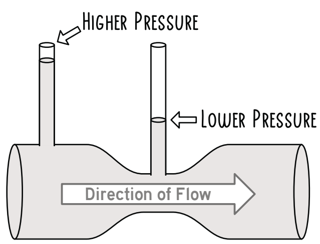
Unit 3: Fluids and Pressure

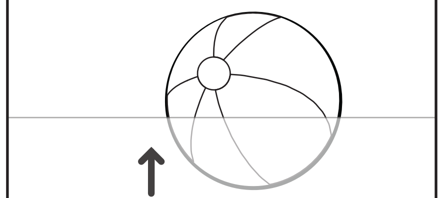
Liquids and gases are both fluids!

BERNOULLI'S PRINCIPLE



As the speed of a fluid increases, the pressure decreases

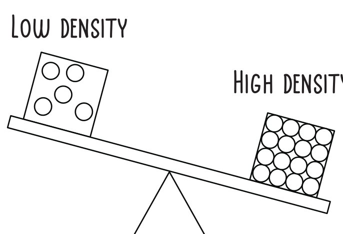
BUOYANCY



$\vec{F}_b=-\rho g V$

The upward force exerted by a fluid on an object

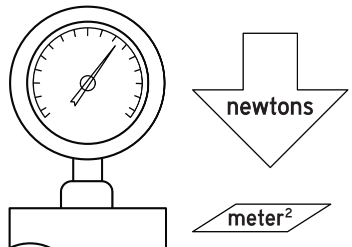
DENSITY



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

How compact something is or how much mass per unit of volume

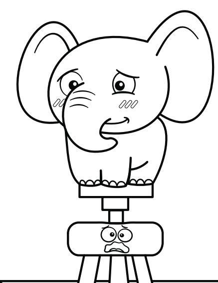
PASCALS



Pa

A measure of pressure: newtons per square meter

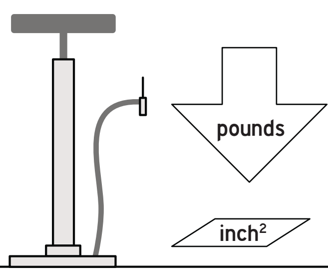
PRESSURE



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

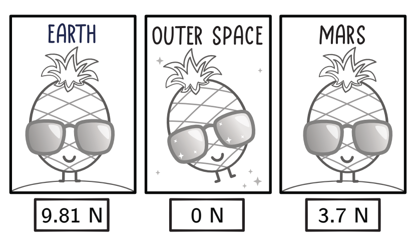
The amount of perpendicular force applied per unit of area

PSI



A measure of pressure: pounds per square inch

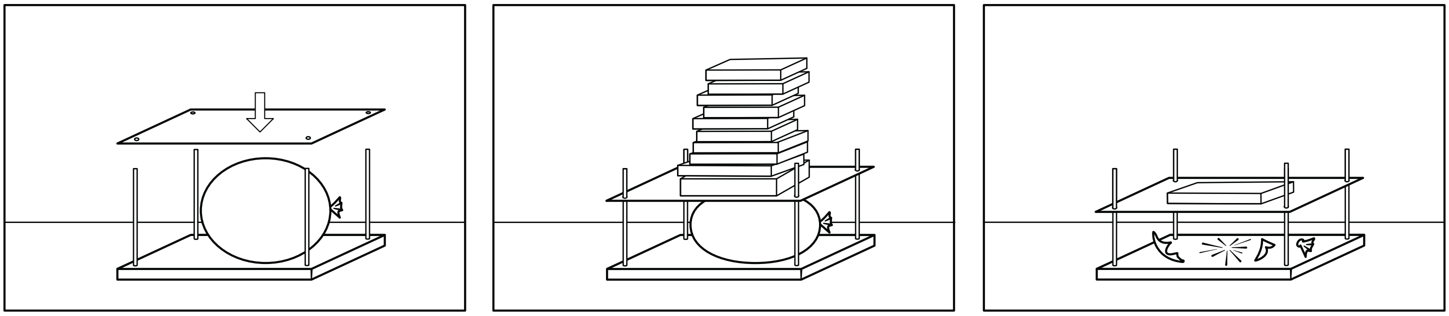
WEIGHT



$W=m\cdot g$

The force acting on an object due to gravity

Pressure



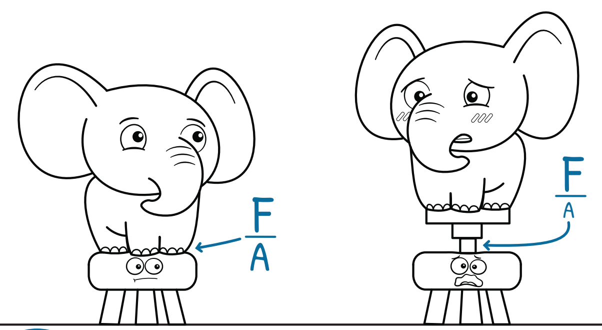
A balloon can support the weight of 10 books before popping. But if a pin is placed on the bottom of the press, then the balloon pops under the weight of one book. Why?

Answers will vary, but hopefully this introduction got you thinking about how the same amount of weight can feel very different depending on how much area it is applied to.

PRESSURE VS WEIGHT

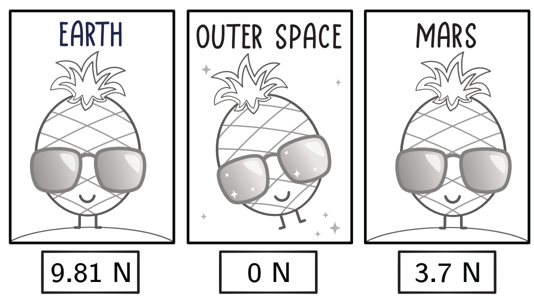
LABEL EACH CARD WITH THE CORRECT TERM AND DEFINITION, THEN DESCRIBE THEIR SIMILARITIES AND DIFFERENCES.

PRESSURE



$P = \frac{F}{A}$ The amount of perpendicular force applied per unit of square area.

WEIGHT



$W = m \cdot g$ The force acting on an object due to gravity

SOMETHING SIMILAR: Both can cause things to move or bend. Weight can cause pressure.

SOMETHING DIFFERENT: Weight is a force and tells you nothing about area. Pressure has area in the units. Also, weight is a vector, pressure is not (it's a scalar quantity)

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

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

Pressure is measured in many different units!

Pascal (Pa) or Kilopascal (kPa)
The SI unit for pressure (N/m^2)

Millimeters of Mercury (mmHg)
Blood pressure measurements. The standard 120/80 is in mmHg

Torr
Used with vacuum applications

Pounds per square inch (PSI)
Mechanical and structural engineering, tire pressure

Atmosphere (atm)
Atmospheric pressure

Bar or millibar (mb)
Meteorology and geology

1 CALCULATING PRESSURE IN PSI

Pounds per square inch (PSI) is commonly used in sports equipment, the automotive industry, hydraulics and pneumatics, plumbing systems, and heating, ventilation, and air conditioning (HVAC) systems.

Bob weighs 140 lbs and wears shoes that have perfectly rectangular soles measuring 4 x 10 inches. How much pressure does Bob exert on the ground in PSI?

Pressure = Force/Area.

The area of the sole of each shoe is 40 in^2. When Bob is standing on both feet his weight is applied across both shoes, so the pressure is 140 lbs/80 in^2 = 1.75 PSI or 1.75 pounds per square inch.

Does the pressure change when Bob stands on one foot? If yes, by how much?

Yes. It doubles.

Bob is standing on one foot, all of his weight is applied on one shoe-print (40 in^2) so the pressure is 140 lbs/40 in^2 = 3.5 PSI or 3.5 pounds per square inch.

Use the conversion table to calculate the pressure of Bob's footprints in kPa and atmospheres (atm).

When standing on 2 feet, Bob is applying 12.07 kPa of pressure or 0.119 atm of pressure:

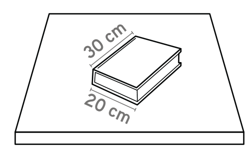
$1.75 \text{ PSI} \; \frac{6.895 \text{ kPa}}{1 \text{ PSI}} = 12.07 \text{ kPa} \qquad 12.07 \text{ kPa} \cdot \frac{1 \text{ atm}}{101.3 \text{ kPa}} = 0.119 \text{ atm}$

When standing on 1 foot, the pressure is doubled (24.14 kPa or 0.238 atm)

2 CALCULATING PRESSURE IN KPA

Pascals is the SI unit for pressure, but it's a SMALL measurement. One pascal is roughly equal to the pressure a piece of paper exerts on a table. So the kilopascal (kPa) is more commonly used.

A book with a mass of 1.5 kg (weighing 14.7 N) rests on a table. The entire surface of the 20 cm x 30 cm cover is in contact with the table. How much pressure is the book exerting on the table in pascals (newtons/m^2)? How much in kilopascals?

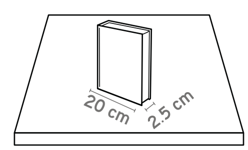


Pressure = Force / Area. To calculate the force the book is exerting on the table in pascals, we need to be sure we have the correct units of newtons/m^2.

The area where the force (weight) is being applied is 20 cm · 30 cm = 600 cm^2 = 0.06 m^2.

The pressure = 14.7N/0.06 m^2 = 245 Pa or 0.245 kPa

Now the book is balanced on its edge so the surface in contact with the table is 2.5 cm x 20 cm. How much pressure does the book exert now? This time calculate both pascals and kilopascals.



The area where the force (weight) is being applied is 20 cm · 2.5 cm = 50 cm^2 = 0.005 m^2.

The pressure = 14.7N/0.005 m^2 = 2,940 Pa or 2.94 kPa

BONUS: FIGURE IT OUT FOR YOU!

HOW MUCH PRESSURE DO YOU EXERT ON THE GROUND? TRACE YOUR FEET ON GRAPH PAPER AND ESTIMATE THE AREA, THEN WEIGH YOURSELF AND CALCULATE THE PRESSURE!

CONVERSIONS

1 PSI = 6.895 kPa
1 Pa = 1,000 kPa
1 atm = 101.3 kPa

Fluids

Gases and liquids are both called **fluids** and share a fundamental property: the ability to flow. Make notes about some of their key characteristics in the spaces below:

FLOW

Fluids move or deform in response to stress or force. This flow behavior results in the fluid spreading out & filling up space.

Ex. Air and CO_2 - can be 'poured' from one cup to another

DENSITY

Like solids, fluids have density (mass/volume)

But fluids can have more dramatic changes in their density when temperature or pressure change.

Ex. Remember cold vs hot water / rubbing alcohol (thermal expansion)

VISCOSITY

Viscosity is the resistance to deformation or flow. All fluids have some viscosity, but it's much more noticeable in liquids than gases.

Ex. Honey is more viscous than water, water is more viscous than gasoline

PRESSURE DISTRIBUTION

Key property!

Fluids exert pressure evenly in all directions. Their molecules are moving rapidly and randomly - this results in an even pressure on all sides of the container.

Ex. Round balloon, fish tank

As with most categories and labels, some items fit within the norm and others do not conform! Draw lines to match each of the following fluids with their best description:

Flows easily: has low viscosity

Resistance to flow: has high viscosity

Behaves in ways that don't match the typical definition of a fluid

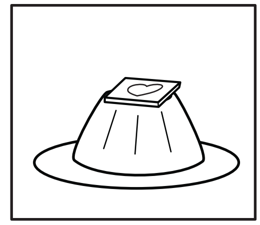
Practice Problems – Pressure & Fluids

① If a force of 10 newtons is applied over an area of 2 square meters, what formula is needed to calculate the pressure? What will the units be?

$P = \frac{F}{A}$ Pressure = Force divided by area. Newtons divided by square meters gives the unit of pascals.

$\frac{10\ N}{2\ m^2} = 5\ N/m^2 = 5\ Pa$

② A decorative book with a weight of 12 N is resting on top of a gelatin dessert at a wedding reception. If the base surface area of the book is 0.04 m^2. How much pressure (in pascals) is the book applying on the gelatin dessert?

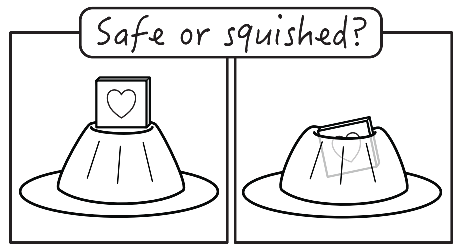


$\frac{12\ N}{0.04\ m^2} = 300\ Pa$

The book is applying 300 pascals of pressure on the dessert.

③ The gelatin desert can withstand pressure of 400 pascals before collapsing. The wedding planner wants the book to be set on edge so it has better visibility. Is this a good idea, or would the new orientation squish the desert?

The base surface area when the book is upright is 0.003 m^2.



$\frac{12\ N}{0.003\ m^2} = 4{,}000\ Pa$

The pressure from an upright book will squish the dessert, but putting a not-too-heavy plate underneath the book would fix that!

④ The pressure exerted by a fluid is evenly applied in all directions. Explain why this is the case.

The molecules in a fluid are moving constantly with rapid motion. The collisions of the molecules against the other object will produce an even pressure that is the same in all directions.

⑤ If an elephant with a mass of 4000 kg stands on 2 feet, each with a surface area of 0.2 m^2, what is the pressure exerted on **each foot** in kPa? (Tip: 1kg = 9.8 N on Earth.)

Each foot is supporting 2000 kg for a total force of $2000\ kg = 2000\ kg \cdot \frac{9.8\ N}{1\ kg} = 19,600\ N$.

The total pressure is force divided by area:

$$\frac{\text{force}}{\text{area}} = \frac{19,600\ N}{0.2\ m^2} = 98,000\ \frac{N}{m^2} = 98,000\ Pa = 98\ kPa.$$

Practice Problems – Pressure & Fluids

7. If the **area** over which a force is applied **increases**, what will happen to the pressure?
   A. It increases
   B. It decreases
   C. It remains the same

8. A 10 N force is applied to a region of area 2 m^2 while a 20 N force is applied to a region of area 4 m^2. Which force created more pressure?
   A. The 10 N force
   B. The 20 N force
   C. Both created the same amount of pressure
   D. There is no way to know

   $10N/2m^2$ = 5 Pa of pressure

   $20N/4m^2$ = 5 Pa of pressure

9. What unit is used to measure tire pressure in the US, Canada, and the UK?

   PSI or pounds per square inch

10. Rank the following activities from MOST to LEAST pressure applied on a surface. (Assume that the same person is doing all 5 actions)
    A. Lying down B. Sitting on bench C. Standing on tiptoes D. Standing on one foot.

    C, D, B, A.

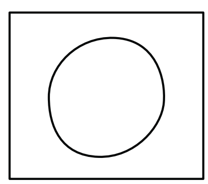
    The same weight applied to a smaller area of contact will result in greater pressure.

11. Which statement about oobleck (a 1:1 mixture of cornstarch and water) is true?
    A. More stress or force causes the viscosity to increase
    B. More stress or force causes the viscosity to decrease
    C. Stress or force has no effect on viscosity
    D. Oobleck is called a "Newtonian fluid"

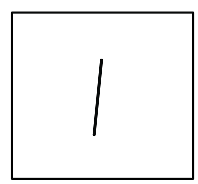
12. Which will exert more pressure on the ground, the footprint of a person wearing ice skates or an elephant? The ice skates are worn by a 110 lb person. The elephant has a mass of 8,800 lb. Each of them have all of their feet on the ground. Calculate the pressure (PSI) for each.
    A. Ice skater
    B. Elephant

    Skater pressure : $\frac{\text{force}}{\text{area}} = \frac{110\text{ lb}}{2 \cdot 1.5\text{ in}^2} \approx 36.7\text{ PSI}$

    Elephant pressure : $\frac{\text{force}}{\text{area}} = \frac{8,800\text{ lb}}{4 \cdot 250\text{ in}^2} \approx 8.8\text{ PSI}$



Surface area of elephant footprint = 250 in^2



Surface area of single ice skate = 1.5 in^2

13. Next the ice skater and elephant each balance on one foot. Who exerts more pressure on the ground?
    A. Ice skater
    B. Elephant

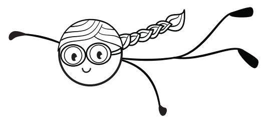
    Skater pressure : $\frac{\text{force}}{\text{area}} = \frac{110\text{ lb}}{1.5\text{ in}^2} \approx 73.3\text{ PSI}$

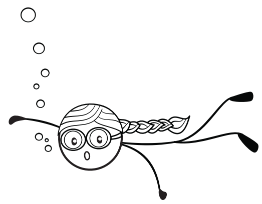
    Elephant pressure : $\frac{\text{force}}{\text{area}} = \frac{8,800\text{ lb}}{250\text{ in}^2} \approx 35.2\text{ PSI}$

Going for a Swim

Think about it:

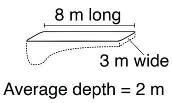
At surface:
Ears don't pop

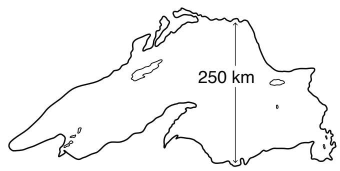




8 feet deep:
Ears pop

Backyard pool:
48 cubic meters

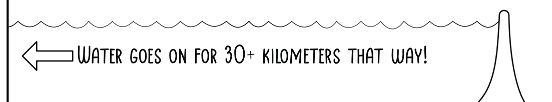




Lake Superior:
12.1 trillion cubic meters

When Emily dives 8 feet deep in a backyard pool, she feels her ears "pop" as the pressure changes. Would there be more, less, or the same pressure diving to 8 feet in Lake Superior?

Answers will vary, but students might know from experience that the feeling of increased pressure from being a certain depth underwater is the same regardless of how large the pool or lake is.



Large lake, 3 meters deep and over 30 km wide

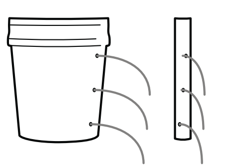
Koi pond, 3 meters deep and 1.5 meters wide

Which of these dams would experience more pressure? The one holding back a large lake or koi pond?

Predictions will vary! The actual answer is that the height is the same for both dams so the pressure is also the same.

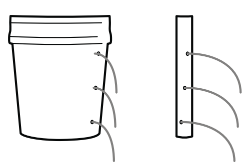
Holes are drilled in a 5 gallon bucket and a narrow piece of pipe. The holes are the same diameter and depth. Which of these drawings matches your prediction for how the water will flow out?

A



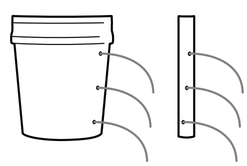
Stronger spouts from bucket but same from all holes. Hole position doesn't matter but container size does.

B



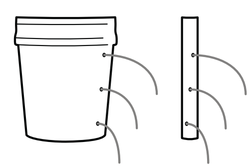
Stronger spouts from pipe but same from all holes. Hole position doesn't matter but container size does.

C



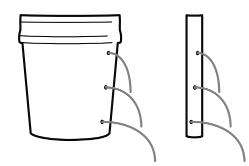
Same-sized spouts from all of the holes. Position and container shape make no difference.

D



Stronger spouts from top but same pattern from bucket and pipe. Hole position matters, not container size.

E



Stronger spouts from bottom but same pattern from bucket and pipe. Hole position matters, not container size.

F

Something different? Draw your prediction here!

Make a prediction and give a reason to support it.

Predictions will vary! Any prediction is valid so long as there is a reason to support it.

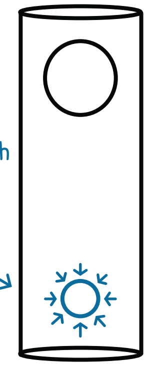
Record the results:

The results demonstrated in class will show that option E is what happens. Depth from the surface is what determines the pressure, not the volume of the container.

Going for a Swim

What shape would a balloon have deep under water?

A balloon would be smaller at greater depth but stay spherical.



$P_{(fluid)} = \rho g h$

The pressure of a fluid is the product of its density (ρ), acceleration due to gravity (g), and the height of the fluid column (h).

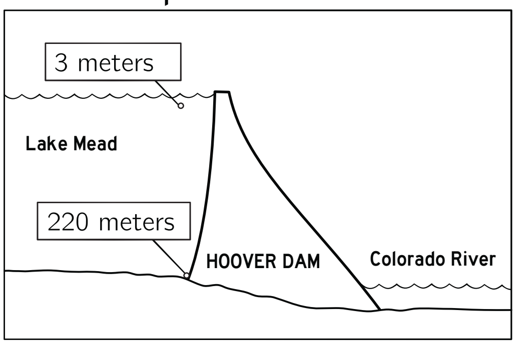
On Earth, $g = 9.8\ m/s^2$

A confined fluid applies pressure EVENLY in EVERY direction.

Fluids with higher density exert more pressure (ex water vs air, molasses vs water)

Pressure increases with depth! In any liquid, the deeper you go, the higher the pressure.

Calculate the pressure:



Calculate the water pressure behind Hoover Dam near the top of the dam (3 m deep) and at the bottom of the dam (220 m deep). The density of water is 1,000 kg/m^3.

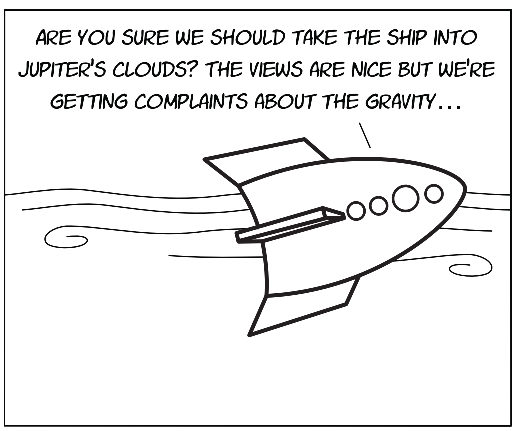
Pressure = ρgh (density · gravity · depth)

Pressure at 3 m = 1,000 kg/m^3 · 9.8 m/s^2 · 3m = 29,400 pascals

Pressure at 220 m = 1,000 kg/m^3 · 9.8 m/s^2 · 220m = 2,156,000 pascals

The pressure is much higher at the bottom of the dam!

In kPa, the pressures are 29.4 kPa and 2,156 kPa.



Calculate the pressure someone would experience if they were swimming at 3 m deep in a pool of water on Jupiter, where the acceleration due to gravity is 24.79 m/s^2.

How deep would someone need to swim on Earth to experience the same pressure?

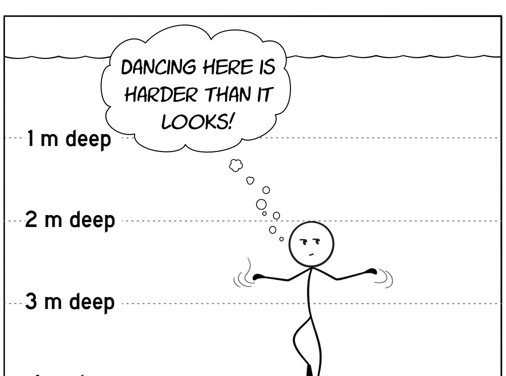
Pressure = ρgh (density · gravity · depth)

Pressure at 3 m = 1,000 kg/m^3 · 24.79 m/s^2 · 3m = 74,370 pascals

To find the depth, use P = ρgh where P = 74,370 Pa and h is unknown:

74,370 Pa = 1,000 kg/m^3 · 9.8 m/s^2 · h

Solving for h, we find that the depth would be 7.59 meters (close to 25 feet deep)

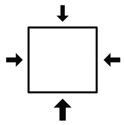


Bob is performing an underwater dance while standing on the bottom of a swimming pool. Calculate the water pressure at Bob's head (2 m deep) and his feet (4 m deep).

Pressure at 1 m = 1,000 kg/m^3 · 9.8 m/s^2 · 2m = 19,600 pascals

Pressure at 3 m = 1,000 kg/m^3 · 9.8 m/s^2 · 4m = 39,200 pascals

Going for a Swim

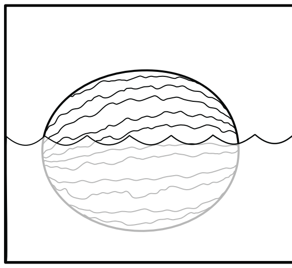


Because pressure increases with depth, the pressure against the bottom of an object in a fluid will always be greater than the pressure against the sides or top. This net upward force is called the **buoyant force**.

ARCHIMEDES PRINCIPLE

An immersed object will be buoyed up by a force equal to the weight of the water it displaces!

Example 1: floating watermelon



The melon displaces 5.91 kg of water. The weight of 5.91 kg of water is approximately 58 newtons.

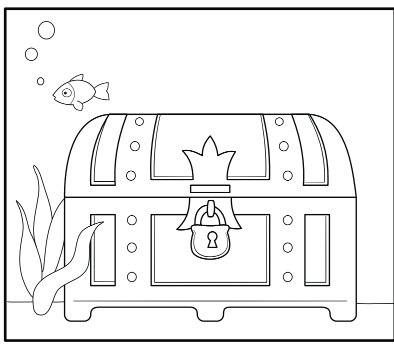
WHAT IS THE BUOYANT FORCE ON THE WATERMELON?

58 N

IS THE WEIGHT OF THE WATERMELON MORE, LESS, OR EQUAL TO 58 NEWTONS?

Equal

Example 2: treasure chest at ocean bottom



The chest displaces 475 kg of water. The weight of 475 kg of water is about 4,660 newtons.

WHAT IS THE BUOYANT FORCE ON THE CHEST?

4,600 N

IS THE WEIGHT OF THE TREASURE CHEST MORE, LESS, OR EQUAL TO 6,622 NEWTONS?

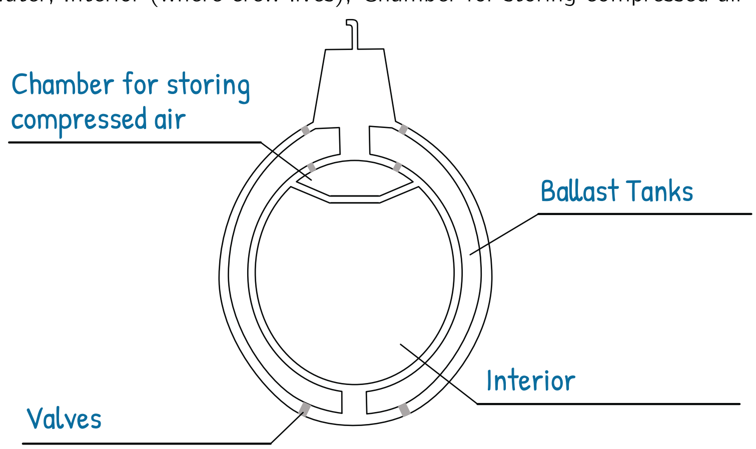
More. If the weight of the chest were equal or less than the buoyant force, then it would be suspended in water or floating.

WHY DOES THE WATERMELON FLOAT WHILE THE TREASURE CHEST SINKS?

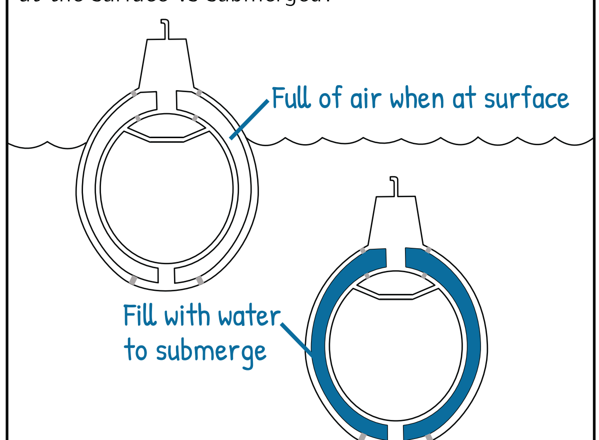
The chest weighs more than the weight of the water it displaces so the chest weighs more than 4,600 N (1,034 pounds). This is true of all objects that sink. Floating objects have a weight equal to the weight of the water they displace. So the weight of the watermelon weight must be equal to 58 N (13 pounds) for it to float.

How a submarine works

Label the following: Ballast Tanks, Valves to release or intake air or water, Interior (where crew lives), Chamber for storing compressed air



How do the ballast tanks differ when the sub is at the surface vs submerged?



Practice Problems – Going for a Swim

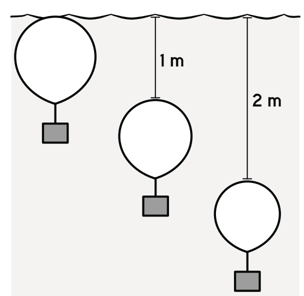
1. How does the volume of a completely submerged object compare with the volume of the water displaced?
   A. The submerged object has more volume than the water displaced.
   B. The submerged object has the same volume as the water displaced.
   C. The submerged object has less volume than the water displaced.
   D. It depends on the exact shape of the object.

2. How does the weight of a floating object compare with the weight of the water displaced?
   A. The floating object has more weight than the water displaced.
   B. The floating object has the same weight as the water displaced.
   C. The floating object has less weight than the water displaced.
   D. It depends on the exact shape of the object.

3. Why is it easier to lift an object submerged in liquid?

   The buoyant force upward is equal to the weight of the water that has been displaced, so the object loses the weight of the water that is displaced.

4. A balloon is attached to a heavy weight and placed in water. Arrange the buoyant force on the balloon from least to greatest for these positions: at the surface, 1 m below the surface, and 2 m below the surface.



   The balloon will compress smaller as it sinks, so it displaces less water the lower it goes. The buoyant force decreases as the amount of water displaced decreases.

   buoyant force at 2 m < buoyant force at 1 m < buoyant force at the surface.

5. Will a basketball float higher in fresh or salt water, or will it have the same amount of ball floating above the water in each type? Explain.

   Salt water is more dense than fresh water. A basketball will displace water equal to its weight, so it will displace less salt water than fresh water. The result is that more of the volume of the basketball will be above the water line in salt water.

6. A 15-lb bowling ball seems to weigh just 3 lb when submerged in water. What is the weight of the water it displaced?

   The buoyant force upward had a magnitude of 12 lb to account for the difference in weight of the ball in water. From Archimedes principle, we know the bowling ball displaced 12 lb of water.

(7) Explain why most of an iceberg is underneath the water.

Ice is just a little less dense than water. The iceberg displaces its weight worth of water which would have a volume just a little less than the iceberg itself, so most of the iceberg is beneath the surface.

(8) When an ice cube floating in a glass of water melts, what will happen to the water level in the cup? Will it rise, fall, or remain unchanged?

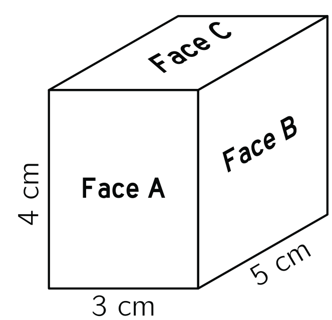
The water level remains unchanged. An ice cube displaces its weight of liquid water. When the ice cube melts, its volume matches exactly the water that it displaced when it was solid.

(9) Explain why a sharp knife cuts better than a dull knife.

A sharp knife has a much smaller surface area along the blade than a dull knife Pressure = force/area, so the pressure the sharp knife exerts for a given amount of force is greater than the pressure a dull knife (with a larger area) exerts.

(10) A box measures 3 cm × 4 cm × 5 cm and weighs 6 N. Calculate how much pressure it exerts on the table when it is laying on each of its faces.

Pressure = force/area. The areas and pressures will be:



FACE A: 3 cm × 4 cm = 12 cm^2=0.0012 m^2,
Pressure = 6 N/0.0012 m^2 = 5,000 Pa = 5 kPa

FACE B: 4 cm × 5 cm = 20 cm^2=0.002 m^2,
Pressure = 6 N/0.002 m^2 = 3000 Pa = 3 kPa

FACE C: 3 cm × 5 cm = 15 cm^2=0.0015 m^2,
Pressure = 6 N/0.0015 m^2 = 4,000 Pa = 4 kPa

(11) What would exert greater pressure, swimming 1 m deep (3.28 ft) in honey or swimming at a depth of 2 m (6.56 feet) deep in water? Both pools are located on Earth. The pool of water has a density of 1,000 kg/m^3 and the pool of honey has a density of 1,400 kg/m^3.

Pressure = density · acceleration due to gravity (9.8 m/s^2) · depth

(If using kg/m for density and m for depth, the units work out to be N/m which = pascals)

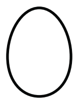
WATER PRESSURE at 2 m deep = 1,000 kg/m^3 · 9.8 m/s^2 · 2 m = 19,600 pascals (19.6 kPa)

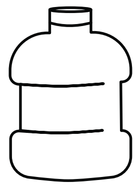
HONEY PRESSURE at 1 m deep = 1,400 kg/m^3 · 9.8 m/s^2 · 1 m = 13,720 pascals (13.72 kPa)

The water exerts more pressure than honey at these depths. But we still wouldn't recommend swimming in honey.

EGG IN A BOTTLE

MATERIALS


2 to 3 medium-size hard boiled eggs


A bottle or container with an opening just a little smaller than an egg.


A small candle


A lighter or a match

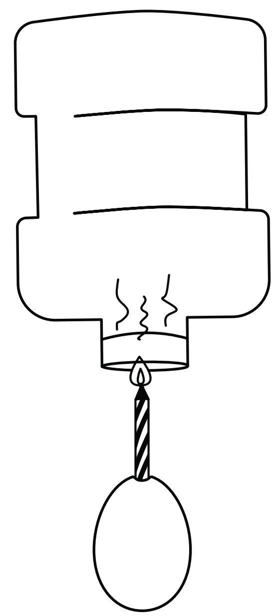
GOALS

- Change the pressure in a container by altering the temperature.
- Demonstrate the strength of atmospheric pressure.

Pre-lab Question: What is suction, and how is it created?

INSTRUCTIONS:

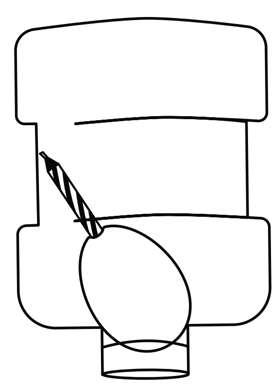
1. Peel a hard boiled egg.
2. Obtain a container that has a mouth that is a little smaller than the hard boiled egg so that the egg will block the opening.
3. Stick the candle in the narrow end of the egg and light the candle.
4. While holding the egg and candle upright, slowly lower the container to cover the egg.
5. Watch in amazement as the egg is pulled inside the container.



EXPLANATION:

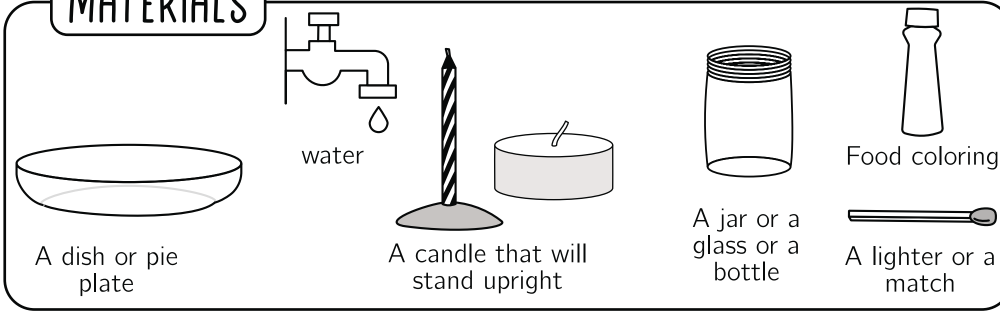
The hot flame heats up the air inside the bottle causing the air to expand as its molecules get excited. Without the heat of the flame, the air molecules cool quickly. Normally, other air would rush in to fill the bottle as the cooler air inside contracts, but the egg blocks the opening. The pressure outside the bottle is higher than the pressure inside the bottle, so it pushes the egg until it is pulled inside.

Did it work? If not, then write about what might have gone wrong. If so, then write some advice that would help another student carry out this demonstration.



RISING WATER

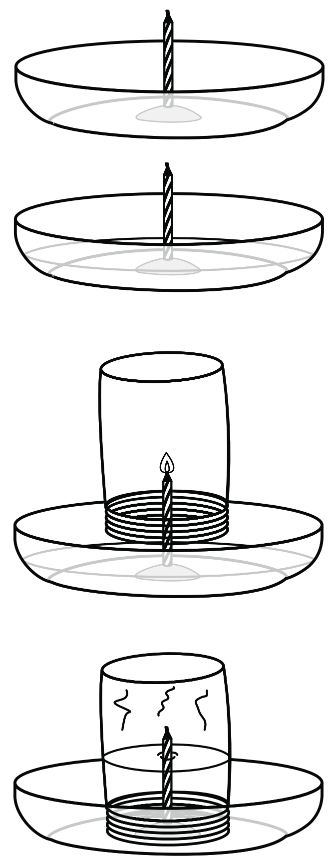
MATERIALS



GOALS

- Create "suction" using a drop in temperature.
- Demonstrate the strength of atmospheric pressure.

Pre-lab Question: What is a vacuum? How is one created?



INSTRUCTIONS:

1. Place an upright candle in the center of a dish. If needed, use dough or gum to get your candle to stand on its own.
2. Use food coloring to color the water and add it to the dish so that it is more than a centimeter deep.
3. Light the candle.
4. Invert the jar, and slowly lower it over the candle and set it upside down on the dish.
5. Watch as the candle goes out and the water is pulled into the jar.

EXPLANATION:

The hot flame heats up the air inside the jar causing the air to expand as its molecules get excited. Without the heat of the flame, the air molecules cool quickly. Normally, other air would rush in to fill the jar as the cooler air inside contracts, but the water at the bottom blocks any air from coming in. The pressure outside the jar is higher than the pressure inside the bottle, so water is pushed into the jar.

Did it work? If not, then write about what might have gone wrong. If so, then write some advice that would help another student carry out this demonstration.

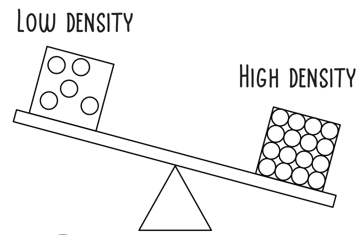
Density

Density is a measure of how much mass or matter

Is in a given amount of space or volume.

Common units = g/cm³ or kg/L or kg/m³. Note: 1 ml = 1 cm³

Density



$\rho = \frac{m}{V}$ Density = $\frac{\text{mass}}{\text{volume}}$

Good to Know

The density of water: 1 g/cm³ or 1 kg/L or 1,000 kg/m³*

*It's actually 0.9998395 g/ml at 4.0° Celsius or 39.2° Fahrenheit. But in most cases, 1 g/cm³ is close enough!

1. A cube of sugar has a volume of 2 cubic centimeters and a mass of 3.6 grams. What is its density?

   Density = mass/volume, so 3.6g/2cm³ = 1.8 g/cm³

   * A sugar cube sinks in oil because it is has a higher density than the oil

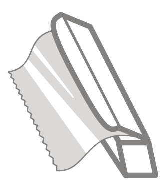
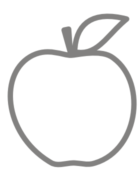
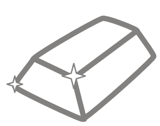
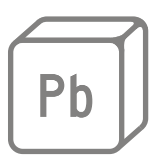
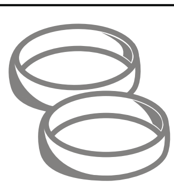
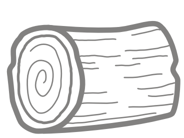
2. 250 milliliters of olive oil weighs 215 grams. What is the density of olive oil?

   Density = mass/volume. Remember ml = cm³, so 250 ml = 250 cm³

   so 215g/250cm³ = 0.86 g/cm³

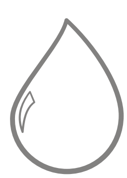
Will it sink or float?

Complete the table to show whether the 9 objects below would float or sink in the following liquids.

 **Air at sea level** 1.2 kg/m³	 **Aluminum** 2,700 kg/m³	 **Apple** 814 kg/m³
 **Gold** 19,300 kg/m³	 **Frozen water** 917 kg/m³	 **Lead** 11,340 kg/m³
 **Platinum** 21,090 kg/m³	 **Sea water at 25°C** 1,024 kg/m³	 **Wood (maple)** 700 kg/m³

*While certain shapes of aluminum can float on water (such as an aluminum foil boat) a solid cube or bolt of aluminum sinks.

	Water at 4°C	Honey	Mercury
Platinum	SINK	SINK	SINK
Gold	SINK	SINK	SINK
Lead	SINK	SINK	FLOAT
Aluminum *	SINK	SINK	FLOAT
Sea Water	SINK	FLOAT	FLOAT
Frozen Water	FLOAT	FLOAT	FLOAT
Wood (maple)	FLOAT	FLOAT	FLOAT
Apple	FLOAT	FLOAT	FLOAT
Air	FLOAT	FLOAT	FLOAT



Density of water at 4 °C is 1,000 kg/m³

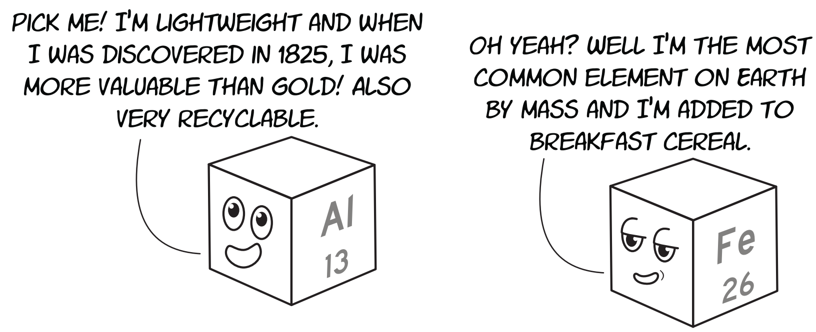
Density of honey is 1,400 kg/m³

Density of mercury is 13,590 kg/m³

Buoyancy

What has greater buoyancy and why? A cubic meter of aluminum or a cubic meter of iron?

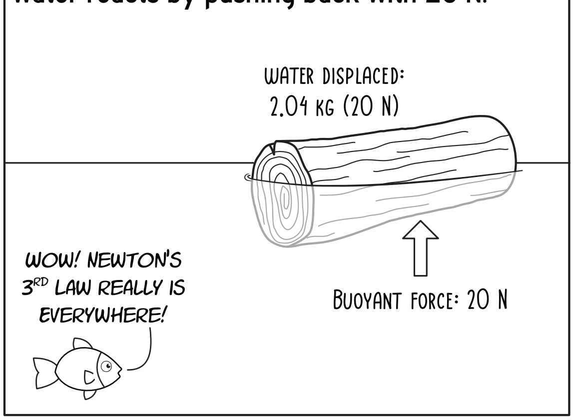
Their buoyancy will be the same! They both displace 1 cubic meter(1,000 kg) of water so they will both experience a buoyant force of 1,000kg·9.81 m/s² = 9,810 N



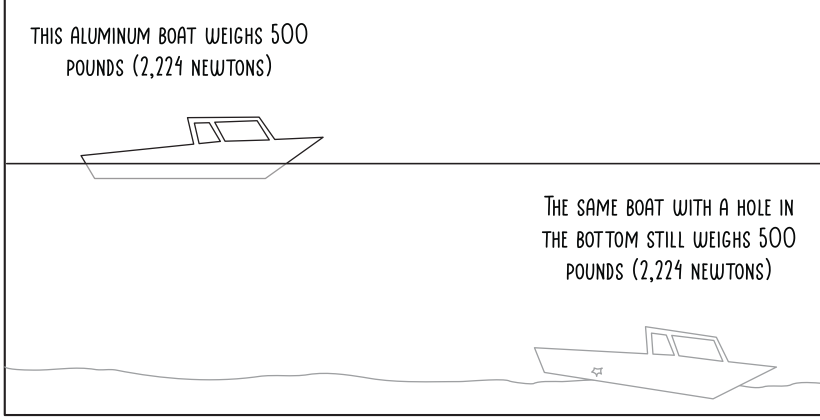
MISCONCEPTION ALERT!

Students sometimes think heavier objects experience more buoyant force, but buoyancy is determined by the VOLUME of an object, not its WEIGHT. Here are 2 cartoons to help you avoid this trap. Which do you like best?

If the log pushes 20 N of water aside, then the water reacts by pushing back with 20 N!



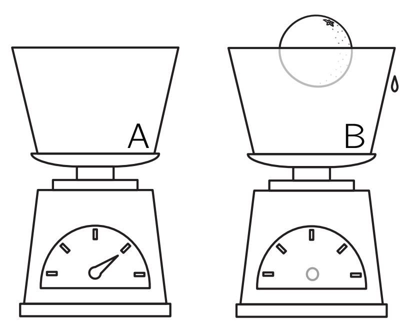
Weight or density alone won't tell you if an object will sink or float!



Use the floatation principle to answer the following questions:

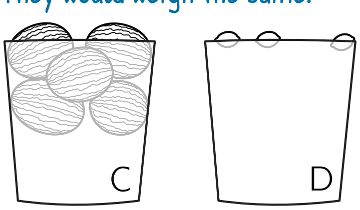
1. A container **full to the brim** with water weighs 30 newtons (A). How much would the container weigh after a grapefruit is placed in the water (B)? *Note: adding the fruit will cause water to spill over the edge.*

   30 newtons! As long as the container was full of water, it would weigh the same no matter what was floating in it.



2. What would weigh more, a 40 liter bucket **full to the brim** with water with 5 watermelons floating in it (picture C) or a 40 liter bucket with 3 floating lemons (D)?

   They would weigh the same.

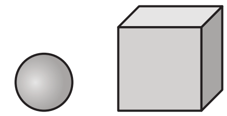


FLOATATION PRINCIPLE:

A FLOATING OBJECT ALWAYS DISPLACES A WEIGHT OF FLUID EQUAL TO ITS OWN WEIGHT.

Practice Problems – Density & Buoyancy

1. What has higher density, a 1 kg sphere of iron or a 10 kg cube of iron?



A. The sphere
B. The cube
C. They have the same density because they're both made of iron
D. There's not enough information to tell

2. If something weighs 1 gram and has a volume of 1 cubic centimeter, what is its density?

A. 1 g/cm^3
B. 1,000 kg/m^3
C. Both A and B
D. None of the above

$$\frac{1\,\text{g}}{1\,\text{cm}^3} = \frac{1\,\text{g}}{1\,\text{cm}^3}\cdot\frac{1\,\text{kg}}{1000\,\text{g}}\cdot\left(\frac{100\,\text{cm}}{1\,\text{m}}\right)^3 = 1000\,\frac{\text{kg}}{\text{m}^3}.$$

3. Rank the following substances from most to least dense: air, gold, ice, wood, and water.

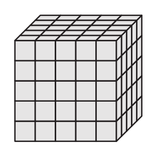
gold	water	ice	wood	air
MOST DENSE				LEAST DENSE

4. What is more dense, 10 grams of gold or 500 grams of aluminum?

Gold is more dense than aluminum. The amount present doesn't affect the density.

5. Is it possible that a hollow cube could be more dense than a solid cube? Explain.

Yes. The outer casing of the hollow cube could be made of a dense material, and the solid cube could be made of a very light material.



6. A tank full of ice weighs less than the same tank full of water. Why?

The water is more dense than the ice, so the water weighs more when occupying the same space.

Another way to think about it is that the water would expand when it freezes, so some of it would have to be removed to exactly fill the tank with ice.

(7) What will happen to a wooden block's buoyant force if it is submerged deeper in water?

A. The buoyant force will increase because the block is deeper.

B. The buoyant force will decrease because the block is under more water.

C. The buoyant force will remain the same regardless of how deep the block is submerged.

D. The wooden block will dissolve, making the buoyant force irrelevant.

Answer: C. The buoyant force will remain the same regardless of how deep the block is submerged because it depends on the volume of water displaced by the object, which does not change with depth.

(8) A baseball has a volume of 212 cm^3 and a mass of 0.145 kg. Is it more or less dense than water? Would you expect the baseball to float or sink in water?

The baseball has a density of 145 g/ 212 cm^3 = 0.684 g/cm^3 which is less than the density of water (1 g/cm^3) so the baseball would float on water.

(9) Cork has a density of 300 kg/m^3. What would be the mass in grams of a sample of cork with a volume of 100 cm^3?

$$\frac{300\text{ kg}}{\text{m}^3}\cdot 100\text{ cm}^3 = \frac{300\text{ kg}}{\text{m}^3}\cdot 100\text{ cm}^3\cdot\Big(\underbrace{\frac{1\text{ m}}{100\text{ cm}}}_{1}\Big)^3\cdot\underbrace{\frac{1000\text{ g}}{1\text{ kg}}}_{1} = 30\text{ g}$$

(10) If an object is lighter than the air it displaces, what will happen to the object?

A. It will rise until it reaches an area of air with similar density.

B. It will fall to the ground

C. It will rise indefinitely

D. It will remain stationary where it is.

(11) A cube of sugar has a volume of 2 cubic centimeters and a mass of 3.6 grams. What is its density?

$$\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{3.6\text{ g}}{2\text{ cm}^3} = 1.8\,\frac{\text{g}}{\text{cm}^3}.$$

(12) A rubber ball floats in water so that it is exactly half submerged. What is the density of the rubber ball?

The ball must have half the density of water. Imagine if all the mass of the ball were in the submerged half. Then we could remove the top half without changing the mass, but the density would double and be exactly equal to the density of water. Since water has a density of 1000 kg/m^3, the ball has a density of 500 kg/m^3.

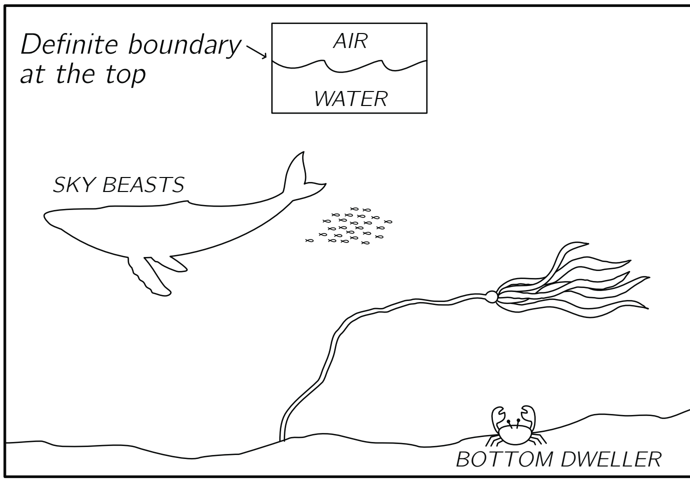
An Ocean of Air

FILL IN THE BLANKS:

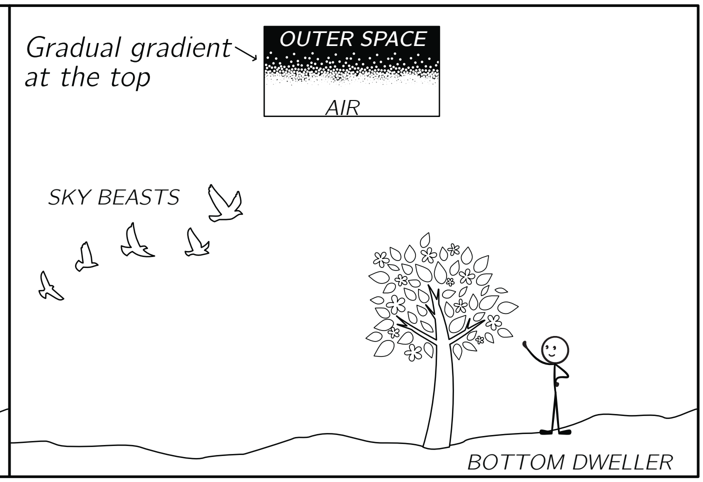
expand | *pressure* | *fluids* | *decreasing* | *increasing*

Water and air are both __fluids__ , and they share several characteristics in common. Higher temperatures will cause the volume of both substances to __expand__ . Both air and water also have increasing __pressure__ at __increasing__ depth. We live submerged in an ocean of air! Since humans live at the bottom of the atmosphere, we often talk about pressure __decreasing__ with elevation.

OCEAN OF WATER



OCEAN OF AIR



When Math Dad stands on two feet, he exerts a pressure of 2.51 PSI on the floor. Using that as a reference, how much pressure do you think the atmosphere is exerting on you right now?

- ☐ *1/10 smaller*
- ☐ *1/5 smaller*
- ☐ *Equal*
- ☑ *5x bigger*
- ☐ *10x bigger*

WHICH DEMONSTRATION FROM CLASS WAS YOUR FAVORITE? HOW DID IT WORK?

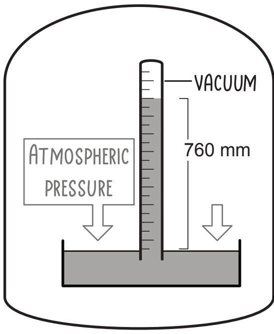
Answers will vary! Brief explanations are:

Can crush: If a certain amount of steam takes up 1 unit of space, when it condenses it will only occupy 1/1600 as much volume. But when the can is inverted and cooled, a partial vacuum forms inside the can. Atmospheric pressure then crushes the can.

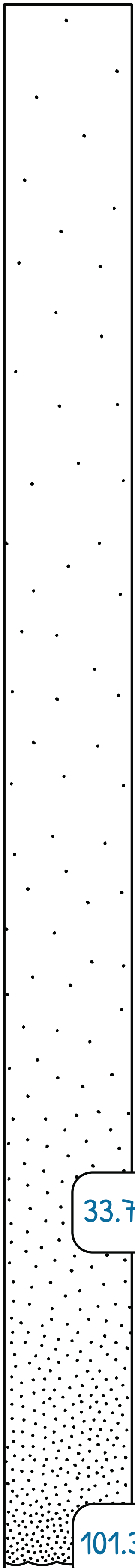
Break Ruler with Newspaper: When the ruler is pushed downward it must lift up the paper. Atmospheric pressure on the paper is strong enough that the ruler will break if it is pushed down quickly.

Magdeburg sphere: If air is pumped out, the atmospheric pressure on the spheres is so strong, they can't be pulled apart!

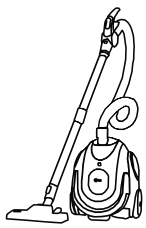
An Ocean of Air



Italian physicist Evangelista Torricelli believed that air had weight and could apply pressure to support a column of water. To test this idea, he filled a glass tube with mercury and inverted it into a dish that was also filled with mercury. This groundbreaking experiment in 1693 led to the development of the mercury barometer, and is why air pressure in weather forecasting is sometimes given in mmHg.



WHAT IS WIND? The movement of air molecules, caused (most often) by a pressure difference! Wind is primarily air moving from a region with high pressure to a region with lower pressure.



A PHYSICIST SAYS THERE'S NO SUCH THING AS SUCTION. IF THIS IS TRUE, HOW DOES A VACUUM WORK?

What we commonly refer to as "suction" is actually the result of differences in air pressure. A vacuum creates an area of low pressure and the pressure of the atmosphere pushes material into it. The same vacuum machine would work better at sea level than at a higher elevation.

Boyle's Law

$$P_1V_1 = P_2V_2$$

When temperature is constant, pressure of a gas is inversely proportional to volume.

- Breathing (diaphragm expands, air flows in)
- Syringe (pull plunger and fluid draws in)
- Carbonated beverages (gas dissolved under high pressure, bubbles expand when pressure is lowered)
- Scuba diving

33.7 kPa AIR PRESSURE AT MOUNT EVEREST

101.3 kPa AIR PRESSURE AT SEA LEVEL

Practice Problems – An Ocean of Air

1. If a sealed 2 liter container contains gas at a pressure of 100 kPa, what will happen to the pressure when the volume is reduced to 1 liter? Assume the temperature remains the same.

   The pressure will double to 200 kPa. Because of Boyle's law ($P_1V_1=P_2V_2$) we know that 2 liter · 100kPa = 1 liter · P_2. Solving for the second pressure gives 200 kPa.

2. When an air bubble rises in water, what happens to the volume of the air?
   - A. It increases
   - B. It decreases
   - C. It remains the same

3. When an air bubble rises in water, what happens to the mass of the air?
   - A. It increases
   - B. It decreases
   - C. It remains the same

4. When an air bubble rises in water, what happens to the density of the air?
   - A. It increases
   - B. It decreases
   - C. It remains the same

5. What keeps a suction cup pressed against a window?
   - A. There is more pressure outside the cup than inside the cup
   - B. There is less pressure outside the cup than inside the cup
   - C. Pressure does not matter, the cup is attached to the window by chemical bonds.

6. Explain in your own words what happens to the air pressure inside a syringe when the plunger is pulled back while its tip is sealed.

   The pressure drops because the same number of air molecules now occupy a bigger space.

Practice Problems – An Ocean of Air

7 Calculate the volume of a room in your home in cubic meters.

Answers will vary but the volume of a room should be calculated by multiplying the width, height, and depth.

8 Estimate the mass of the air in kilograms by using the table provided on this page. Choose an elevation that is most similar to your own.

Answers will vary based on elevation and room size. But as an example:

A 20 m^3 room at sea level would contain 24.12 kg of air.

$20m^3 \cdot 1.206\ kg/m^3 = 24.12\ kg$

Elevation (ft)	Elevation (m)	Weight of 1 m^3 of air at 20 °C
Sea level	Sea level	1.206 kg
1,000 ft	305 m	1.192 kg
2,000 ft	610 m	1.177 kg
3,000 ft	914 m	1.163 kg
4,000 ft	1,219 m	1.149 kg
5,000 ft	1,524 m	1.135 kg
6,000 ft	1,829 m	1.120 kg
7,000 ft	2,134 m	1.106 kg
8,000 ft	2,438 m	1.092 kg
9,000 ft	2,743 m	1.077 kg
10,000 ft	3,048 m	1.063 kg
11,000 ft	3,353 m	1.049 kg
12,000 ft	3,658 m	1.035 kg

Fun Fact: 76 of the 195 countries in the world have capitals that are coastal cities (think Amsterdam, Bangkok, Copenhagen, Jakarta, Tokyo, Washington DC, etc). Here are the elevations of some other capitals:

Beijing, China: Elevation 144 feet (44 meters)	**Bern, Switzerland**: Elevation 1,778 feet (542 meters)
Brasília, Brazil: Elevation 3,540 feet (1,079 meters)	**Nairobi, Kenya**: Elevation 5,550 feet (1,680 meters)
Mexico City, Mexico: Elevation 7,350 feet (2,240 meters)	**La Paz, Bolivia**: Elevation 11,942 feet (3,650 meters)

Bonus content! We didn't have time to focus on the awesome equation $PV = nRT$, but it's another way you can calculate the mass of air in a room. Just rearrange to solve for number of moles (n):

$$n = PV/RT$$

*Remember **P** should be in kPa (if your atmospheric pressure is unknown, you can calculate the mass of air in your room if it were at sea level: 101.3 kPa)*

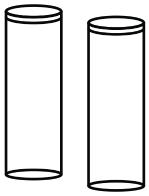
***R** is the ideal gas constant (8.314 J/(mol·K)*

***T** should be in degrees kelvin.*

*Once moles are found, use the average molar mass of air to convert to kilograms. (multiply the value of **n** by 0.029 kg/mol)*

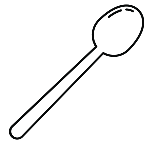
OPTION 1: DENSITY COLUMN

MATERIALS

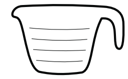


2 tall narrow clear containers

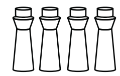
Several liquids of different densities OR sugar and water



Spoon



Measuring cup



Food coloring (optional)

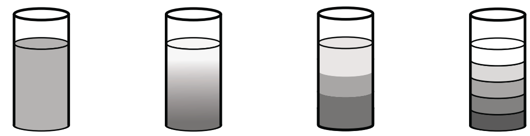
GOALS

- Better understand the concept of density
- Make observations, record data, and communicate conclusions

Pre-lab Questions:

1. What is density? Describe it in your own words:

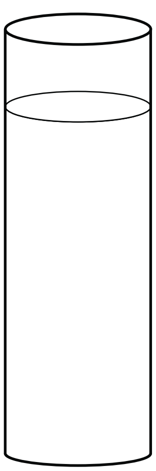
2. What do you think will happen when 5 liquids with different densities are layered? Will you see no layers at all? Very blurred layers? 3 layers? 5 layers? Or something else?



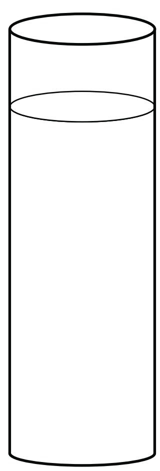
No layers | 2 blurred layers | 3 layers | 5 layers

Draw and explain your prediction for when the liquids are layered from *most dense* on bottom to *least dense* on top (container 1). Also make a prediction for what you expect to see when they are layered from *least dense* on bottom to *most dense* on top (container 2).

PREDICTION FOR CONTAINER 1:



PREDICTION FOR CONTAINER 2:



INSTRUCTIONS:

1. Choose which option of column you want to do and prepare your liquids. If doing the **sugar water column**, make solutions of different concentrations and apply food dye so they are different colors. If doing the **various liquids column**, gather at least 4 of the liquids from the list.
2. Get 2 clear glasses, flasks, or narrow vases of the same size and decide how thick or tall your layers will be. Pour plain water into the vase to see how much of each liquid you will need to make your column. Then pour that water into a measuring cup. This amount indicates how much of each liquid you will use.
3. In the first container, add the amount of liquid you have chosen and arrange the layers from bottom to top. For example, if using sugar water, place the 3:1 sugar water on bottom and plain water on top. If using the layer stack, start with corn syrup on bottom and put rubbing alcohol on top. **Add the layers SLOWLY and CAREFULLY by pouring them onto a spoon held just over the surface**.
4. In the second container, add the liquids in the reverse order.
5. Observe what happens to each layer.

Sugar Water Column
Plain water
1:2 sugar to water ratio
1:1 sugar to water ratio
2:1 sugar to water ratio
3:1 sugar to water ratio

Various Liquids Column
Rubbing alcohol or baby oil
Vegetable oil
Water
Dishwashing soap
Corn syrup or honey

What did the columns look like?

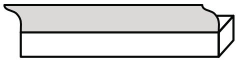
Did your observations match your predictions?

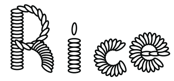
Conclusions

Can you explain the results? What did you learn about density? What tips would you give someone else trying this experiment?

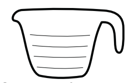
OPTION 2: BOAT FLOAT

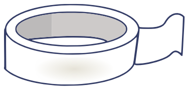
MATERIALS

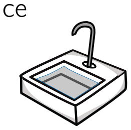

Aluminum foil

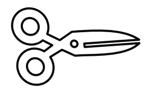

Rice

2 rolls of pennies or another weight


Measuring cup


Tape


A sink or other container that can be filled with water


Scissors (if needed)

GOALS

☆ Create models to determine if the size and shape of an object affects the maximum density it can support and graph the results

Pre-lab Question:

A bolt or screwdriver made of steel will quickly sink when dropped in water.
How is it that large ships made of steel are able to float?

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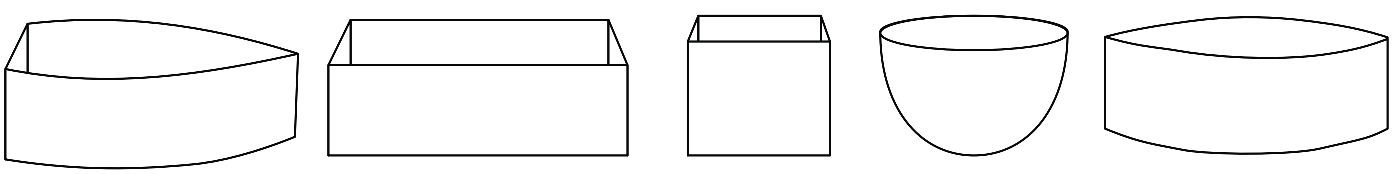
INSTRUCTIONS:

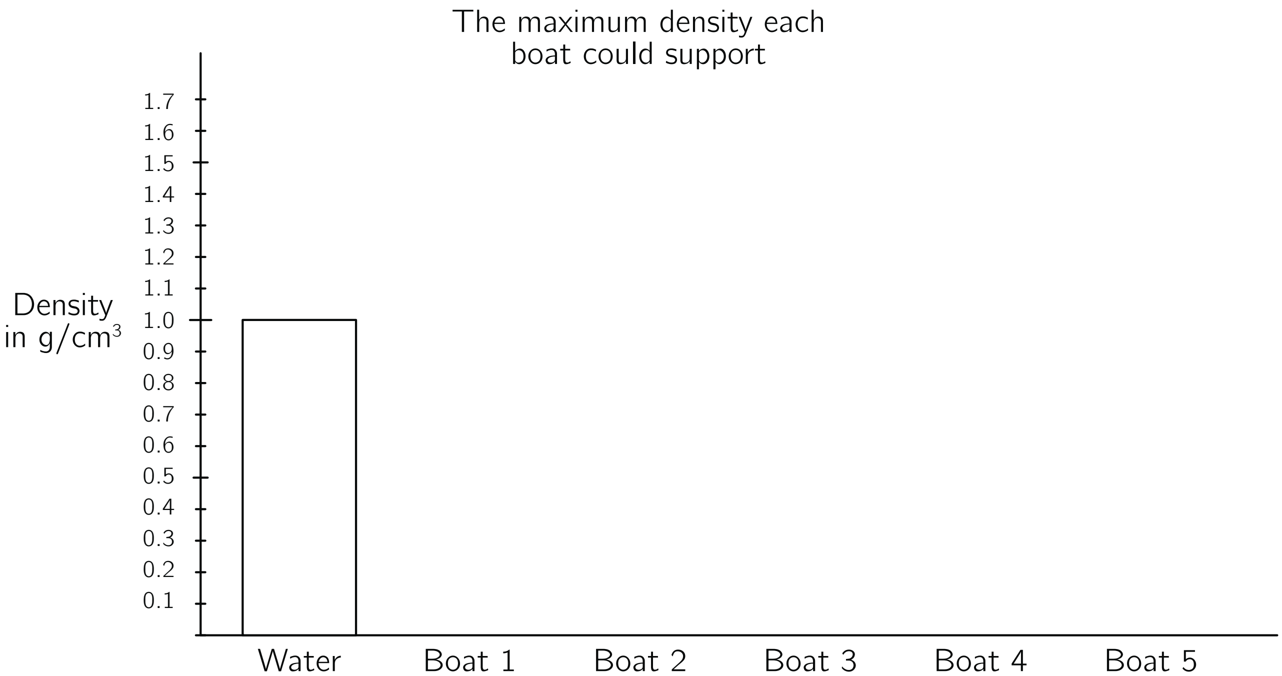
Note: The next page has a chart and a graph that you'll use to complete the project.

1. Use aluminum foil and tape to construct five small boat hulls. Each boat should have a different size and shape (e.g. boxy, pointed, wide, or triangular). Check to make sure your boats do not leak. Each boat should be strong enough to keep its shape when filled with rice.



2. Find the volume of each boat by carefully filling the boat with dry rice. Then pour the rice into a measuring cup with markings for liquids and read the volume in mL. Record the volume in cm^3. Note that 1 mL = 1 cm^3.
3. Measure the buoyancy of each boat hull by floating the boat in a sink or tub and slowly adding dry pennies to the boat. Count the pennies the boat could support before sinking, and then record it.
4. Multiply the number of pennies by 2.5 g/penny to get the mass in grams.
5. Calculate the density of the maximally loaded boat by dividing the number of grams it could support by its volume (recorded in instruction 2. in cm^3).
6. Add bars to the bar chart to display the density of each boat.

Boat	Volume in cm^3 (1 mL = 1 cm^3)	Number of pennies supported	Mass supported (in g)	Density before sinking (in g/cm^3)
1				
2				
3				
4				
5				



Did the shape make a noticeable difference in the maximum density each boat could support?

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Did the total volume make a noticeable difference in the maximum density each boat could support?

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How do you think the results would have turned out differently if you had used a different liquid than water?

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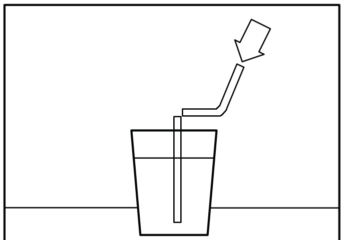
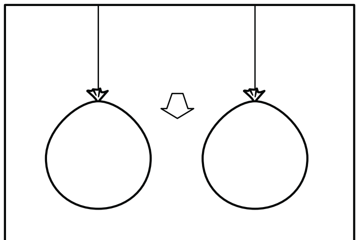
Fluids in Motion

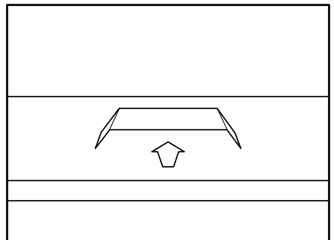
What will happen when the air moves fast in the direction the arrow is pointing?
Draw or record your **prediction** below:



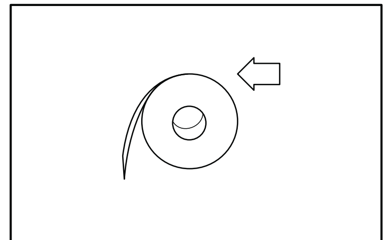
Blowing air over a straw that's in a cup of water



Blowing air between two balloons hanging from string



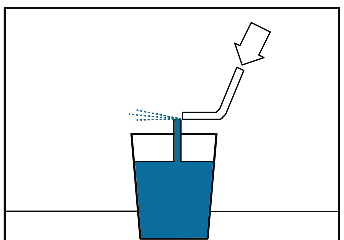
Blowing air under a bent index card resting on a table



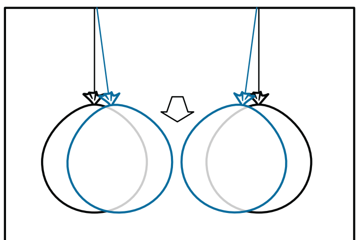
Blowing air over the top of a roll of toilet paper

Predictions will vary

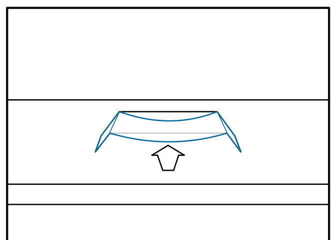
Now draw or describe **what happened** when the air moved quickly in these situations:



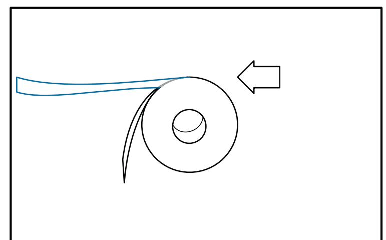
Blowing air over a straw that's in a cup of water



Blowing air between two balloons hanging from string



Blowing air under a bent index card resting on a table



Blowing air over the top of a roll of toilet paper

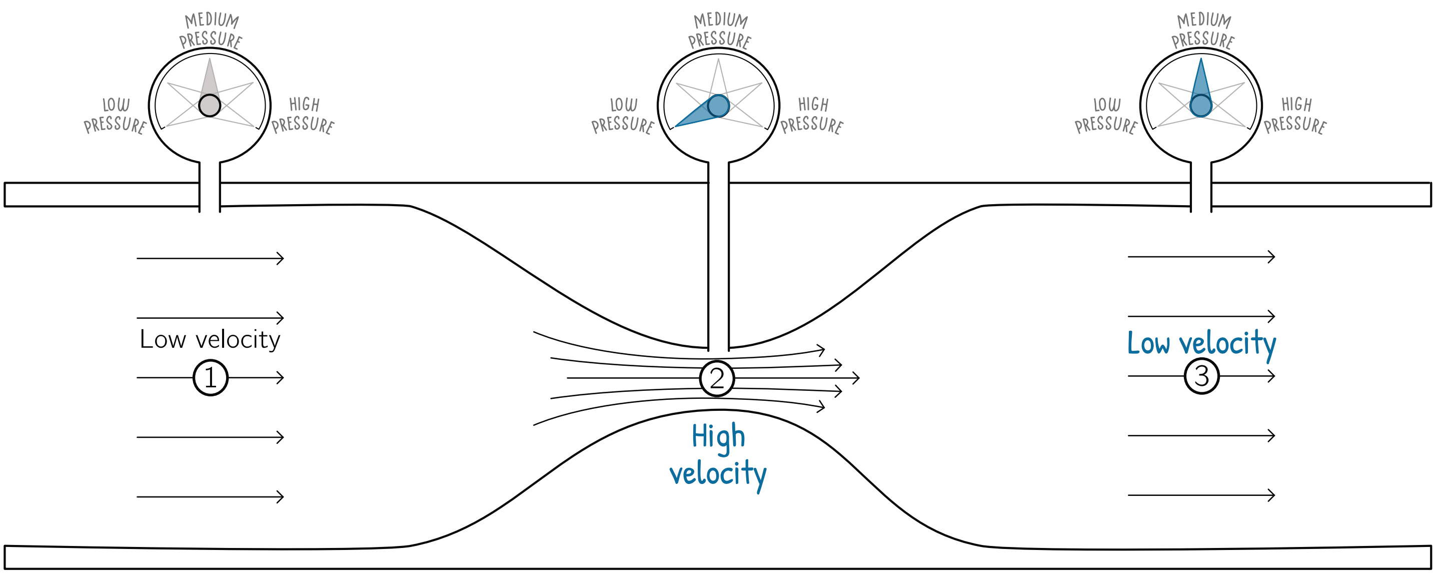
Water goes up and out from the straw!

The balloons move closer together

The card pulls down toward the table

The paper lifts up!

Fluid flows through a pipe with a narrow point. What will the pressure and velocity be at points 2 & 3?

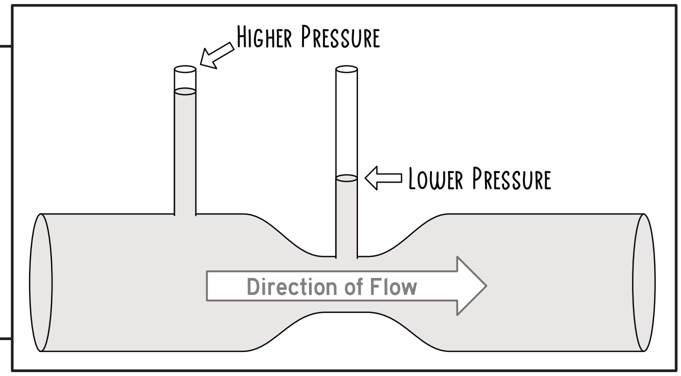


Fluids in Motion

Bernoulli's Principle

As the velocity of a fluid increases,

the pressure decreases.



Laminar Flow

Fluid moves smoothly in parallel layers with minimal mixing.

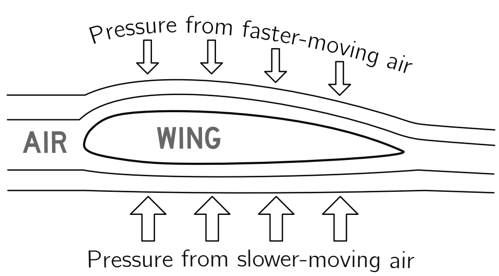
- Predictable
- Less friction or energy loss due to drag
- Movement of objects through fluids are more efficient with laminar flow

Turbulent Flow

Fluid movement is chaotic and irregular with rapid changes in pressure and flow velocity.

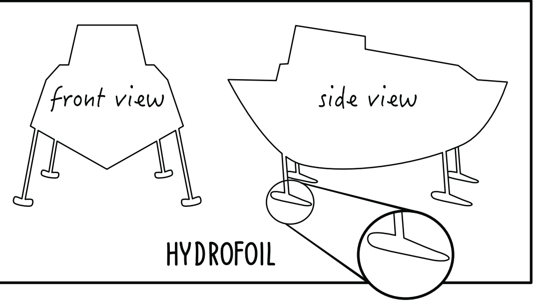
- Unpredictable
- Usually occurs at high velocities or in fluids with low viscosity (ie air)
- Enhances heat transfer and mixing

Here are simple diagrams of an airplane wing, hydrofoil, spoiler, and a reentry capsule. Make a note about how the design of each object interacts with the flow of air or water around it:



AIRPLANE WING

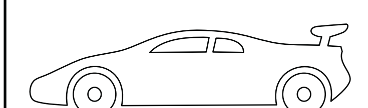
Airplane wing: the curved edge (airfoil) causes air to move faster over the top. As speed increases, lift increases.



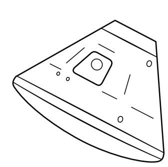
HYDROFOIL

Hydrofoil: Similar shape to an airplane wing, but designed for water. As speed increases, lift increases, raising the boat and reducing drag.

Spoiler: Similar shape to an airplane wing, but upside down! The faster the car travels, the more "downforce" the spoiler provides.



SPOILER



REENTRY CAPSULE

Reentry capsule: The blunt front creates a shock wave which deflects intense heat away from the capsule.

The angle and smooth sides encourage laminar flow.

Practice Problems – Fluids in Motion

1. "It is dangerous to stand near a fast-moving train because the Bernoulli effect could cause you to be pulled toward the train."
Is the above statement true or false? Explain.

It is true. The air close to the train is moving with high velocity and thus has lower pressure than air further away from the train. This pressure differential can create a suction effect that can throw other objects off balance and move them toward the train. For the same reason, it's also dangerous for fast moving boats to travel too close to other boats because they can be pulled together and collide.

2. Bernoulli's principle states that as the speed of a fluid increases, its:
A. Temperature increases
B. Temperature decreases
C. Pressure increases
D. Pressure decreases

3. Which of the following is an example of laminar flow?
A. Honey flowing from a spoon
B. Smoke rising from a chimney
C. Water in a fast-moving river
D. Steam erupting from a geyser

4. Which of these principles or laws explains why shower curtains get sucked inward when a shower is running?
A. Newton's 3rd law
B. Boyle's law
C. Archimedes principle
D. Bernoulli's principle

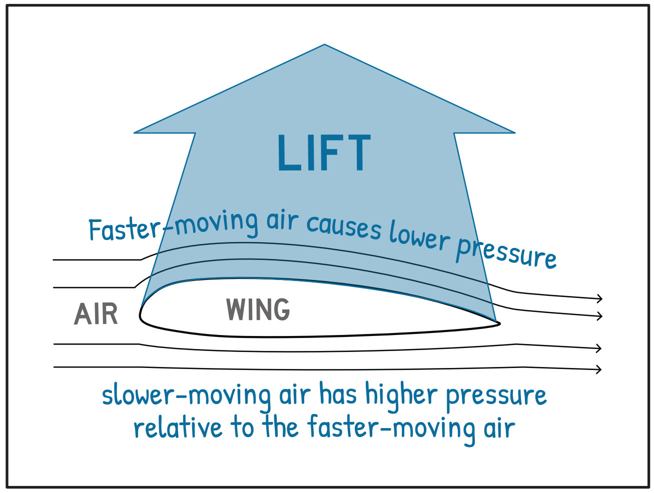
It's the combined result of the Bernoulli effect and hot air rising that pulls the curtain inward

5. Assuming that the fluids are of the same material and temperature, if a fluid is moving at higher speed, it will have:
A. Higher pressure than a slower-moving fluid
B. Lower pressure than a slower-moving fluid
C. The same pressure as a slower-moving fluid
D. There is no way to know whether the pressure will be higher or lower.

6. Laminar flow is most likely to occur in:
A. Narrow, smooth pipes
B. Fast-moving rivers
C. High-velocity air currents
D. Stormy ocean currents

Practice Problems – Fluids in Motion

7. Without looking at the previous pages, can you explain how the shape of an airplane wing generates lift? Diagram this drawing and/or explain below.
   Where is the air speed highest? Where is the pressure highest? Where is it lowest?

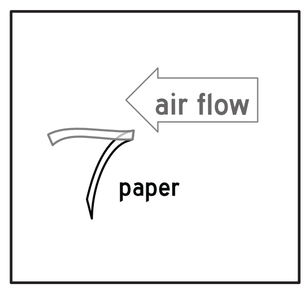


The wing is curved more on the top and flatter on the bottom, which makes air travel faster over the top surface than the bottom. The faster-moving air has lower pressure and this difference in pressure produces lift. The angle of attack (the angle between the wing and the oncoming air) also contributes to lift.

8. In most cases, if the cross-sectional area of a pipe decreases, what happens to the flow speed of the fluid?
   A. It decreases
   B. It increases
   C. It remains the same
   D. It becomes turbulent

9. Fluid flowing through a pipe experiences a decrease in pressure when:
   A. The pipe widens
   B. The pipe narrows

10. Consider a piece of tissue paper that is hanging vertically in the air as shown. Why does the paper lift up when air is blown over it?
    A. Gravity decreases
    B. Gravity increases
    C. The air flow creates an area of lower pressure above the paper
    D. The air flow creates an area of high pressure above the paper



11. Explain Bernoulli's principle in your own words:

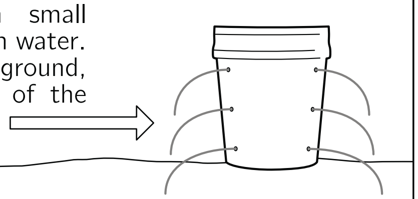
    Faster-moving fluid = lower pressure

When Push Comes to Shove

We've learned some neat things about pressure and fluids in this unit! Use what you know to make predictions about what will happen in these 3 demonstrations. Then record what actually happens, and why!

1

A bucket with small holes is filled with water. When on the ground, water flows out of the bucket as shown.



What will happen when the bucket is dropped?

What do you predict will happen and why?

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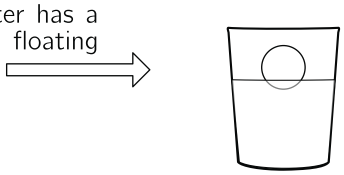
What actually happened?

2

A cup with water has a ping pong ball floating on the surface.



What will happen when the cup is dropped?

What do you predict will happen and why?

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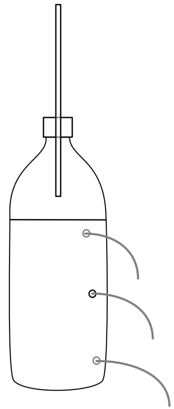
3

A bottle filled with water has a hole in the lid. A straw is placed in the hole. The straw fits tightly in the hole. The only way for air to enter the bottle is through the straw.

There are also 3 holes in the side of the bottle.

When the straw is positioned as follows, water flows out of the holes.

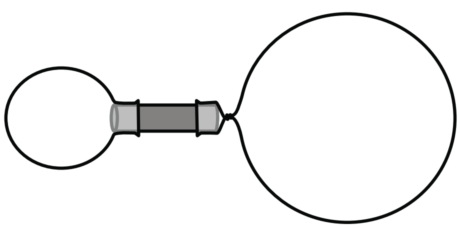


What will happen when the straw is lowered into the bottle?

What do you predict will happen and why?

4

Two balloons are connected with a hollow tube as shown, but one of them is twisted so no air can flow in or out.



What will happen when air is allowed to flow?

What do you predict will happen and why?

Practice Problems – When Push Comes to Shove

1. How does drinking through a straw work? Bonus question: why is someone who has had their wisdom teeth out told to avoid drinking anything with a straw for several days?

When someone drinks through a straw, they reduce the air pressure inside their mouth compared to the atmospheric pressure outside the container. This difference in pressure causes the liquid to be pushed up the straw and into the mouth. It's the higher atmospheric pressure acting on the surface of the liquid that does the pushing.

During wisdom teeth removal, a clot forms over the wound which is important for proper healing. If the clot is dislodged it can result in a painful condition called dry socket.

2. What is free fall?

A. Movement under the influence of gravity alone.
B. Falling without any resistance.
C. Falling in a vacuum.
D. Any downward movement in air.

3. What does Archimedes' principle state about buoyancy?

A. An object will float if it is heavier than the fluid it displaces.
B. An object in a fluid experiences a buoyant force equal to the weight of the fluid displaced.
C. Buoyancy only applies to objects in water.
D. The buoyant force is directly proportional to the depth submerged.

4. Which statement about fluid flow is correct?

A. The mass of the fluid entering a system is equal to the mass exiting the system.
B. As the cross-sectional area of a pipe decreases, the velocity of the fluid flow also decreases
C. As the cross-sectional area of a pipe decreases, the pressure increases
D. None of the above

5. Why do objects feel or appear to be weightless when in a state of freefall?

Because the only force acting on them is gravity, and gravity is a non-contact force. Everything inside a freefalling system moves at the same rate.

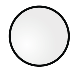
6. A cruise ship can weigh around 200,000 imperial tons, which is over 200 million kilograms! How can such a heavy boat float in water?

Because it is displacing more than 200,000 tons of water, and therefore experiences a buoyant force that is more than its weight.

PING PONG LAUNCH

MATERIALS

Blow Dryer



Ping Pong Ball

Paper towel tube or toilet paper tube

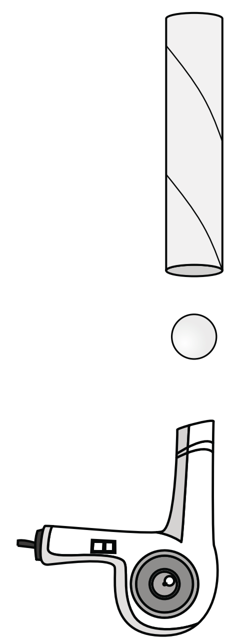
GOALS

- Demonstrate Bernoulli's principle.
- Explain a surprising change in motion using the language of physics.

Pre-lab Question: What is Bernoulli's principle?

INSTRUCTIONS:

1. Turn on the blow dryer on its highest speed setting.
2. Point the blow dryer upward and release a ping pong ball in the air stream so that the ball hovers in place.
3. Tilt the blow dryer to the side to see how far you can tilt it before the ball will fall out of the air stream.
4. While blowing the ping pong ball upward, slowly lower the paper towel tube over the ping pong ball.
5. Watch in amazement as the ball is launched into the air.



EXPLANATION:

The ping pong ball stays in place because the net forces are balanced. The flowing air pushes against the ball, while gravity pulls the ball. The atmospheric pressure pushes against the ball while a lower pressure from the fast moving air pushes with less force from below the ball. As the blow dryer tilts, the atmospheric pressure is strong enough to push the ball toward the lower-pressure of the fast-moving column of air until it tips far enough that the forces are no longer balanced.

Would this demonstration work with a leaf blower that can blow air much faster than a blow dryer? If so, explain why. If not, what might go wrong?

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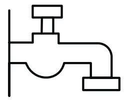
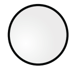
A BALL ON A STRING

MATERIALS


Tape or a glue gun


Faucet


Ping Pong Ball


String

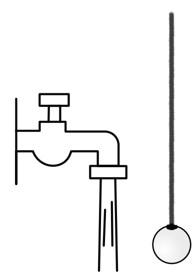
GOALS

- Demonstrate Bernoulli's principle.
- Create a low pressure column of water and air.

Pre-lab Question: Is the air pressure higher or lower in a straw when you are blowing air through it than when the air is not moving?

INSTRUCTIONS:

1. Attach a ping pong ball to a string using a glue gun or tape.
2. Turn on a water faucet so there is a steady stream of water coming out.
3. Dangle the ping pong ball near the column of water.
4. Watch as the ball is pulled into the stream of water.
5. Experiment to see whether the amount of water makes a difference. How far away can the ping pong ball be held from the water and still get pulled over to the stream?



EXPLANATION:

The moving water also moves the air creating a region of lower pressure as predicted by Bernoulli's principle. The ball is pushed by the atmosphere into the region of lower pressure. Even though the collision of the water and ball pushes the ball away, the lower pressure is enough to keep the ball in place.

Would this demonstration work if we replaced the ping pong ball with a golf ball? Explain.

Fluids & Pressure Assessment

In your own words!

Define each of the following terms in your own words! Explain the terms without looking them up. Then, after writing your definitions, compare what you wrote with the definitions in the notes. Make corrections as needed.

DENSITY: The amount of stuff in a given amount of space (or mass/volume etc)

BUOYANCY: The upward force that acts on an object in a fluid (from the displaced fluid)

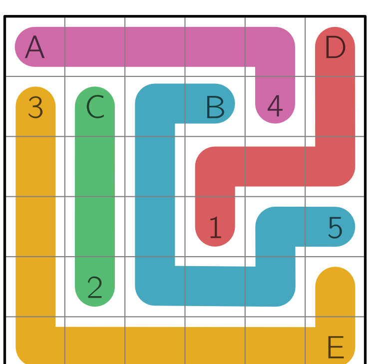
FLUID: Gas or liquid - something that can flow and does not have a fixed shape.

PASCALS: Newtons per meter squared! A unit of pressure.

PRESSURE: How much force is applied to an area, pascals and PSI are measures of pressure.

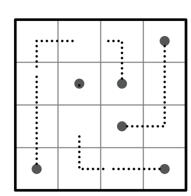
PSI: Pounds per square inch.

Pipe Flow Matching



Match each unit with the quantity being measured by joining them with a continuous stroke (pipe). Each square in the grid should be visited by exactly one pipe.

1. pressure	A. m^2
2. temperature	B. kg/m^3
3. heat	C. K
4. area	D. N/m^2
5. density	E. J



1. What is density?:
   A. How heavy something is
   B. The amount of mass per unit of volume
   C. The force of gravity on an object
   D. The amount of surface area something has

2. Which of the following would increase the pressure a weight exerts on a surface?
   A. Spreading out the weight over a larger area
   B. Placing the weight on a softer surface
   C. Concentrating the weight over a smaller area
   D. Lightening the weight

3. What happens to the pressure experienced as you dive deeper into the ocean?
   A. It decreases
   B. It stays the same
   C. It increases
   D. It first increases, then decreases

4. If you quadruple the volume of a gas and keep the temperature constant, what happens to the pressure?
   A. The pressure is ¼ of what it was before
   B. It stays the same
   C. It is quadrupled
   D. It first increases, then decreases

5. What is true about air pressure at higher altitudes?
   A. It increases because you are closer to the Sun
   B. It stays the same as at sea level
   C. It decreases because the air is thinner
   D. It increases because the air is colder

6. Why does ice float in water?
   A. Because it is colder than water
   B. Because it has a lower density than water
   C. Because water expands when it freezes
   D. B and C

7. Which principle explains why ships made of steel can float on water?
   A. Boyle's Law
   B. Bernoulli's Principle
   C. Principle of Buoyancy
   D. Principle of Relativity

8. If you squeeze the middle of a closed, half-full water bottle, what happens to the air pressure inside the bottle?
   A. It decreases
   B. It stays the same
   C. It increases
   D. It first decreases, then increases

9. Which of the following would float in freshwater?
   A. A rock with density 3 g/cm^3
   B. An ice cube with density 0.92 g/cm^3
   C. A piece of metal with density 7.8 g/cm^3
   D. A rubber ball with density 1.5 g/cm^3

10. Why do your ears pop when you go up a mountain or take off in an airplane?
    A. Because the air pressure outside your body decreases, causing pressure to build up inside your ears
    B. Because the air pressure outside your body increases, causing your eardrums to expand
    C. Because of the change in oxygen levels at high altitudes
    D. Because the temperature changes affect the air inside your ears

11. As altitude increases, air pressure:
    A. Increases
    B. Decreases
    C. Stays the same
    D. Initially decreases, then increases

12. Which statement best describes why fish are able to float at different depths in water?
    A. Fish change their volume by inflating or deflating air bladders, adjusting their density
    B. Fish constantly swim upward to stay afloat
    C. The water's density changes to accommodate the fish
    D. Fish have less mass than the water

13. Why does a helium balloon rise into the air?
    A. The helium leaks through the balloon propelling the balloon upward
    B. The buoyant force on the balloon is more than the weight of the balloon
    C. The negative charge of the helium ions is repelled by the positive charges on the ground
    D. Convection currents cause the air to flow upward

14. How does wearing snowshoes prevent you from sinking into the snow?
    A. They decrease your mass
    B. They increase the pressure you exert on the snow
    C. They decrease the area over which your weight is distributed
    D. They increase the area over which your weight is distributed, reducing pressure

15. What is the primary reason airplanes fly at higher altitudes?
    A. Air is denser at higher altitudes, which improves lift.
    B. Air is less dense at higher altitudes, reducing drag on the airplane
    C. It is colder at higher altitudes, which improves engine performance.
    D. There is more oxygen at higher altitudes, which improves combustion.

16. Why does a diver feel more pressure as they dive deeper?
    A. Because water temperature decreases with depth, increasing pressure
    B. Because the volume of water above the diver increases, increasing pressure
    C. Because the density of water increases with depth
    D. Because of increased oxygen levels in deeper water