

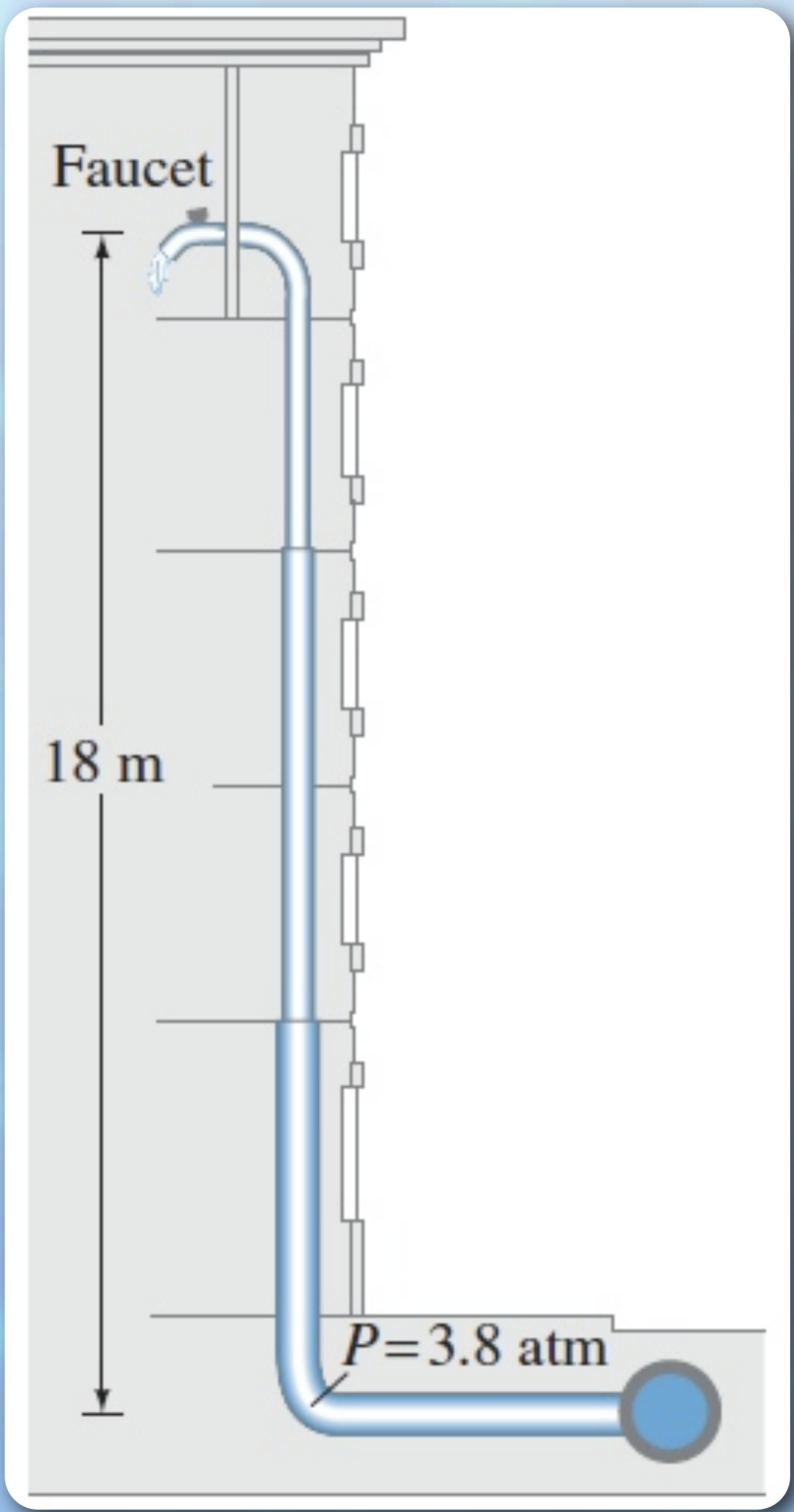
$$A\,v = V\,a$$



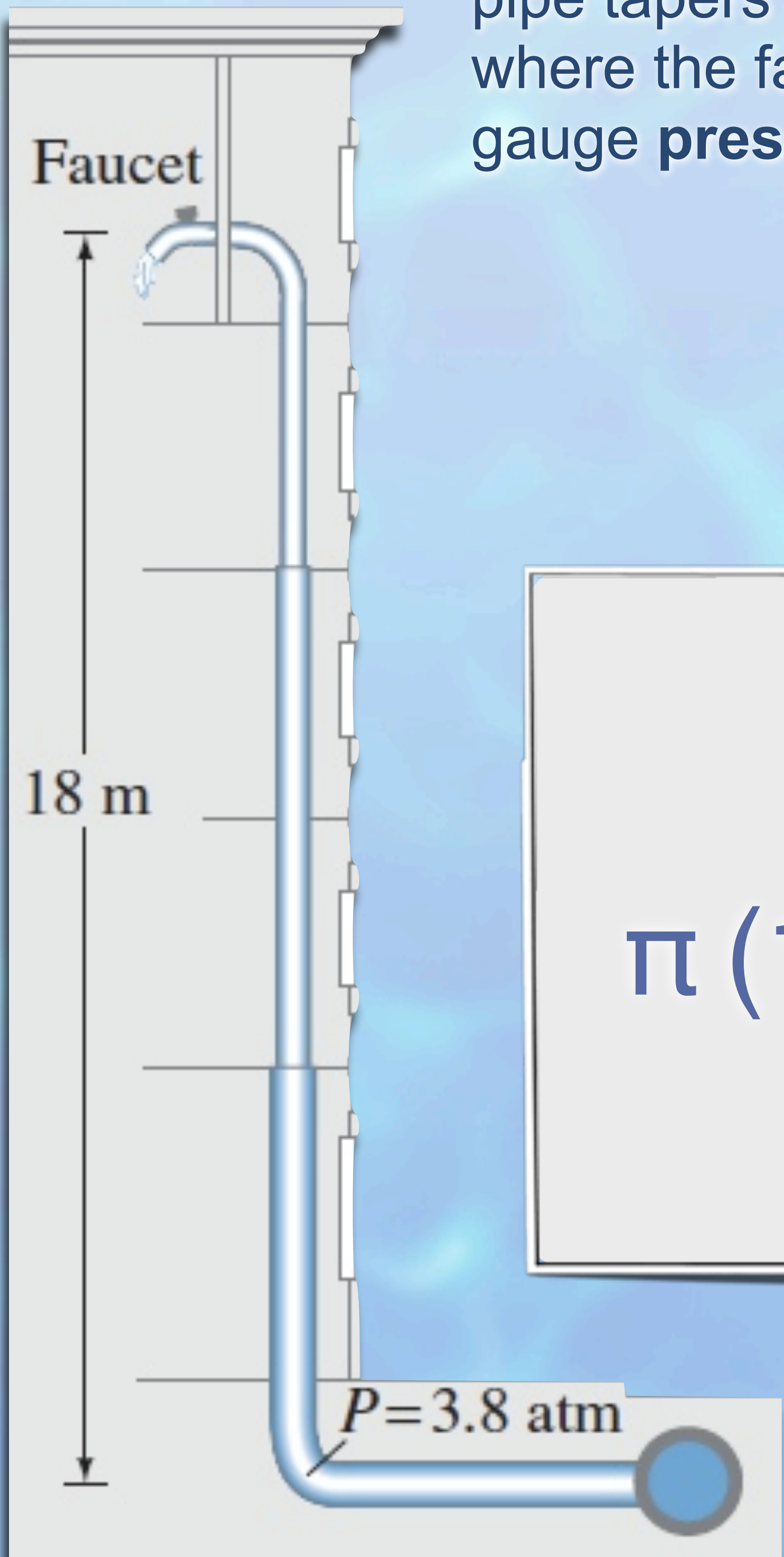
Bernoulli

$$P + \frac{1}{2}\rho v^2 + \rho g h$$

G # 46



Water at a gauge pressure of 3.8 atm at street level flows into an office building at a speed of 0.6 m/s through a pipe 5.0 cm in diameter. The pipe tapers down to 2.6 cm in diameter by the top floor, 18 m above , where the faucet has been left open. Calculate the flow velocity and the gauge pressure in such a pipe on the top floor.



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$$A_a v_a = A_b v_b$$

Top		Bottom
$\pi\,(1.3)^2\ V_{top}$	$=$	$\pi\,(2.5)^2\,(0.6)$
V_{top}	$=$	2.219 m/s

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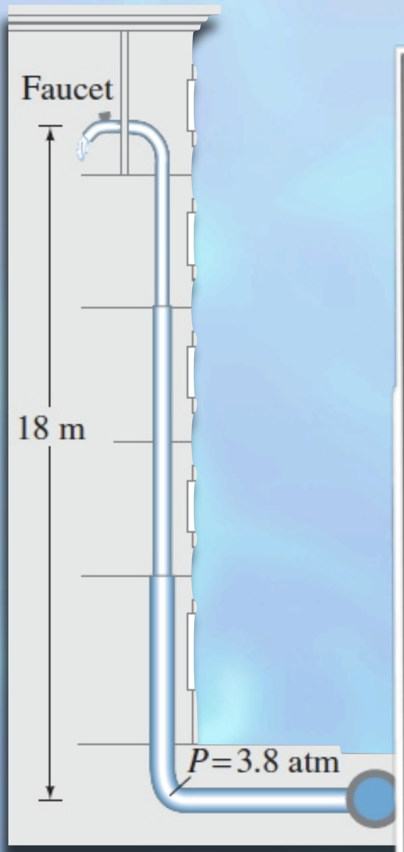
$$P_a + \rho g h_a + \tfrac{1}{2}\rho {v_a}^2 = P_b + \rho g h_b + \tfrac{1}{2}\rho {v_b}^2$$



Bottom

P +	ρgh +	0.5ρv²
3.8atm +	(1000)(9.8)(0) +	(0.5)(1000)(0.6²)
383,800 +	0 +	180

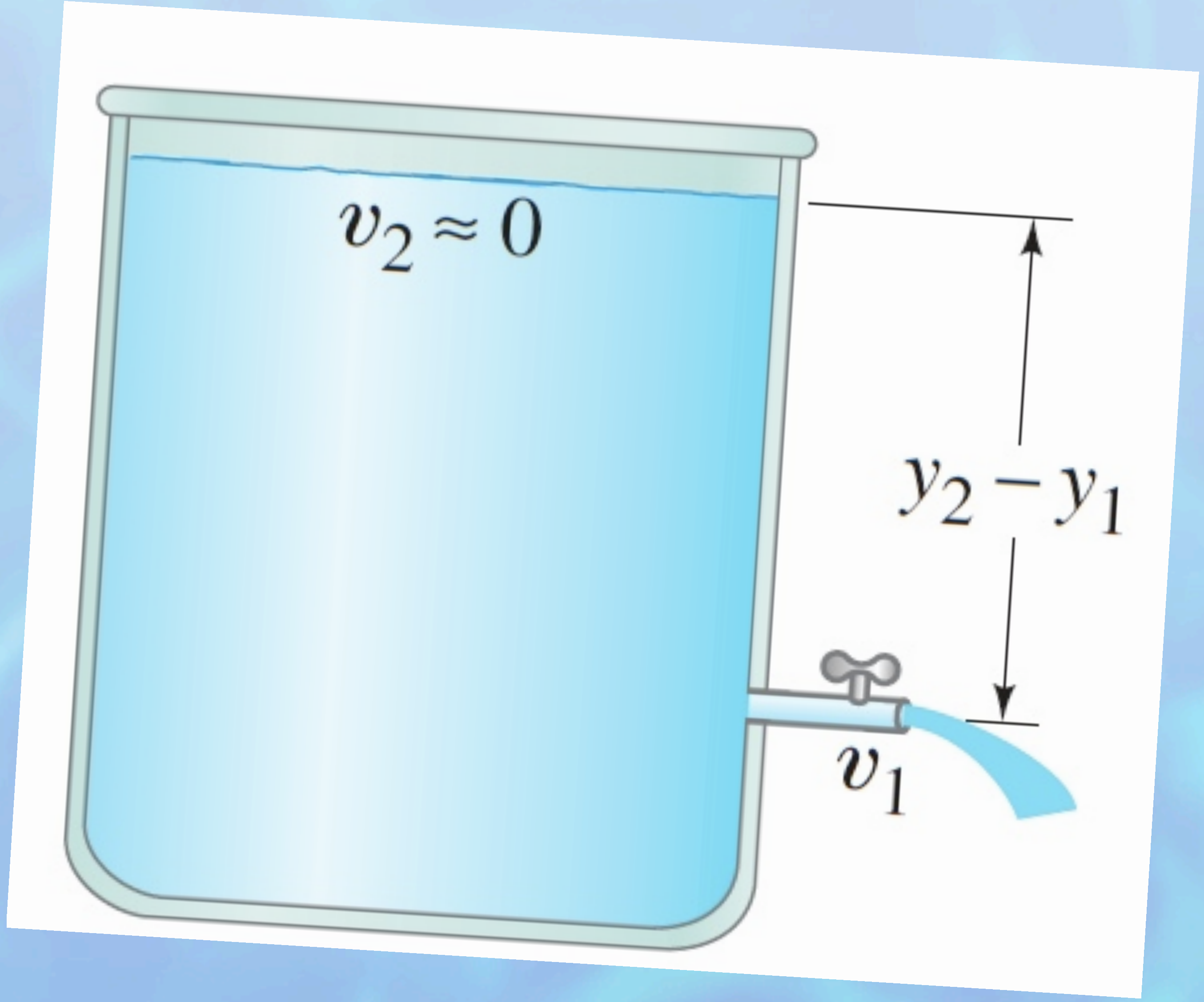
Total = 383,980 Pascal (Pa)

P +	ρgh +	0.5ρv²
P +	(1000)(9.8)(18) +	(0.5)(1000)(2.219²)
P +	176,400 +	2462

P = 205,118 Pa = 2.03 atm

G. #38

- How fast does water flow from a hole at the bottom of a very wide, 4.6-m-deep storage tank filled with water?



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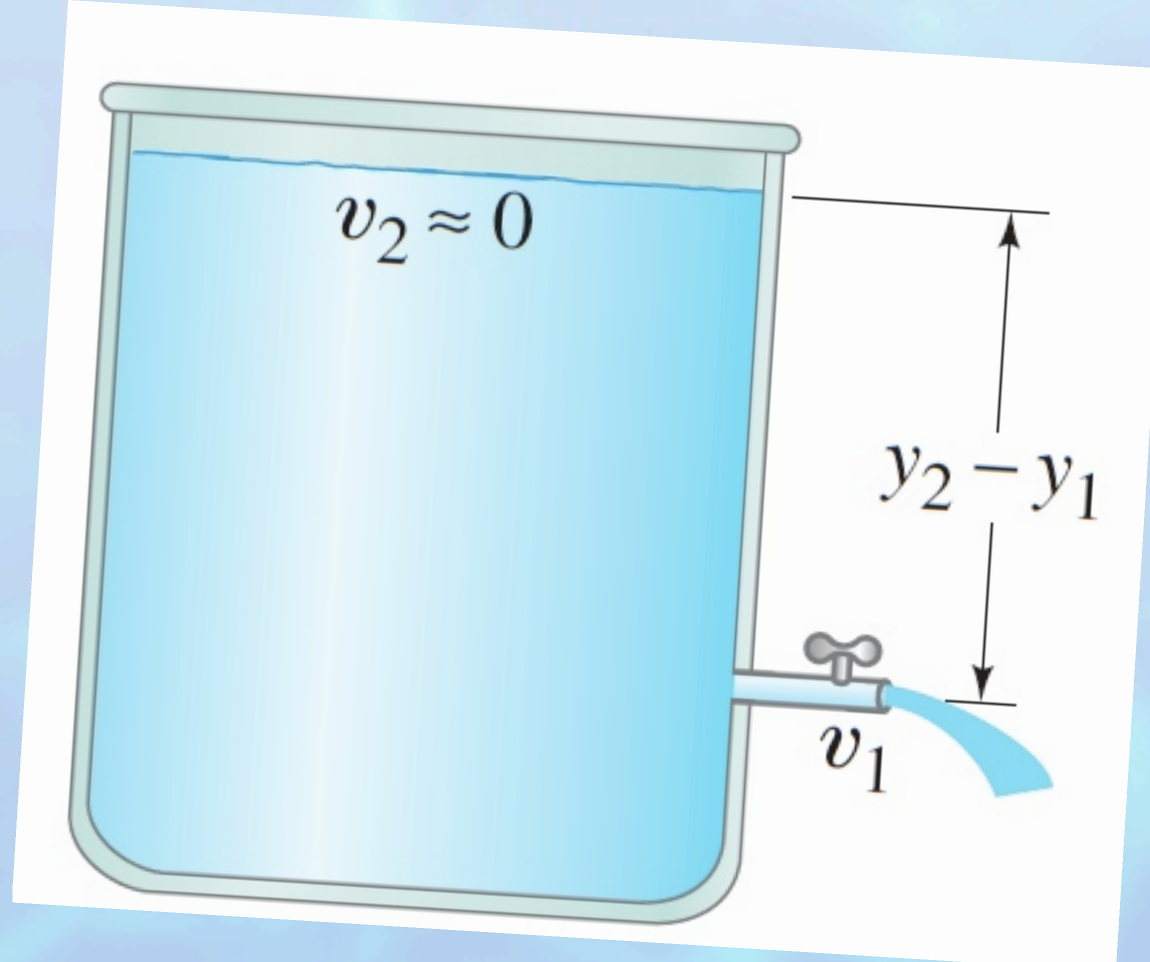
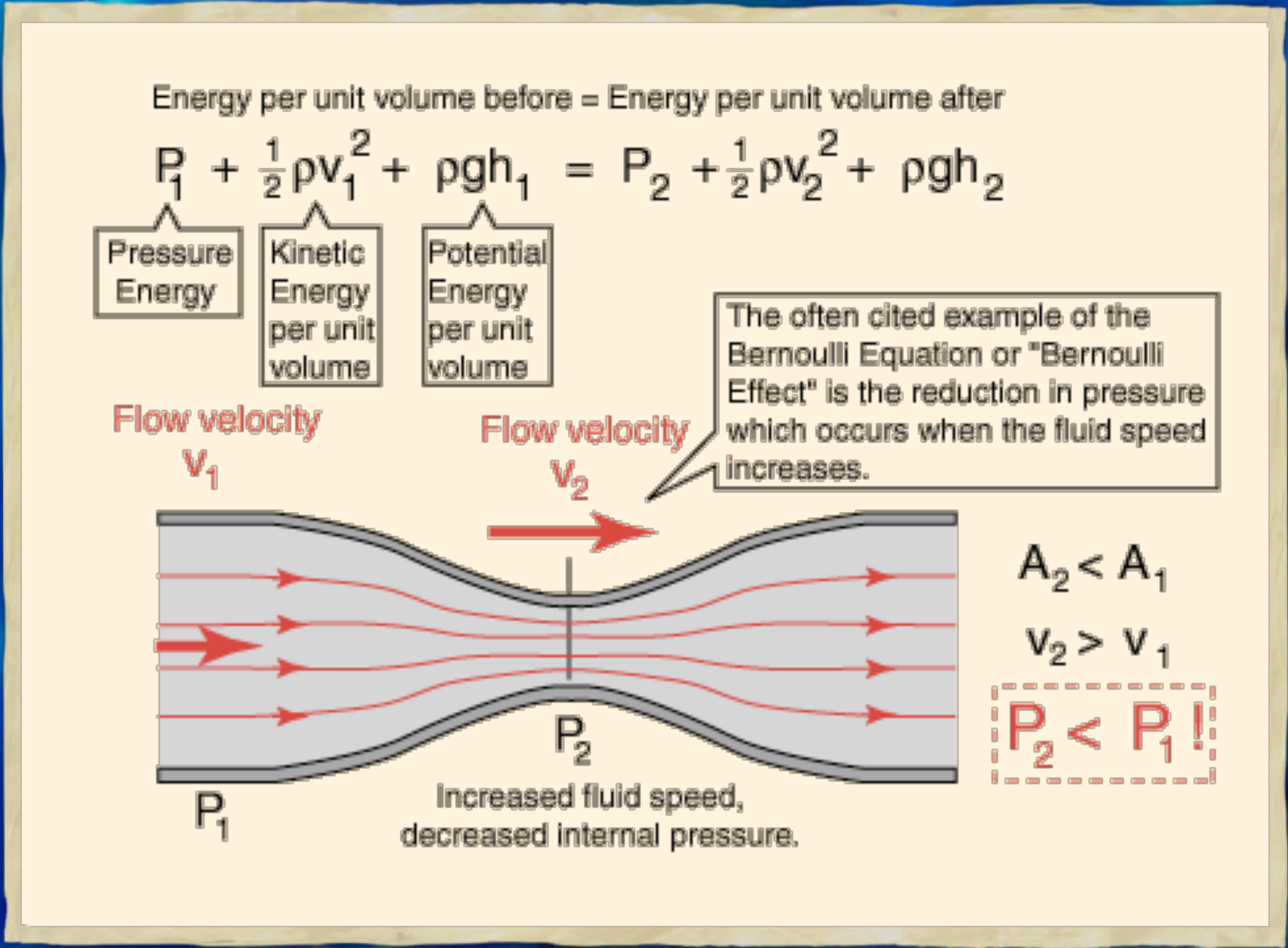


$$P_a + \rho g h_a + \tfrac{1}{2}\rho v_a{}^2 = P_b + \rho g h_b + \tfrac{1}{2}\rho v_b{}^2$$

$$v_b = \sqrt{2g(h_a - h_b)}$$

Bernoulli's Theorem



Bernoulli's Theorem