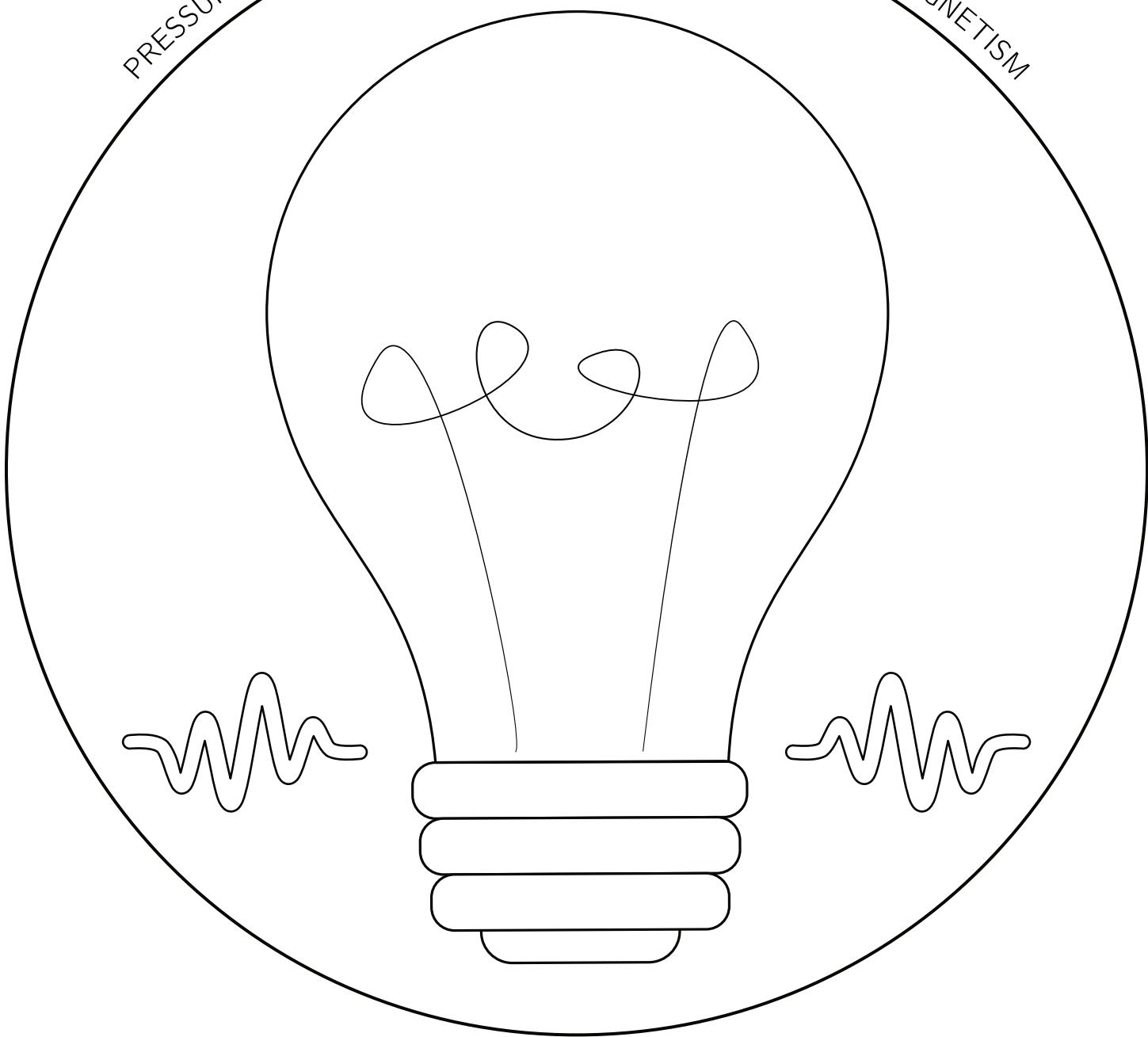


# Physics 2

PRESSURE, THERMODYNAMICS, WAVES, ELECTRICITY, & MAGNETISM



# PHYSICS 2

## PRESSURE, THERMODYNAMICS, WAVES, ELECTRICITY, & MAGNETISM

Lesson	Date	Topic	Pages
1	Wednesday, Jan 17	Introduction	5-7
2	Monday, Jan 22	What's the matter?	7-11
3	Wednesday, Jan 24	Elemental	12-15
4	Self-paced	Fun Physics Tricks	16-19
5	Monday, Jan 29	No Such Thing as Cold	21-25
6	Wednesday, Jan 31	Heat Transfer	26-29
7	Self-paced	Clay pot fridge	30-31
8	Monday, Feb 5	Heat Capacity & Phase Changes	32-36
9	Wednesday, Feb 7	Laws of Thermodynamics	37-40
10	Self-paced	Make Your Own Ice Cream	41-43
11	Monday, Feb 12	THERMODYNAMICS QUIZ SHOW	44-46
<b>Unit 2 End Break</b>			
12	Monday, Feb 19	Pressure & Fluids	47-52
13	Wednesday, Feb 21	Going for a Swim	53-57
14	Self-paced	Egg in a Bottle or Rising Water	58-59
15	Monday, Feb 26	Density & Buoyancy	60-63
16	Wednesday, Feb 28	Ocean of Air	64-67
17	Self-paced	Boat Float or Density Column	68-71
18	Monday, Mar 4	Fluids in Motion	72-75
19	Wednesday, Mar 6	When Push Comes to Shove	76-78
20	Self-paced	Ping Pong Tricks	79-80
21	Monday, Mar 11	PRESSURE QUIZ SHOW	81-83
<b>Unit 3 End Break</b>			
22	Monday, Mar 18	Making Waves	84-87
23	Wednesday, Mar 20	Good Vibrations	88-91
24	Self-paced	Make your own instrument	92-93
25	Monday, Mar 25	Resonance and Decibels	94-97
26	Wednesday, Mar 27	Electromagnetic Spectrum	98-101
27	Self-paced	Tabletop Kaleidoscope	102-103
28	Monday, Apr 1	Colors and Sending Signals	104-107
29	Wednesday April 3	WAVES QUIZ SHOW	108-109

Lesson	Date	Topic	Pages
<b>Apr 8-12 · SPRING BREAK</b>			
32	Monday, Apr 15	Electrostatics	110-113
33	Wednesday, Apr 17	The Current Event	114-117
34	Self-paced	Super Static	118-119
35	Monday, Apr 22	What's a Watt?	120-123
36	Wednesday, Apr 24	Marvelous Magnets	124-127
37	Self-paced	LED Holiday Card	128-133
38	Monday, Apr 29	Electromagnetism	134-137
39	Wednesday, May 1	Nuclear Physics	138-140
	Self-paced	Review for Quiz Show	143-144
40	Monday, May 6	The weird world of quantum	141-142
41	Wednesday, May 8	Final Quiz Show	

## SUPPLY LIST:

### Fun Physics Tricks

- Bottle with narrow neck
- Drawing supplies and paper
- Empty aluminum can
- Balloon
- Coin
- Glass cup or jar
- Teabags (the style with a tag and string attached)
- Matches or a lighter

### Clay Pot Fridge

- 2 small clay pots
- 2 larger clay pots
- 2 metal lids or aluminum pie tins to cover the pots
- Enough sand to fill the space between the clay pots
- 2 small towels
- thermometer
- water

### Homemade Ice Cream

- Ingredients for ice cream
- Ice
- Rock salt
- Oven mitts or towels
- Either 2 metal cans of different sizes and duct tape  
OR ziplock bags of different sizes

### Boat Float

- Aluminum foil
- A sink or container that can be filled with water
- Coins
- Rice
- Tape
- Liquid measuring cup
- Scissors

### Density Column

- 2 tall clear cups or cylindrical containers
- Sugar and water OR various liquids such as vegetable oil, and corn syrup
- Measuring cup
- Food coloring
- Spoon

### Egg in a Bottle

- 2-3 hardboiled eggs (medium size)
- Bottle with an opening slightly smaller than the egg
- Small birthday candles or matches
- Matches or lighter

### Rising Water

- Dish or pie plate
- Water
- Candle that can stand upright
- A transparent jar, glass or bottle
- Food coloring (optional)
- Matches or lighter

### Ping Pong Ball Launch

- Blow dryer
- Ping pong ball
- Paper towel or toilet paper tube

### Ball on a String

- Tape or glue gun
- Faucet or hose
- Ping pong ball
- String

### Make your own instrument

- Supplies depend on the instrument

### Tabletop Kaleidoscope

- 2 flat mirrors, tape, and small object for viewing such as a dice or pebble

## SUPPLY LIST:

### Sticky Balloons

- Two balloons
- A soft cloth for charging the balloon
- A wall, a window, and various furniture items

### Levitating Ring

- Balloon or a short length of PVC pipe
- A soft cloth for charging the balloon
- A very thin plastic bag (such as the type used grocery stores in the produce department)
- Scissors

### Paper Vacuum & Scooting Bubbles

- Balloon or short length of PVC pipe
- A soft cloth for charging the balloon
- Tissue paper
- Scissors
- Bubble solution or water and dish soap
- A flat counter or table

### Bending Water

- Balloon or short length of PVC pipe
- A soft cloth for charging the balloon
- A faucet or container that can create a thin stream of water

### LED Holiday Card

- 1 piece of cardstock
- 2 button batteries (CR2032 3-volt batteries work well.)
- Between 3 to 20 LED lights (3 mm)
- 0.5 m of conductive maker tape
- Scissors
- Push pin OR sewing needle
- Printed templates Or pencil and pen to create your own design
- Glue stick and tape
- A small piece of cardboard (optional)
- Coloring supplies

# PHYSICS – THE FUNDAMENTAL SCIENCE

Physics is a broad field of science dedicated to understanding matter, space, energy, and time. It has dozens of different areas of specialization!

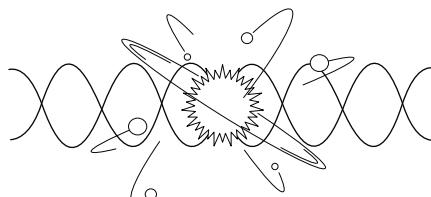
IN OUR PHYSICS 1 CLASS WE STUDIED CLASSICAL MECHANICS AND HAD ONE BONUS LESSON ON RELATIVITY (WHICH IS A PRETTY IMPORTANT CONCEPT IN ASTROPHYSICS). IN PHYSICS 2 WE'LL BE COVERING A WIDE VARIETY OF TOPICS!

## CLASSICAL MECHANICS



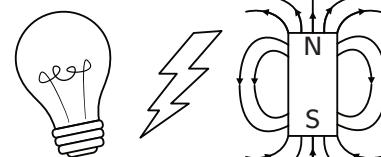
The study of how everyday objects move and behave

## QUANTUM MECHANICS



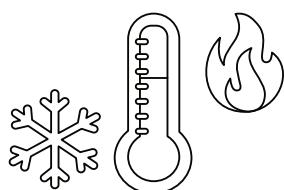
The study of how very small particles behave

## ELECTROMAGNETISM



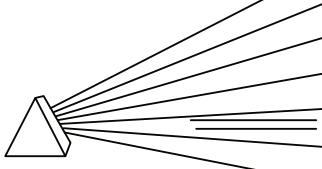
The study of electric and magnetic fields

## THERMODYNAMICS



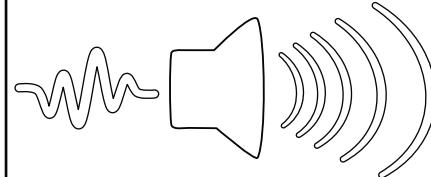
The study of heat, energy, and entropy

## OPTICS



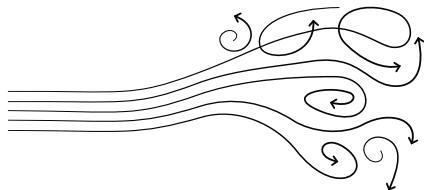
The study of the behavior and properties of light

## ACOUSTICS



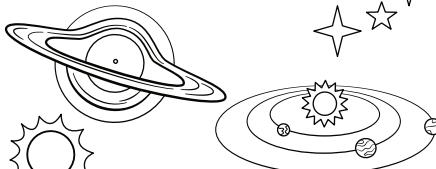
The study of mechanical waves such as sound

## FLUID DYNAMICS



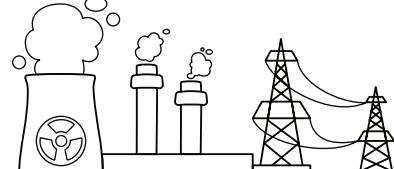
The study of the flow of liquids and gases

## ASTROPHYSICS



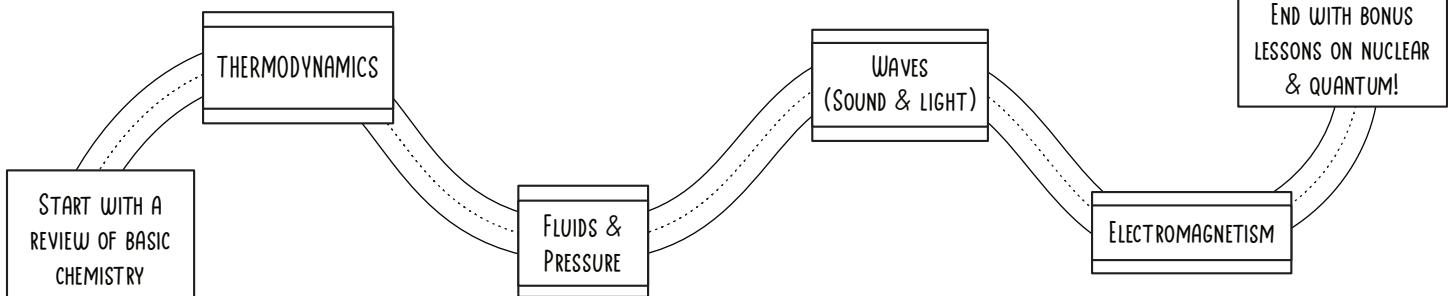
Physics in outer space! How stars, black holes, and solar systems work

## NUCLEAR PHYSICS



The study of atomic nuclei and the generation of nuclear energy

## PHYSICS 2 ROAD MAP:



# WHY PHYSICS?

## WHAT DO YOU WANT FROM THIS CLASS?

Before we start, think about your **why**. Why study physics? What are your goals for this class?



MAKE A NOTE OR TWO ABOUT WHY YOU ARE TAKING THIS CLASS. WHAT DO YOU HOPE TO LEARN OR EXPERIENCE?

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## MAKE A PLAN

You'll learn more about physics in this course if you are actively engaged in the learning. There are 3 great tools for this: using the notes, doing the practice problems, and completing the hands-on activities.

Consider each of these and make a plan for how to best adapt them to your circumstances and preferences. Be specific with each plan! Describe when and where you'll do coursework. Think about what you'll do if interruptions or other commitments come up.



 MY PLAN FOR WATCHING THE LESSONS AND USING THE NOTES:

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 MY PLAN FOR DOING THE PRACTICE PROBLEMS:

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 MY PLAN FOR COMPLETING THE LABS OR HANDS-ON ACTIVITIES:

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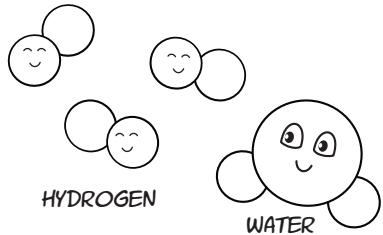
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# Unit 1: the chemistry you need for physics!

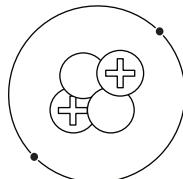


## MOLECULE



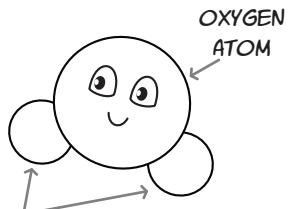
The smallest fundamental unit of a substance, often formed by two or more atoms

## ATOM



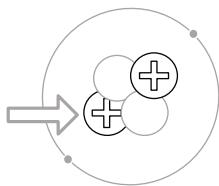
One atom of helium

## COMPOUND



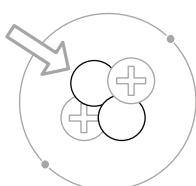
A molecule or substance made of two or more elements bonded together

## PROTON



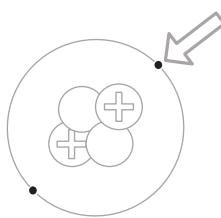
Positively charged particle in the nucleus of an atom

## NEUTRON



A particle with no charge in the nucleus of an atom

## ELECTRON



A negatively charged particle that orbits the nucleus of an atom

## ELEMENT



A substance that cannot be broken down by chemical reactions

## MATTER

EARTH	yes
AIR	yes
WATER	yes
LIGHT	no

Material that takes up space and can be weighed (it has mass)

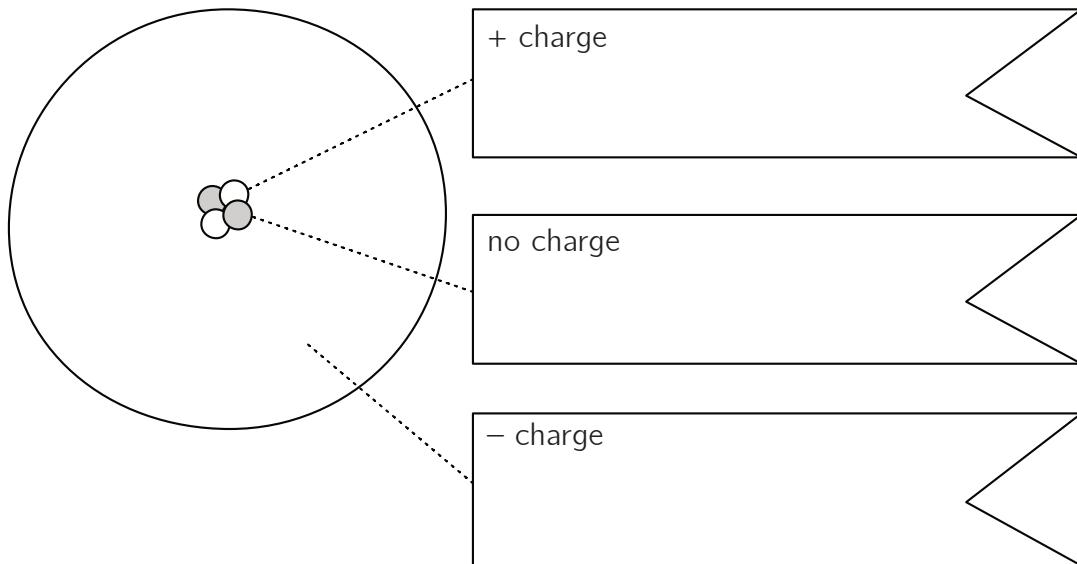
# WHAT'S THE MATTER?

FILL IN THE BLANKS:

nucleus    neutrons    properties    sharing    atoms    bond    protons

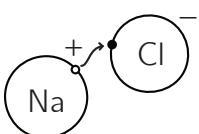
\_\_\_\_\_ are the smallest units of matter that retain the physical \_\_\_\_\_ of an element. They contain a nucleus which has positively charged \_\_\_\_\_ and neutrally charged \_\_\_\_\_. Negatively charged electrons surround the \_\_\_\_\_. Two or more atoms can \_\_\_\_\_ together by \_\_\_\_\_ or transferring electrons.

THE PARTS OF AN ATOM:

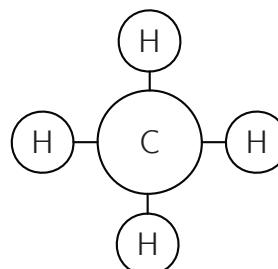


## TYPES OF CHEMICAL BONDS

Electrons transferred from one atom to another

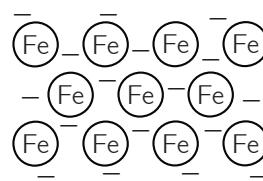


Makes + and - ions!

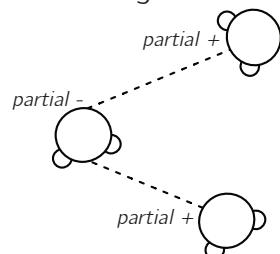


Share electrons between atoms

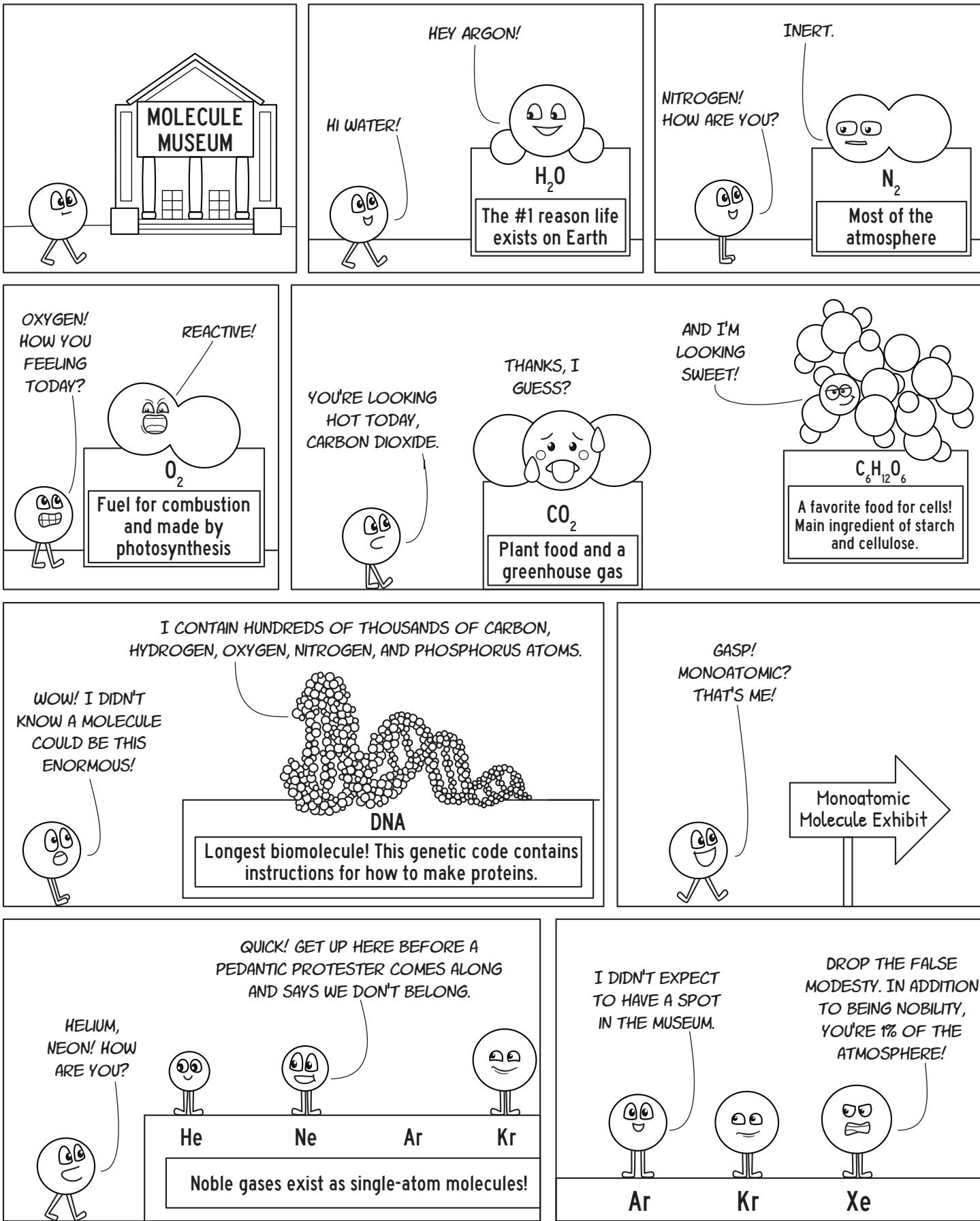
Electrons are shared between all atoms in an "electron sea"



Weak attraction between partially + and - regions



# Famous Molecules



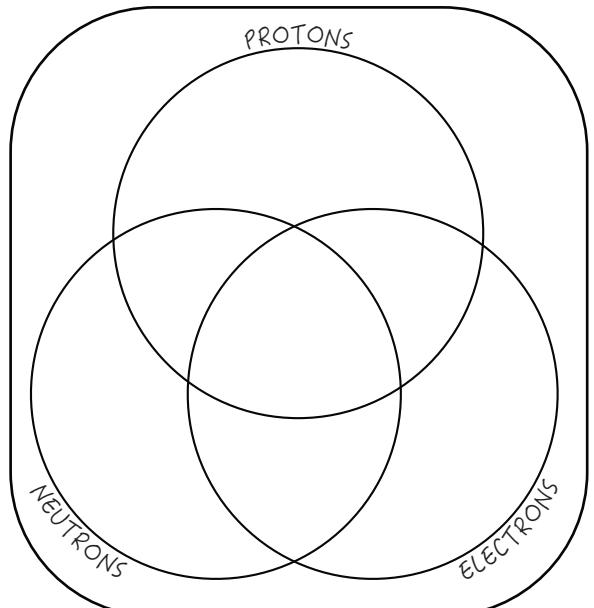
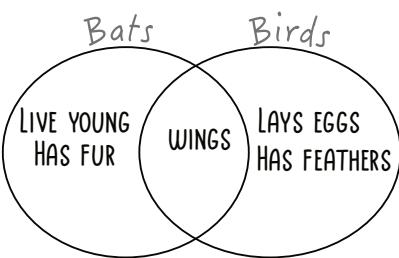
## PRACTICE PROBLEMS – WHAT'S THE MATTER?

- ① What is the smallest unit of an element that retains the properties of that element?
  - A. A compound
  - B. An electron
  - C. A molecule
  - D. An atom
- ② What is the center of an atom called?
  - A. Electron
  - B. Nucleus
  - C. Proton
  - D. Neutron
- ③ Which statement best describes the term molecule?
  - A. The smallest fundamental unit of a substance, often made of 2 or more atoms
  - B. The smallest particle of a chemical element
  - C. Something that cannot be broken down into simpler substances
  - D. Something that is always made of the same type of atom
- ④ Which particles are found in the nucleus of an atom?
  - A. Protons and Neutrons
  - B. Electrons and Protons
  - C. Neutrons and Electrons
  - D. Protons and Photons
- ⑤ What is the charge of an electron?
  - A. Positive
  - B. Negative
  - C. Neutral
  - D. Variable
- ⑥ All atoms of the same element contain the same number of:
  - A. Electrons
  - B. Protons
  - C. Neutrons
  - D. Ions
- ⑦ What is the charge of a neutron?
  - A. Positive
  - B. Negative
  - C. Neutral
  - D. Variable

## PRACTICE PROBLEMS – WHAT'S THE MATTER?

- ⑧ How many hydrogen atoms are present in a molecule of glucose ( $C_6H_{12}O_6$ )?
- A. 6
  - B. 12
  - C. 18
  - D. 24
- ⑨ Which type of chemical bond could be described as sharing of a sea of electrons amongst many positively charged ions?
- A. Ionic Bond
  - B. Metallic Bond
  - C. Covalent Bond
  - D. Hydrogen Bond
- ⑩ Which of the following is not composed of atoms?
- A. Water
  - B. Rock
  - C. Sunlight
  - D. Plastic
- ⑪ Bonds between atoms primarily involve:
- A. Sharing or transferring protons
  - B. Sharing or transferring neutrons.
  - C. Sharing or transferring electrons.
  - D. Sharing or transferring photons.
- ⑫ Which statement is more correct?
- A. An atom contains very little empty space.
  - B. By volume, an atom is mostly empty space.
- ⑬ Place each letter in the appropriate part of the Venn diagram of protons, neutrons, and electrons.
- A. Has a positive charge
  - B. Contributes significant mass to the atom
  - C. Is a subatomic particle
  - D. Orbits the nucleus
  - E. Is a molecule
  - F. Determines the atomic number
  - G. Has a charge
  - H. Is in the nucleus of an atom
  - I. Has no charge
  - J. Found in an oxygen atom

A VENN DIAGRAM USES OVERLAPPING SHAPES TO SHOW RELATIONSHIPS BETWEEN 2 OR MORE THINGS. SHARED CHARACTERISTICS ARE PLACED IN THE OVERLAPPING REGION:



# Elemental

Atoms and molecules can exist as different **states of matter**. The most commonly-encountered states are solid, liquid, and gas. But other states (such as plasma) exist as well. Substances that cannot be broken down further by chemical reactions are called **elements**.

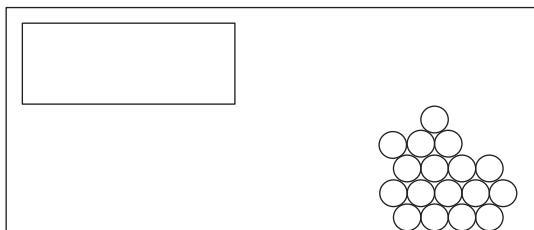
Complete the cards below for each state of matter. Would you describe their shape and volume as fixed or flexible? On a scale of one (least energetic) to five (most energetic), how would you rate them for particle movement? Draw a face on each state of matter avatar.



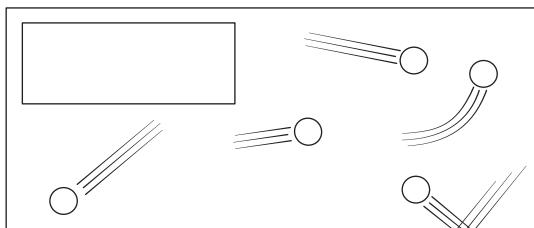
SOLID	LIQUID	GAS
SHAPE: _____	SHAPE: _____	SHAPE: _____
VOLUME: _____	VOLUME: _____	VOLUME: _____
ENERGY LEVEL:	ENERGY LEVEL:	ENERGY LEVEL:

THE ENERGY OF MOVING PARTICLES IS CALLED \_\_\_\_\_ ENERGY.

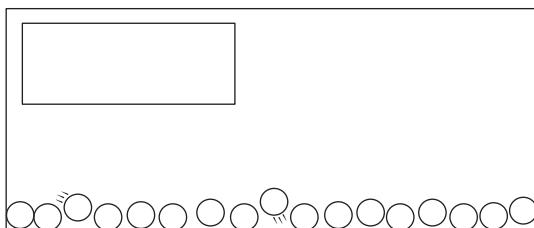
The boxes below show the movement of the molecules in the same substance at different temperatures. Write the name of each state of matter and then draw lines to match them to their corresponding tag or label below.



Particles slide past each other but are still close together



Particles move quickly and are often very far apart from each other



Particles vibrate in place and have low kinetic energy

# THE PERIODIC TABLE OF ELEMENTS

1 <b>H</b> Hydrogen	2 <b>He</b> Helium
3 <b>Li</b> Lithium	4 <b>Be</b> Beryllium
11 <b>Na</b> Sodium	12 <b>Mg</b> Magnesium
19 <b>K</b> Potassium	20 <b>Ca</b> Calcium
37 <b>Rb</b> Rubidium	21 <b>Sc</b> Scandium
38 <b>Sr</b> Strontium	22 <b>Ti</b> Titanium
39 <b>Y</b> Yttrium	23 <b>V</b> Vanadium
40 <b>Zr</b> Zirconium	24 <b>Cr</b> Chromium
41 <b>Nb</b> Niobium	25 <b>Mn</b> Manganese
42 <b>Mo</b> Molybdenum	26 <b>Fe</b> Iron
43 <b>Tc</b> Technetium	27 <b>Co</b> Cobalt
44 <b>Ru</b> Ruthenium	28 <b>Ni</b> Nickel
45 <b>Rh</b> Rhodium	29 <b>Cu</b> Copper
46 <b>Pd</b> Palladium	30 <b>Zn</b> Zinc
47 <b>Ag</b> Silver	31 <b>Ga</b> Gallium
48 <b>Cd</b> Cadmium	32 <b>Ge</b> Germanium
49 <b>In</b> Indium	33 <b>As</b> Arsenic
50 <b>Sn</b> Tin	34 <b>Se</b> Selenium
51 <b>Sb</b> Antimony	35 <b>Br</b> Bromine
52 <b>Te</b> Tellurium	36 <b>Kr</b> Krypton
53 <b>I</b> Iodine	
54 <b>Xe</b> Xenon	
55 <b>Cs</b> Caesium	56 <b>Ba</b> Barium
56 <b>Ra</b> Radium	72 <b>Hf</b> Hafnium
87 <b>Fr</b> Francium	73 <b>Ta</b> Tantalum
88 <b>Ra</b> Radium	74 <b>W</b> Tungsten
	75 <b>Re</b> Rhenium
	76 <b>Os</b> Osmium
	77 <b>Ir</b> Iridium
	78 <b>Pt</b> Platinum
	79 <b>Au</b> Gold
	80 <b>Hg</b> Mercury
	81 <b>Tl</b> Thallium
	82 <b>Pb</b> Lead
	83 <b>Bi</b> Bismuth
	84 <b>Po</b> Polonium
	85 <b>At</b> Astatine
	86 <b>Rn</b> Radon
	104 <b>Rf</b> Rutherfordium
	105 <b>Db</b> Dubnium
	106 <b>Sg</b> Seaborgium
	107 <b>Bh</b> Bohrium
	108 <b>Hs</b> Hassium
	109 <b>Mt</b> Meitnerium
	110 <b>Ds</b> Darmstadtium
	111 <b>Rg</b> Roentgenium
	112 <b>Cn</b> Copernicium
	113 <b>Nh</b> Nihonium
	114 <b>Fl</b> Flerovium
	115 <b>Mc</b> Moscovium
	116 <b>Lv</b> Livermorium
	117 <b>Ts</b> Tennessine
	118 <b>Og</b> Oganesson

57 <b>La</b> Lanthanum	58 <b>Ce</b> Cerium	59 <b>Pr</b> Praseodymium	60 <b>Nd</b> Neodymium	61 <b>Pm</b> Promethium	62 <b>Sm</b> Samarium	63 <b>Eu</b> Europium	64 <b>Gd</b> Gadolinium	65 <b>Tb</b> Terbium	66 <b>Dy</b> Dysprosium	67 <b>Ho</b> Holmium	68 <b>Er</b> Erbium	69 <b>Tm</b> Thulium	70 <b>Yb</b> Ytterbium	71 <b>Lu</b> Lutetium
89 <b>Ac</b> Actinium	90 <b>Th</b> Thorium	91 <b>Pa</b> Protactinium	92 <b>U</b> Uranium	93 <b>Np</b> Neptunium	94 <b>Pu</b> Plutonium	95 <b>Am</b> Americium	96 <b>Cm</b> Curium	97 <b>Bk</b> Berkelium	98 <b>Cf</b> Californium	99 <b>Es</b> Einsteinium	100 <b>Fm</b> Fermium	101 <b>Md</b> Mendelevium	102 <b>No</b> Nobelium	103 <b>Lr</b> Lawrencium

MATCH EACH ELEMENT SYMBOL WITH THE CORRESPONDING NAME AND FACT:

7 <b>N</b>
---------------

**Carbon** - Forms strong covalent bonds with many other elements and with itself. The primary element in biomolecules and living organisms.

17 <b>Cl</b>
-----------------

**Hydrogen** - The lightest and most abundant element in the universe. The Sun, Jupiter, and Saturn are all mostly made of hydrogen.

6 <b>C</b>
---------------

**Nitrogen** - 78% of the atmosphere is nitrogen gas ( $N_2$ ). This element is also an essential ingredient of proteins and DNA.

1 <b>H</b>
---------------

**Chlorine** - Widely used to purify water and as a cleaning agent. In pure form, it is toxic and highly reactive.

8 <b>O</b>
---------------

**Oxygen** - Approximately 21% of the atmosphere is made from this element. It is reactive and forms many compounds with other elements.

94 <b>Pu</b>
-----------------

**Iron** - This magnetic element is abundant in the Earth's crust and essential for many animals because of its role in transporting oxygen in the blood.

26 <b>Fe</b>
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**Plutonium** - Highly radioactive. Used in nuclear reactors and weapons.

## PRACTICE PROBLEMS – ELEMENTAL

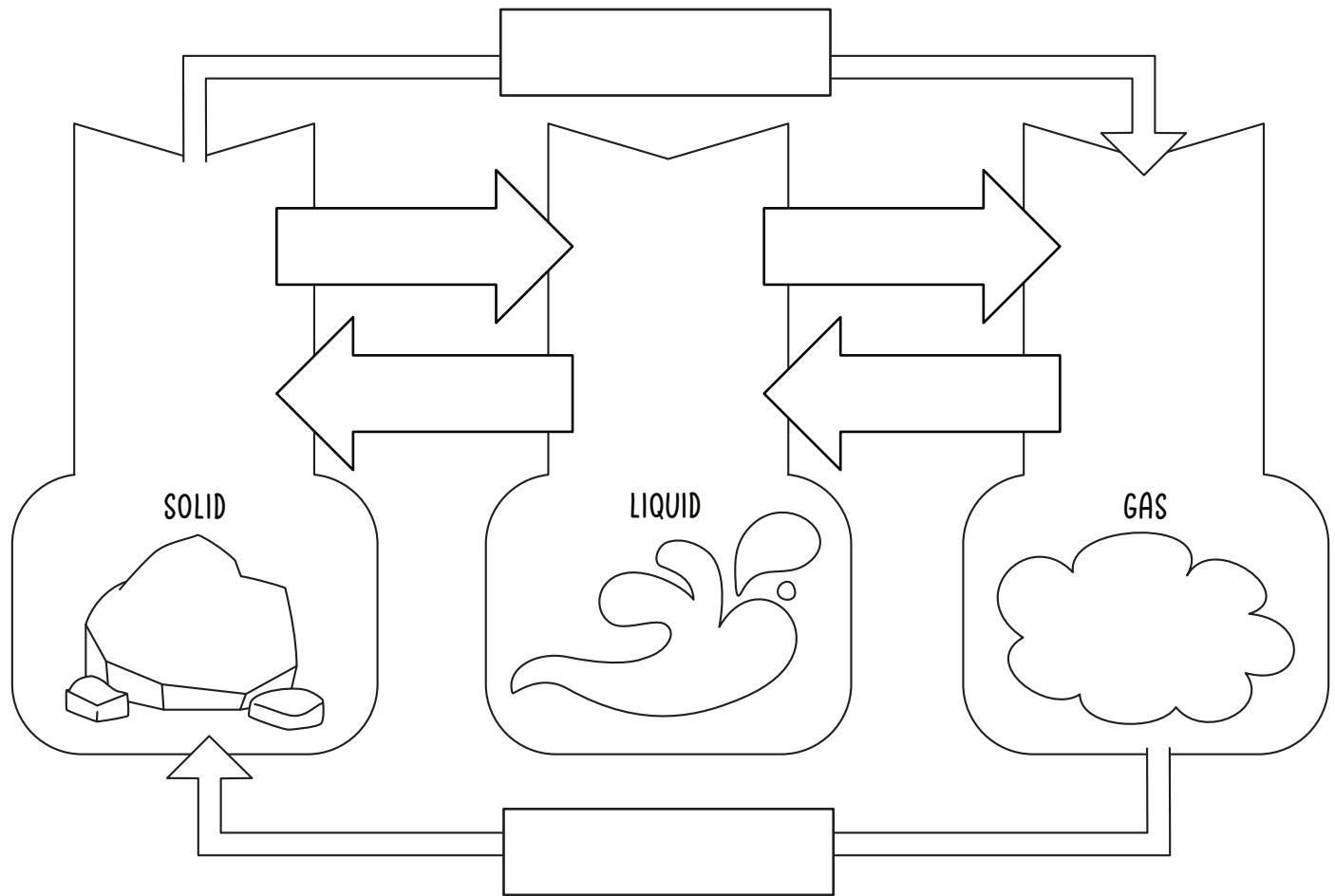
- 1) Which best defines an element?
  - A. A pure substance containing only one type of atom
  - B. Two or more atoms bonded together
  - C. An atom with one or more electrons removed
  - D. The smallest unit of matter
- 2) Which is not considered an element?
  - A. Salt
  - B. Hydrogen
  - C. Oxygen
  - D. Aluminum
- 3) What is the smallest unit of an element that retains the properties of that element?
  - A. Atom
  - B. Molecule
  - C. Compound
  - D. Mixture
- 4) Which element is represented by the symbol 'Fe' on the periodic table?
  - A. Fermium
  - B. Lead
  - C. Fluorine
  - D. Iron
- 5) The process of a liquid turning into a gas can be called:
  - A. Vaporization
  - B. Melting
  - C. Condensation
  - D. All of the above
- 6) A volcano erupts and lava flows down a hillside. After a few weeks, the lava flow has become solid rock. What phase change describes this change?
  - A. Boiling
  - B. Condensation
  - C. Freezing
  - D. Melting
- 7) How many elements are in a water molecule?
  - A. One
  - B. Two
  - C. Three
  - D. Four

# PRACTICE PROBLEMS – ELEMENTAL

- (8) What happens to particles when a substance changes from solid to liquid?
- A. They move closer together and more slowly
  - B. They spread out and move slower
  - C. They move closer together and faster
  - D. They spread out and move faster
- (9) Which element is known for being the lightest and having the atomic number 1?
- A. Helium
  - B. Hydrogen
  - C. Oxygen
  - D. Carbon
- (10) Knowing the terms for changes of state is an important skill for our next unit! Use the vocabulary words listed below to label the changes between states in the boxes or arrows.

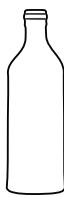
Note: one of the arrows will have three words.

Melt      Freeze      Evaporate      Condense      Sublimate      Deposit      Boil      Vaporize



# FUN PHYSICS TRICKS

## MATERIALS



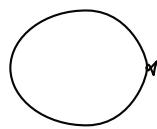
1 bottle with a narrow neck



Drawing supplies and paper



An empty aluminum can



1 balloon or a short length of plastic pipe



A coin



1 glass cup or jar



1 teabag made from filter paper and of the style that is folded over. A plastic or square teabag won't work!



Matches or a lighter

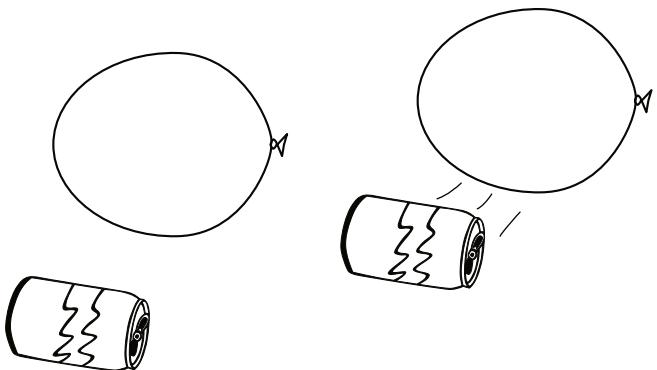
## GOALS

- ★ Experience curiosity and wonder about physics!
- ★ Get hands-on experience with physics principles that we will learn about later in this course.
- ★ Bonus: Learn 5 tricks that can stump your friends and family members!

## 1 ALUMINUM CAN MOVER

Can you move an empty aluminum can across a table without blowing on it or touching it?

1. Place an empty soda can on a horizontal surface so that it is laying on its side.
2. Blow up a balloon and tie off the end.
3. Rub the balloon back and forth on cloth or hair to build up a static charge.
4. Hold the balloon close to the can (but don't touch it!) and then move it away from the can. The can will roll towards the balloon.

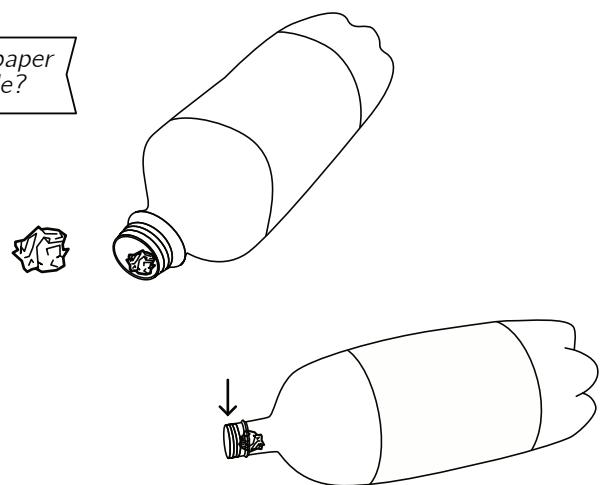


*Tip: If you do not have a balloon, a piece of plastic pipe will also gather a static charge.*

## 2 PAPER WAD CHALLENGE

Can you blow the wad of paper into the empty water bottle?

1. Crumple up a small piece of paper and place it in the mouth of an empty 1 L or 2 L bottle laying on its side. The ball of paper should be about 1/3 the size of the opening of the bottle.
2. Challenge a friend to get the paper into the bottle by blowing on it.
3. After they fail, demonstrate the correct way to blow in the paper by blowing gently from directly above the mouth of the bottle.



## FUN PHYSICS TRICKS

### 3 DISAPPEARING COIN

*Watch a coin disappear!*

1. Place the coin on a table or counter.
2. Place a clear glass or jar over the coin and ask a person to watch the coin from the side of the jar (rather than looking straight down at the coin)
3. Fill up the jar with water. Do they still see the coin?

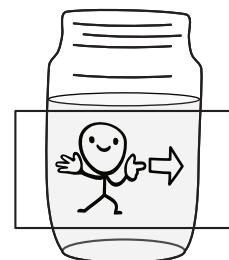


### 4 IMAGE REVERSER

*Can you reverse an image without a mirror?*

1. Draw an image on a piece of paper that is not symmetrical.
2. Get a clear, cylindrical glass, jar, or vase.
3. Place the image about 10 cm behind the glass. It should look about the same.
4. Now pour water into the glass and watch as the image changes directions!

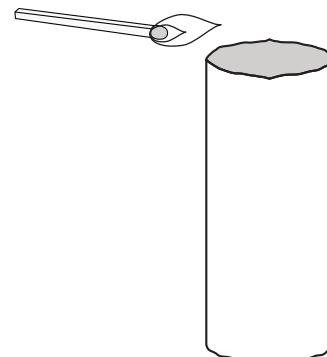
Note, that you might have to move the drawing closer or further to the glass to see the effect. Experiment until you see the reverse image!



### 5 FLYING TEA BAG

*Can you make a tea bag launch into the sky by lighting it on fire?*

- This activity must be done with adult supervision!
1. Unfold the teabag and remove the string.
  2. Empty the tea out. It can be placed in a coffee filter. Pour hot water over and let the water filter through to enjoy a cup of tea!
  3. Unfold and straighten out the teabag into a cylinder. Then stand it up vertically. What do you predict would happen if you lit the teabag on fire?
  4. Check to be sure that the area surrounding the teabag is open and uncluttered. There should be no flammable material within 7 feet of the teabag.
  5. Carefully use a match to light the top of the teabag. Stand back and watch the results!



## YOUR THOUGHTS & NOTES!

Take a moment to make some notes!

Color in the stars to give each physics trick a rating for how satisfying it was. Which one was your favorite? Which of these did you find the most surprising?

Are there any tips you'd give someone else who was trying out these tricks for the first time? Anything you'd like to remember if you were to do these again later?

Most important, what questions did these activities spark? What did you notice, what did you wonder about? Do you have any ideas for why these worked?

*You don't need to figure out the answers for how they worked right now. We'll be revisiting each of these physics tricks later in our class!*

### 1 ALUMINUM CAN MOVER



#### YOUR RATING

FROM ONE STAR (NOT SATISFYING)  
TO 5 STARS (VERY SATISFYING!)

Tips for next time (optional): \_\_\_\_\_

Something you noticed or wondered about: \_\_\_\_\_

How or why did it work? Make a guess!  
\_\_\_\_\_  
\_\_\_\_\_

### 2 PAPER WAD CHALLENGE



Tips for next time (optional): \_\_\_\_\_

Something you noticed or wondered about: \_\_\_\_\_

How or why did it work? Make a guess!  
\_\_\_\_\_  
\_\_\_\_\_

## YOUR THOUGHTS & NOTES!

3 DISAPPEARING COIN



Tips for next time (optional): \_\_\_\_\_

Something you noticed or wondered about: \_\_\_\_\_

How or why did it work? Make a guess! \_\_\_\_\_

4 MIRROR IMAGE



Tips for next time (optional): \_\_\_\_\_

Something you noticed or wondered about: \_\_\_\_\_

How or why did it work? Make a guess! \_\_\_\_\_

5 FLYING TEABAG



Tips for next time (optional): \_\_\_\_\_

Something you noticed or wondered about: \_\_\_\_\_

How or why did it work? Make a guess! \_\_\_\_\_



## Unit 2: Thermodynamics

All about heat and the transfer of energy!

### CELSIUS vs KELVIN vs FAHRENHEIT

Three different systems for measuring temperature

K  
°C  
°F

### TEMPERATURE

A measure of the average kinetic energy of the particles in a system.

### HEAT

cal or J

Energy moving from one object to another because of a difference in temperature.

### CONVECTION

Heat transfer by the movement of fluids (gas or liquid)

### CONDUCTION

The movement of heat or electricity through a material.

### RADIATION

HEAT (IR)   LIGHT   UV   X-RAY

Energy transmitted by electromagnetic waves

### ENTROPY

S

A measure of the disorder or randomness in a system

### INTERNAL ENERGY

The total kinetic and potential energy of the particles in a system.

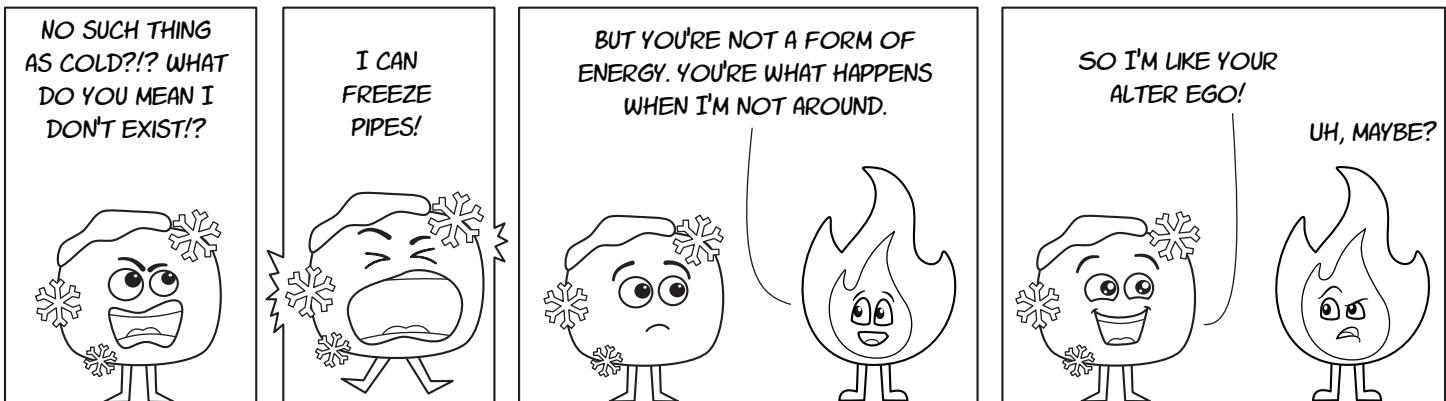
### SPECIFIC HEAT CAPACITY

1 gram

1°C

The amount of heat required to raise the temperature of 1 gram by 1 °C

# NO SUCH THING AS COLD

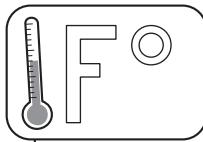
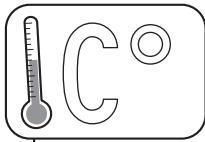


FILL IN THE BLANKS:

molecules      temperature      energy      cold      absence      higher      kinetic

Temperature is the \_\_\_\_\_ energy of the \_\_\_\_\_ in a substance. The faster the molecules move, the more kinetic \_\_\_\_\_ they have and the \_\_\_\_\_ their measured \_\_\_\_\_ will be. People often talk about hot and \_\_\_\_\_ as being opposite of each other. But heat is a form of energy. Cold is not. In reality, cold is just the \_\_\_\_\_ of heat.

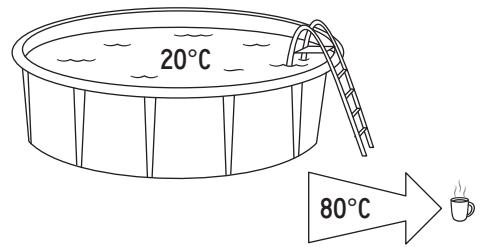
Record some facts about each temperature measurement system:



Consider an amoeba that can survive in water as long as the temperature stays ABOVE 15° C (59° F).

Your job is to keep the amoeba alive overnight and you have 2 choices for where to place it:

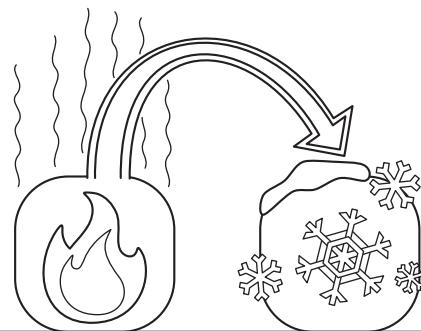
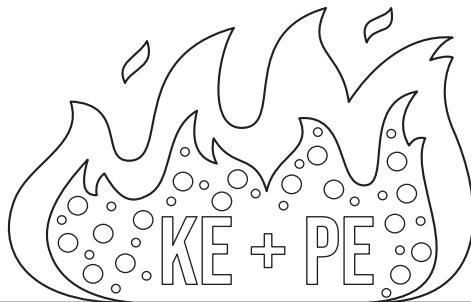
- A 2,000 liter tepid pool of water that is 20° C (68° F)
- A ½ liter of very hot water heated to 80° C (176° F)



WHICH CONTAINER WOULD KEEP THE AMOEBA WARM THE LONGEST AND WHY?

# INTERNAL ENERGY VS HEAT

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

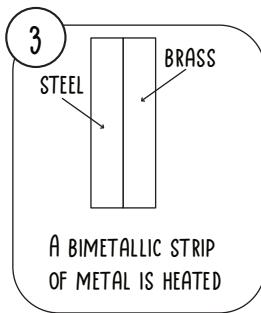
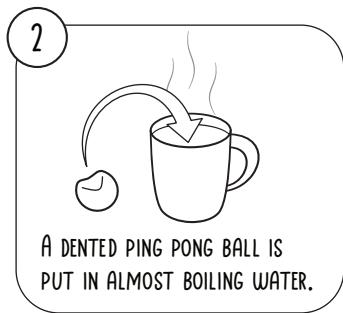
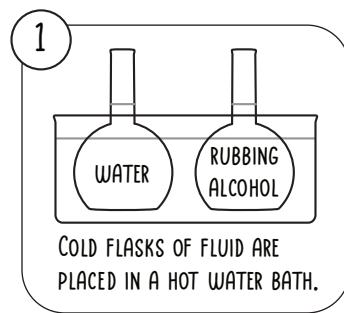


SOMETHING SIMILAR: \_\_\_\_\_

SOMETHING DIFFERENT: \_\_\_\_\_

## THERMAL EXPANSION

Record what happens in each case below. Is it what you expected?



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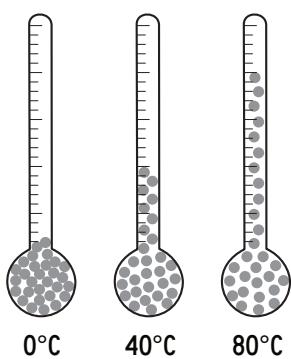
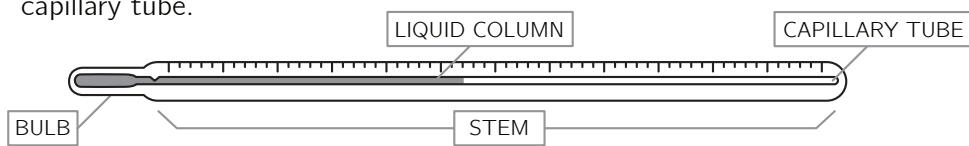
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## HOW A THERMOMETER WORKS

A thermometer has a bulb connected to a narrow capillary tube. The tube contains both gas (usually nitrogen) and a liquid such as alcohol, kerosene, or mercury.

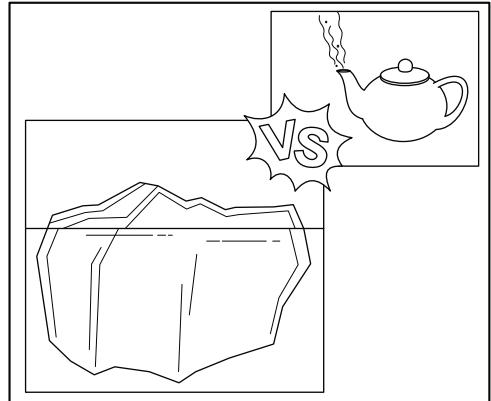
As temperature increases, the molecules in the liquid move faster and take up more space. The gas molecules are also moving faster, but since they were so spread out to begin with, they simply move faster within a smaller space as the liquid moves up the capillary tube.



# PRACTICE PROBLEMS – NO SUCH THING AS COLD

① List 3 examples of thermal expansion that occur in every day life?

② What has a higher **temperature**, an iceberg 1 kilometer wide or a tea kettle with 0.5 liters of boiling water? Explain.



③ What has more total **internal energy**, a large iceberg that is 1 km wide or a teakettle with 0.5 liters of boiling water? Explain.

④ Absolute zero is sometimes defined as the temperature at which:

- A. Molecular motion would cease.
- B. Thermal energy is at its maximum
- C. Heat transfer is at its maximum
- D. Thermal expansion is rapid

⑤ What is heat?

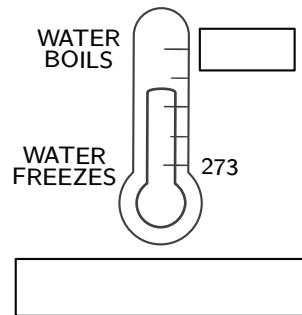
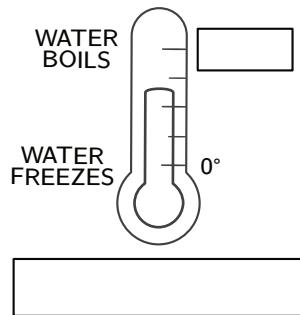
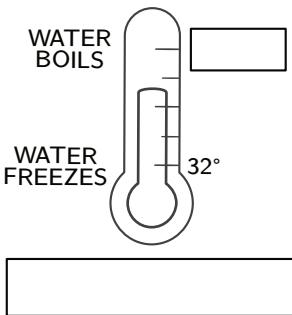
- A. The kinetic energy of an object
- B. The movement of energy from one object to another
- C. The energy arising from the position and interactions of the molecules within an object

⑥ What is temperature a measure of?

- A. The total energy of a substance
- B. The transfer of thermal energy between two systems
- C. The average kinetic energy of the molecules in a substance
- D. The lack of energy in a substance

## PRACTICE PROBLEMS – NO SUCH THING AS COLD

- 7) Label the three thermometers according to their temperature scales ( $^{\circ}\text{C}$ ,  $^{\circ}\text{F}$ , or K) and write the temperature at which water boils. Then put a star by the scale that doesn't have negative numbers.



- 8) What causes thermal expansion in substances?
- A. Loss of heat
  - B. Reflection of heat
  - C. Decrease in molecular motion
  - D. Increase in molecular motion
- 9) What happens to the motion of molecules when the temperature of a substance increases?
- A. The motion decreases
  - B. The motion increases
  - C. The motion remains constant
  - D. The motion changes directions
- 10) In the thermal expansion experiment, why does the level of the fluid rise when the flask is placed in hot water?
- A. The temperature increases
  - B. The temperature decreases
  - C. The molecules move more quickly and are further apart from each other
  - D. The molecules move more slowly and are closer together to each other
  - E. Both B and D
  - F. Both A and C

# HEAT TRANSFER

In Aesop's fable "The Satyr and the Traveler," a man is wandering in a forest during winter. A satyr sees him and invites him to its home. The satyr observes the man blow on his fingers to warm them and then blow on soup to cool it.

The satyr is bothered by the duplicity and leaves saying that it can't trust a being that blows both hot and cold in the same breath!

In actuality, the temperature of the man's breath was always the same. How can you explain the fact that the same breath can be used both to cool and warm something?

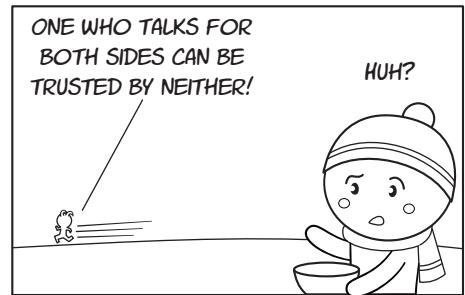
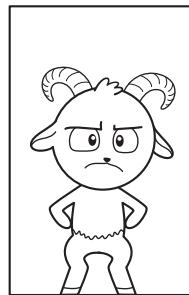
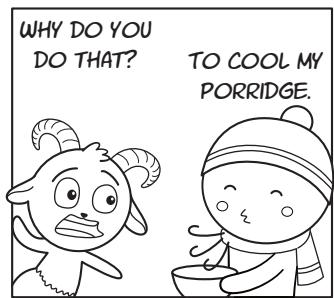
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*What is your prediction for each situation below? Check the box you agree with, then describe how the heat is being transferred.*



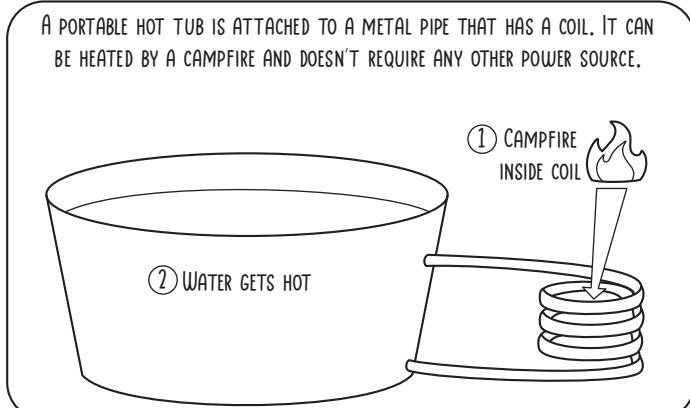
2 SPOONS ARE PLACED IN A POT OF BOILING WATER FOR 5 MINUTES. HOW WOULD THEIR HANDLES FEEL?

Both spoons are hot

Metal spoon is hot, wooden spoon is cool

Wooden spoon is hot, metal spoon is cool

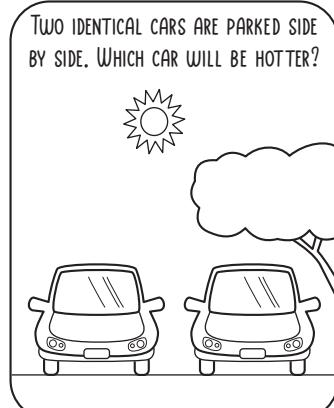
Both spoons are cool



A PORTABLE HOT TUB IS ATTACHED TO A METAL PIPE THAT HAS A COIL. IT CAN BE HEATED BY A CAMPFIRE AND DOESN'T REQUIRE ANY OTHER POWER SOURCE.

② WATER GETS HOT

① CAMPFIRE INSIDE COIL



TWO IDENTICAL CARS ARE PARKED SIDE BY SIDE. WHICH CAR WILL BE HOTTER?



Car in the sun

Car in the shade

What is TRANSFERRING the heat?

The 3 main types of heat transfer are listed below. Draw lines to match the term to its corresponding tag or label.

## CONDUCTION

## CONVECTION

## RADIATION

*The transfer of heat between currents of a gas or liquid due to a difference in temperature.*

ONLY IN FLUIDS

*The transfer of heat between two objects in direct contact with each other.*

FASTEAST FORM OF HEAT TRANSFER

*The transfer of heat by electromagnetic waves.*

CAN TRAVEL THROUGH A VACUUM

The ability of a material to conduct or insulate heat depends on its thermal *conductivity*, which is a measure of how quickly heat can flow through the material.

Materials like copper and aluminum have high thermal conductivity and are called **thermal conductors**.

Materials such as wood, styrofoam, and air have low thermal conductivity. These are called **thermal insulators**.

### SCAVENGER HUNT!

FIND 3 EXAMPLES OF THERMAL CONDUCTORS IN YOUR HOME:

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FIND 3 EXAMPLES OF THERMAL INSULATORS IN YOUR HOME:

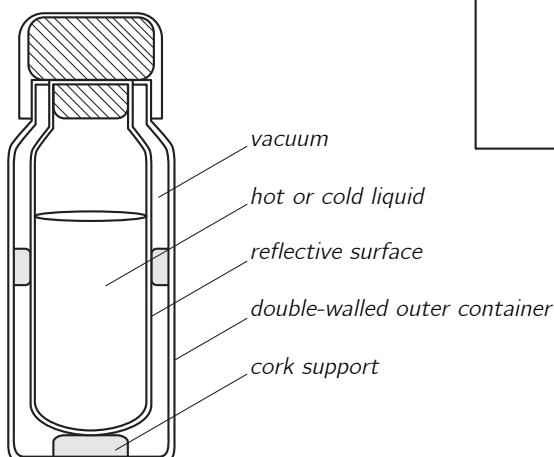
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### DIAGRAM OF A THERMOS

*The gap between the outer and inner container of this thermos contains a vacuum. Would the thermos work better if this space contained air instead?*



*What type of heat transfer is reduced by the reflective surface of the inner container?*

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## PRACTICE PROBLEMS – HEAT TRANSFER

- ① Which of the following is NOT a type of heat transfer?
- A. Conduction
  - B. Convection
  - C. Radiation
  - D. Combustion
- ② A cup of hot chocolate is placed on a table. Would placing a lid on a cup of hot chocolate cause it to stay warm longer or make no difference in how quickly it cooled? Explain.
- 
- 

- ③ Why do dark surfaces get warmer than light surfaces under sunlight?

- A. Dark surfaces reflect all radiation.
- B. Dark surfaces are usually thicker.
- C. Dark surfaces absorb more radiation.
- D. Dark surfaces conduct heat better.

- ④ In which situation is heat being transferred by conduction?

- A. Using a fan to cool a room
- B. Cooking food in a microwave
- C. Melting ice in your hand
- D. Steam rising from hot water

- ⑤ When you touch a cold metal pole in winter, your hand feels cold because:

- A. Heat is moving from your hand to the pole through conduction.
- B. The pole is giving cold to your hand.
- C. The pole radiates cold air around it.
- D. Convection currents move cold into your hand.

- ⑥ What makes air a good insulator?

- A. It conducts heat very well.
- B. It is dense and heavy.
- C. It has a lot of moisture.
- D. It has low density and its molecules are spread out.

- ⑦ On a cold day, Emily touches her hand to a metal railing and then a wooden fence post. Both objects have the same temperature, but the metal railing feels colder. Explain why.
- 
-

## PRACTICE PROBLEMS – HEAT TRANSFER

- 7) Which of the following is an example of convection?
- A. A metal handle getting hot on a pot of boiling water
  - B. Feeling the heat from a light bulb without touching it
  - C. Warm air rising near a radiator
  - D. Heat from the Sun warming the Earth
- 8) Which of the following is an example of radiation?
- A. Boiling water in a pot
  - B. A metal rod getting hot at one end after the other end is placed in a flame
  - C. Feeling warmth from a campfire from a distance
  - D. Wind blowing warm air
- 9) Draw a line to classify each material as either a thermal conductor or insulator.

iron  
plastic  
wood  
copper

insulator  
conductor

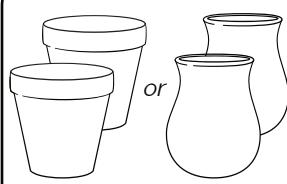
gold  
wool  
styrofoam  
air

- 10) What makes a substance a good thermal conductor?

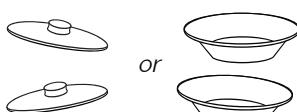
- 11) Why do insulators prevent the transfer of heat?

# MAKE A FRIDGE FROM CLAY AND SAND

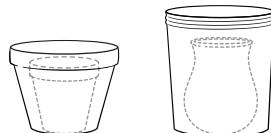
## MATERIALS



2 small clay pots or vases



2 metal lids or aluminum pie tins that can cover the top of the clay pots



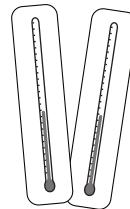
2 buckets or clay pots that are larger than the small clay pots



Enough dry sand to fill the space between the small and large pots or buckets



2 small towels



2 thermometers



water

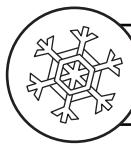
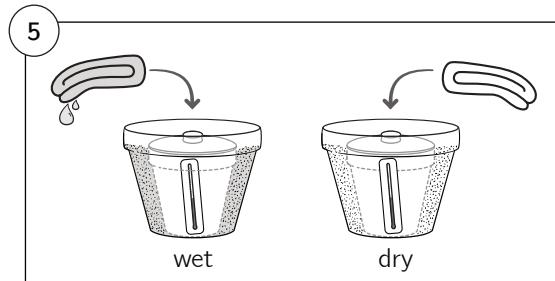
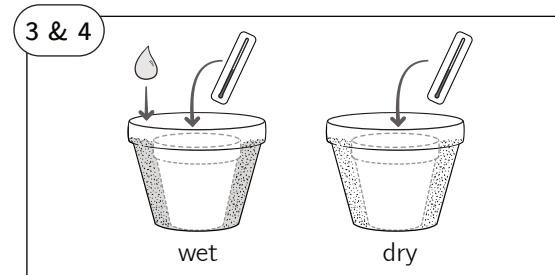
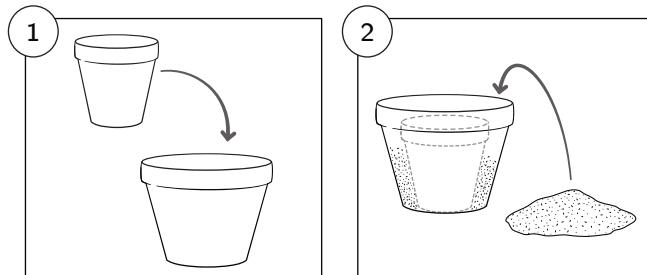
## GOALS

★ Design and modify a device that absorbs thermal energy.

★ Learn more about the transfer of energy and refrigeration.

## Steps:

1. Place each small clay pot inside the larger pot or bucket.
2. Fill the space between the small pots and the larger containers with sand. Label one setup "wet" and the other one "dry."
3. Pour water into the sand of the pot labeled as "wet" until the sand is completely moist. Be careful not to pour water into the inner pot. Leave the sand in the "dry" pot as is.
4. Place a thermometer inside each clay pot and take a temperature reading. Then cover both of the clay pots with metal lids.
5. Get one of the towels completely wet and ring out excess water. Place it over the clay pot that has wet sand. Place the other towel over the dry clay pot.
6. Check both pots every hour over the next 8 hours and record the temperatures on the thermometers of the inside pot. If the towel or sand in the "with water" pot appears dry, add more water so that they become damp again.



When water evaporates, it absorbs heat from its surroundings. This principle is used in many cooling methods such as sweating, swamp coolers, misters, cooling towers in industrial plants, and "pot in pot" refrigerators or Zeer pots.

# A COOL EXPERIMENT

Label temperature on the Y axis



Use a different color to record for the data for each pot.

- Wet  
 Dry



Label time on the X axis

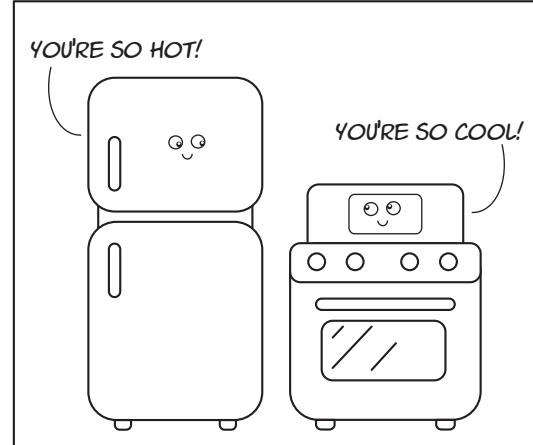
Which clay pot fridge had lower temperatures inside?

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What caused the differences in temperature between the 2 pots?

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What environmental factors influence the effectiveness of the clay pot fridge and how would they impact it? Consider things like air temperature, air flow, and humidity.

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What could be changed to improve the clay pot fridge? Could it preserve food and keep the internal temperature near 3 to 5 °C or 40° F? Why or why not?

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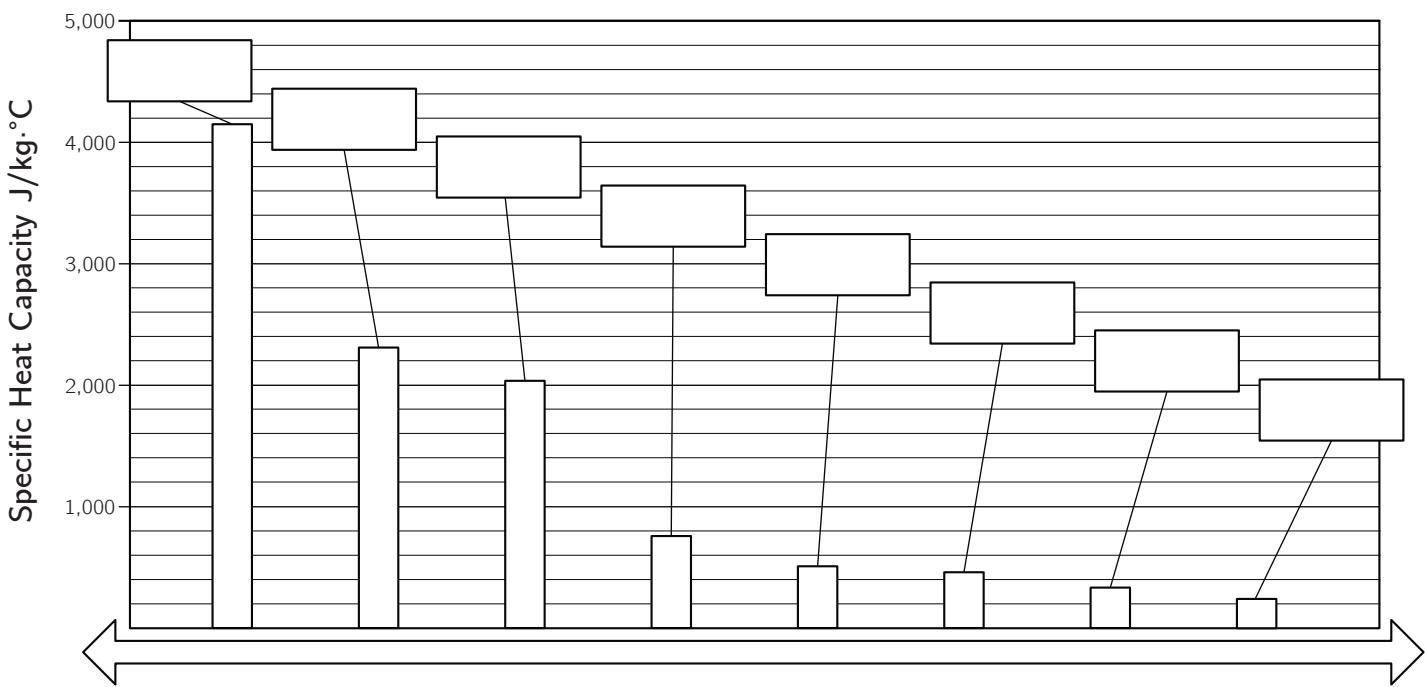
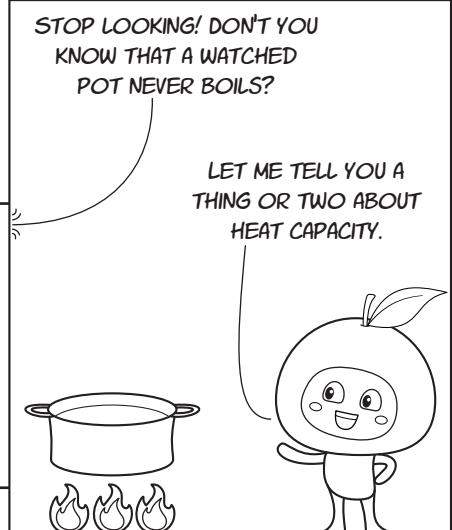
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# SPECIFIC HEAT CAPACITY

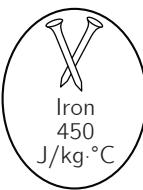
FILL IN THE BLANKS:

heated      energy      degree      gram

Specific Heat is the amount of heat \_\_\_\_\_ required to raise the temperature of one \_\_\_\_\_ of a substance by one \_\_\_\_\_. It is a measure of how easily a substance can be \_\_\_\_\_ or cooled.



USE THE INFORMATION IN THE CIRCLES BELOW TO LABEL THE CHART ABOVE. COLOR THE BAR FOR WATER BLUE AND COPPER YELLOW.



Iron  
450  
J/kg·°C



Paraffin wax  
2,325  
J/kg·°C



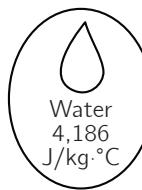
Ice  
2,050  
J/kg·°C



Granite  
790  
J/kg·°C



Diamond  
509  
J/kg·°C



Water  
4,186  
J/kg·°C



Copper  
386  
J/kg·°C



Silver  
233  
J/kg·°C

LIST 2 OR 3 EXAMPLES WHERE OBJECTS RESPOND DIFFERENTLY WHEN EXPOSED TO THE SAME AMOUNT OF HEAT:

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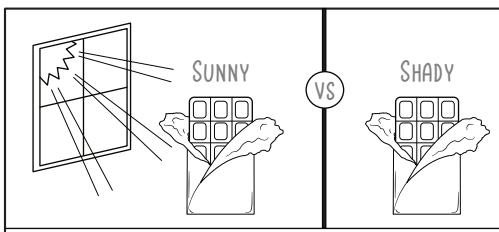
## DID YOU KNOW?

Intermolecular forces are the forces that hold molecules together.

Materials with strong intermolecular forces require more heat to change their temperature than materials with weak intermolecular forces.

# CHANGE OF PHASE

Do melting & vaporization ABSORB or RELEASE energy? Consider these questions before answering:



Two pieces of chocolate in different locations. Both experience the same air temperature of 23 °C or 75 °F.

Which one will melt? Which location is experiencing an input of energy?

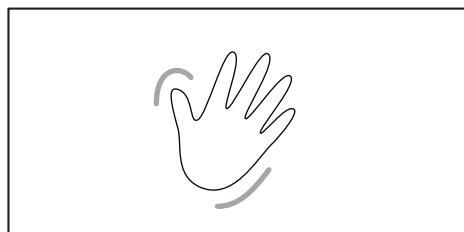
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A hand being waved in the air because it is wet with too much hand-sanitizer.

Will the hand feel warmer or colder? Is heat transferring happening?

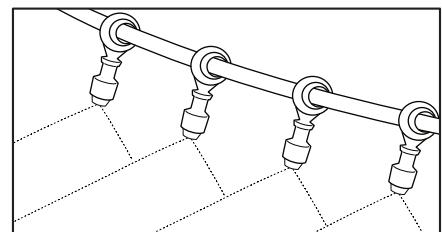
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Misters spray super small water droplets into the air, which then evaporate.

Why do the misters cool the area underneath?

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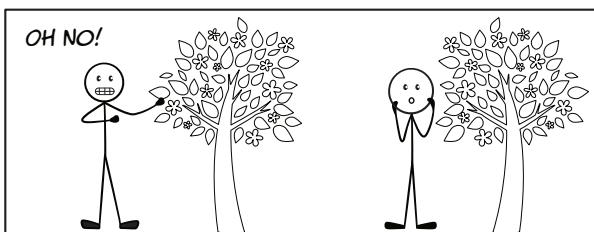


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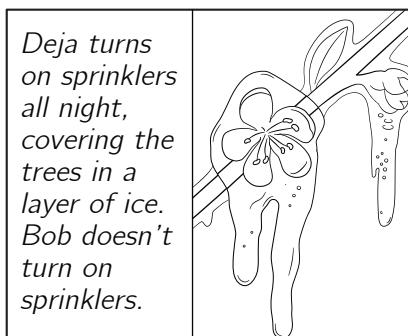


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Do freezing and condensation ABSORB or RELEASE energy? Consider this example:



Two farmers have orchards. A late frost is in the forecast and if the blossoms freeze, the farmers will lose the entire year's harvest.



Deja turns on sprinklers all night, covering the trees in a layer of ice. Bob doesn't turn on sprinklers.



Deja's trees have flowers after the frost. Bob's trees lose all of their blossoms.

The practice of "frost irrigation" is commonly used in real life to protect orchards and other crops from frost damage. Why does it work? How can 'freezing' plants in a layer of ice keep them warm?

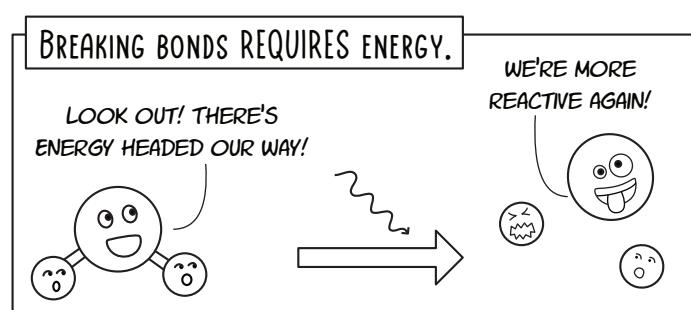
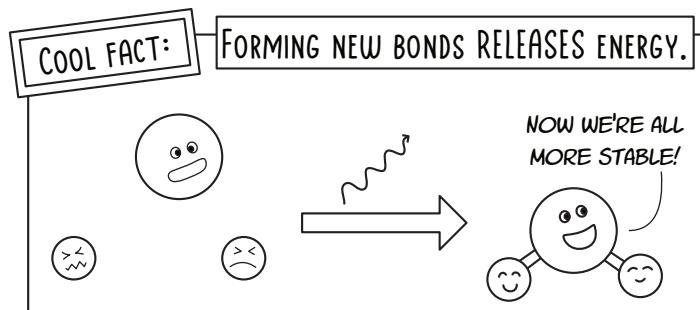
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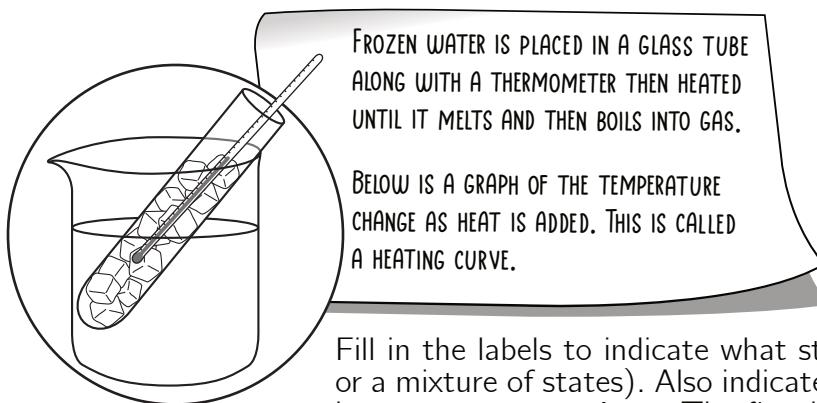
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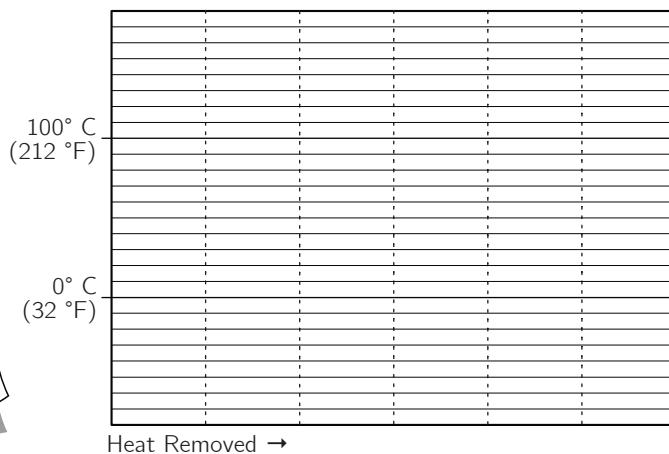
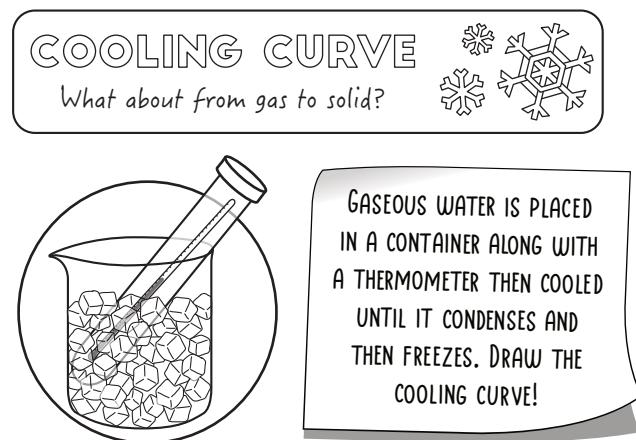
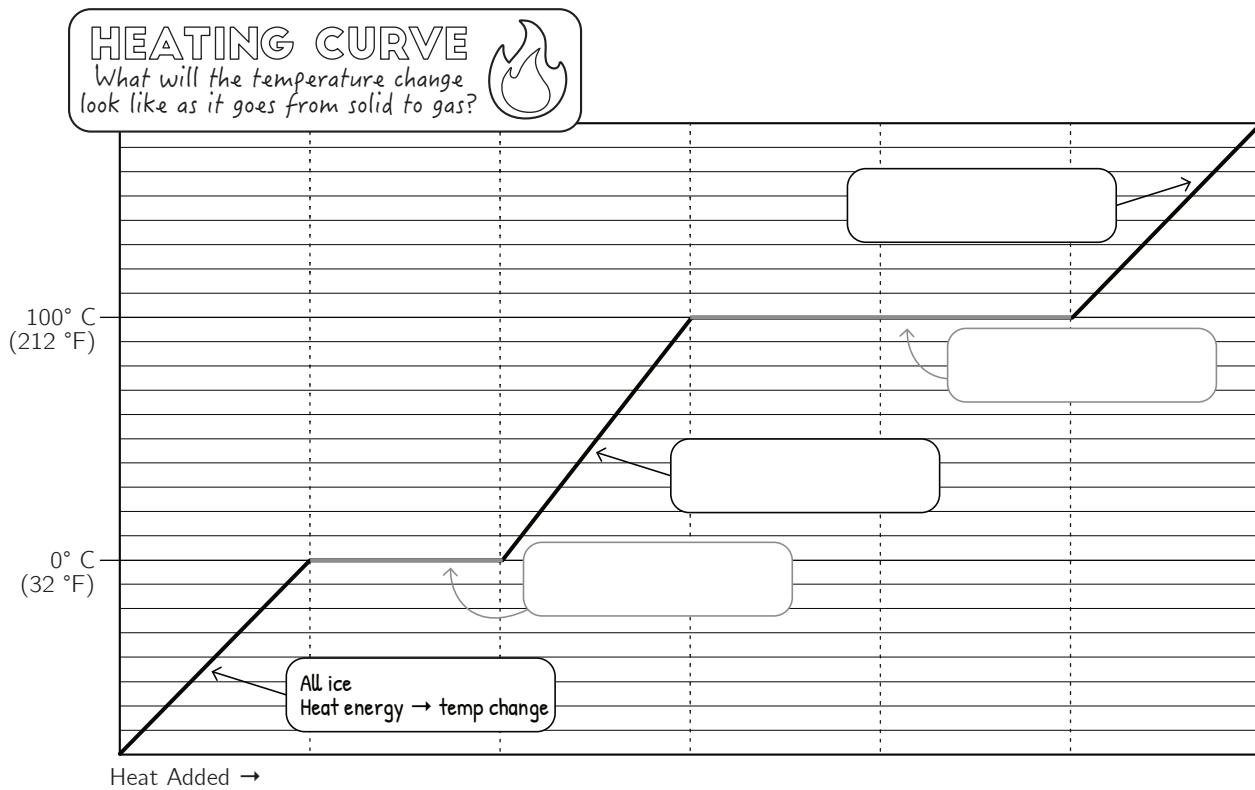
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# CHANGE OF PHASE

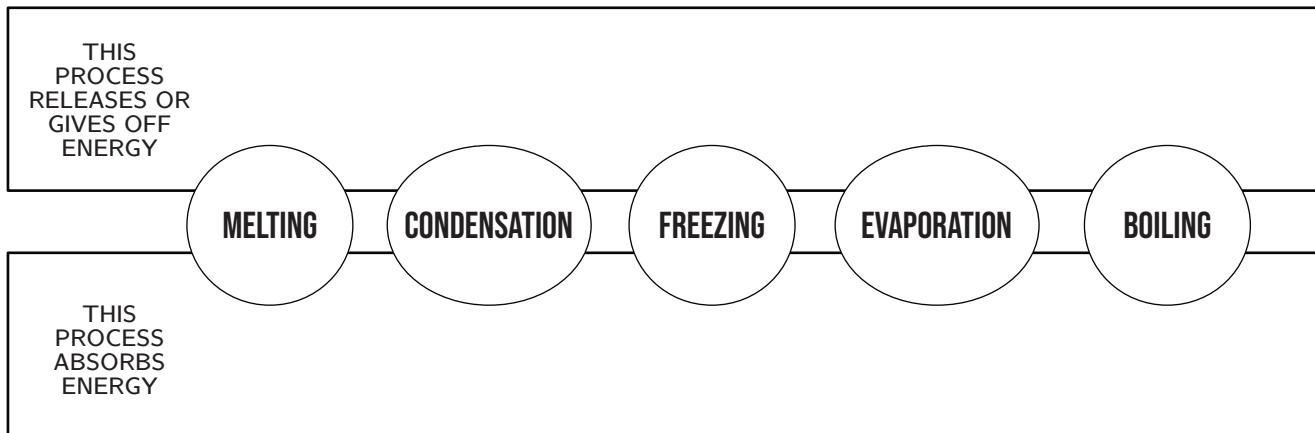


Fill in the labels to indicate what state of matter is present (ice, water, steam, or a mixture of states). Also indicate whether the heat energy is driving a change in **temperature** or **phase**. The first label has been filled in as an example.



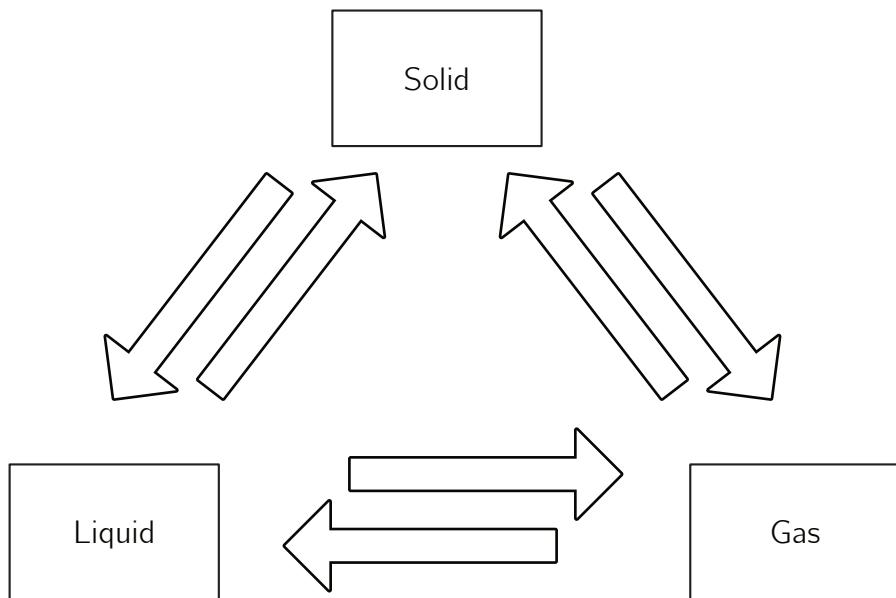
## PRACTICE PROBLEMS – HEAT CAPACITY & CHANGE OF PHASE

- (1) When water is boiling, it is undergoing which phase change?
  - A. Melting
  - B. Freezing
  - C. Vaporization
  - D. Condensation
- (2) Which phase change is exothermic, meaning it releases heat?
  - A. Melting
  - B. Vaporization
  - C. Freezing
  - D. Sublimation
- (3) When a cold glass of water "sweats" in a warm room, which phase change is occurring on the outside of the glass?
  - A. Vaporization
  - B. Condensation
  - C. Melting
  - D. Freezing
- (4) A substance has a high specific heat if:
  - A. It always remains warm.
  - B. Relatively little heat is required to change its temperature.
  - C. A lot of heat is required to change its temperature.
  - D. Its temperature remains constant regardless of the environment.
- (5) Draw an “up arrow” above each change of phase where heat energy is **released** and a “down arrow” under each phase where heat is **required or absorbed**.



## PRACTICE PROBLEMS – HEAT CAPACITY & CHANGE OF PHASE

- ⑥ Describe the difference between melting and freezing in terms of heat transfer.
- ⑦ What is the difference between vaporization and condensation when considering heat transfer?
- ⑧ Why might some substances have a higher heat capacity than others?
- ⑨ Label each arrow in the diagram below with the term that describes the change of phase. Shade in the arrows that represent an exothermic phase change.



# THERMODYNAMICS

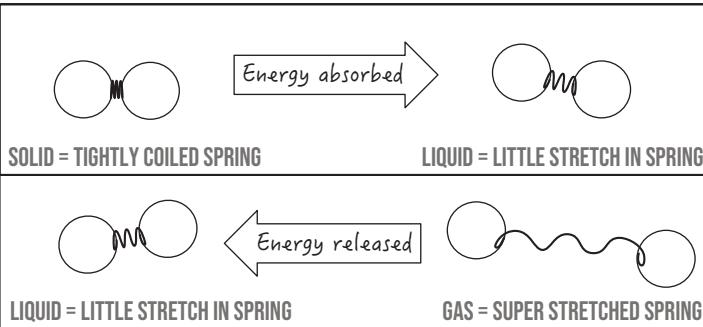
**Review:** Bob has water condensing on the outside of his fish tank and wants to know if the condensation is warming up or cooling down the tank. In other words, does condensation absorb or release heat? How would you explain the answer to Bob?

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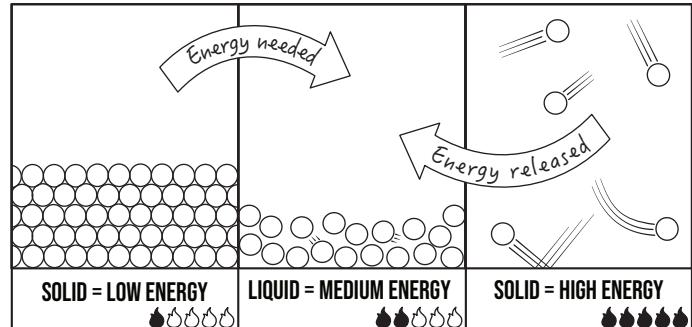
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BONDS BETWEEN ATOMS ARE LIKE SPRINGS. IT TAKES ENERGY TO STRETCH THEM APART AND SNAPPING BACK IN PLACE RELEASES ENERGY.



EACH STATE OF MATTER IS AN ENERGY LEVEL. LEVELING UP REQUIRES AN INPUT OF ENERGY. LEVELING DOWN RELEASES ENERGY.



Bob would like an analogy to help him remember how heat is transferred when a substance changes state. Which of the analogies above would you recommend and why?

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**Review:** The words heat and temperature are sometimes used interchangeably in non-scientific settings. But in physics, heat and temperature are two very different things! Match each term to its correct description. Then draw diagrams or pictures to represent each concept.

HEAT

A measurement of the  
average kinetic energy of  
the particles in a substance.

Thermal energy that is  
transferred from a warmer  
object to a cooler one.

TEMPERATURE

## CORRECT THE MISCONCEPTIONS

Below are two common misconceptions about thermodynamics, along with an example that seems to support each of them. Correct each statement and explain what is happening with the example.

### MISCONCEPTION #1

COLD IS A TRANSFERABLE ENTITY.  
IT CAN BE EMITTED OR TRANSFERRED  
FROM ONE OBJECT TO ANOTHER.

WHEN YOU HOLD AN ICE CUBE ON YOUR HAND, IT FEELS COLD BECAUSE THE ICE CUBE TRANSFERS COLDNESS TO YOUR HAND.



### MISCONCEPTION #2

A HIGHER AMOUNT OF HEAT ALWAYS = HIGHER TEMPERATURE. FOR EXAMPLE, IF OBJECTS W AND X BOTH RECEIVE THE SAME AMOUNT OF HEAT, THEN THEIR TEMPERATURES WILL INCREASE THE SAME AMOUNT.



COPPER CUP



STAINLESS STEEL CUP



STYROFOAM CUP

WHEN FILLED WITH BOILING WATER, WILL ALL THREE OF THESE CUPS BECOME TOO HOT TO HOLD COMFORTABLY WITH BARE HANDS?

Correct the misconception:

Correct the misconception:

## PUTTING IT ALL TOGETHER

Much of what we've learned in this unit can be summarized in the three laws of thermodynamics.

Fill in the words that are missing from each law on the following page. Then find an example of heat transfer in your own home. As a bonus (optional) extension, can you identify any laws that are involved? Draw a picture of where heat is flowing and why.

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### HEAT TRANSFER EXAMPLE

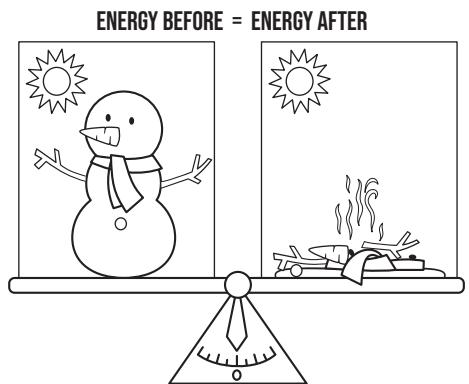
## FIRST LAW OF THERMODYNAMICS

Also known as the Law of Energy Conservation!

IN A \_\_\_\_\_ OR ISOLATED SYSTEM, ENERGY CANNOT BE  
\_\_\_\_\_ OR \_\_\_\_\_. IT CAN ONLY BE  
\_\_\_\_\_ FROM ONE FORM TO ANOTHER.

$$\Delta U = Q - W$$

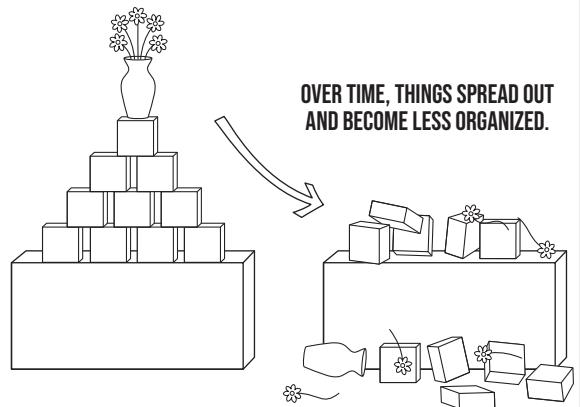
The change in the internal energy of a system is equal to the heat added or lost to the system and the work done by the system on its surroundings.



## SECOND LAW OF THERMODYNAMICS

Also known as the Law of Entropy!

IN ANY PROCESS, THE OVERALL \_\_\_\_\_ OR MESSINESS  
OF THINGS TENDS TO \_\_\_\_\_. THE TRANSFER OF  
\_\_\_\_\_ CANNOT BE 100% \_\_\_\_!  
IN OTHER WORDS, \_\_\_\_\_ IS ALWAYS INCREASING.



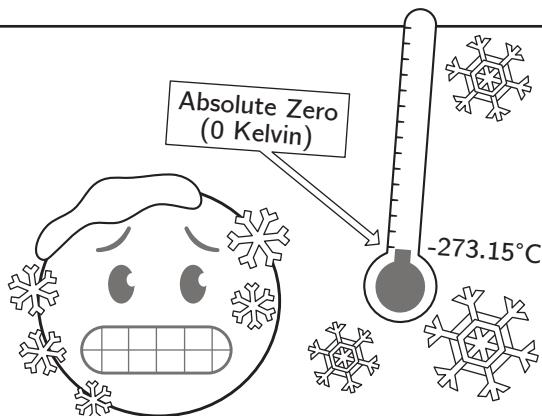
**S** Entropy

The entropy of an isolated system not in equilibrium will increase over time, approaching a maximum value at equilibrium. Heat cannot spontaneously flow from a colder body to a hotter body.

## THIRD LAW OF THERMODYNAMICS

All about absolute zero

AT ABSOLUTE ZERO, ALL \_\_\_\_\_ WOULD STOP.  
AS THE TEMPERATURE APPROACHES ABSOLUTE ZERO,  
THE ENTROPY OF THE SYSTEM \_\_\_\_\_.



At absolute zero, the entropy of a perfect crystal would be exactly zero. But absolute zero cannot be reached! The closer you get, the harder it is to remove heat. Also, being at absolute zero would violate the Heisenberg Uncertainty Principle.

## PRACTICE PROBLEMS – THERMODYNAMICS

- ① What does the first law of thermodynamics state?
- A. Energy can be created and destroyed.
  - B. Energy is always conserved.
  - C. Heat flows from cold objects to hot objects.
  - D. Energy increases with temperature.
- ② Explain entropy in your own words and give an example where entropy increases:
- 
- 

- ③ The second law of thermodynamics explains that:
- A. Energy cannot be transferred or transformed.
  - B. Heat flows from hot objects to cold objects.
  - C. Total energy of an isolated system decreases over time.
  - D. Heat is a form of kinetic energy.
- ④ What is absolute zero?
- A. The temperature at which a substance freezes.
  - B. The highest possible temperature.
  - C. The temperature at which all particle motion stops.
  - D. The temperature of a vacuum
- ⑤ If you leave a hot cup of coffee in a cold room, what will happen according to the second law of thermodynamics?
- A. The coffee will get hotter.
  - B. The temperature of the coffee and the room will equalize.
  - C. The room will become hotter than the coffee.
  - D. Nothing; the temperature will remain the same.
- ⑥ When a system goes from a more ordered state to a less ordered state:
- A. Its entropy decreases.
  - B. Its entropy increases.
  - C. Its temperature always increases.
  - D. It violates the first law of thermodynamics.
- ⑦ If energy is conserved in a closed system, what does this imply?
- A. The total energy in the system will increase over time.
  - B. The energy can change forms but the total amount remains constant.
  - C. Energy flows from cold objects to hot objects.
  - D. Marmoset.

# MAKE YOUR OWN ICE CREAM

## MATERIALS

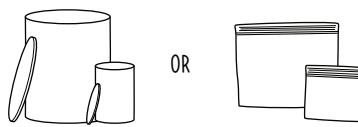


Ingredients for ice cream

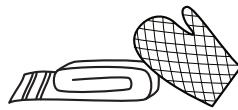
(For a dairy-based dessert, use sugar, cream, and desired flavorings. For a dairy-free dessert, use coconut milk, dates, and cocoa powder.)

Ice

Rock salt



2 metal cans of different sizes with lids OR 2 ziplock bags of different size

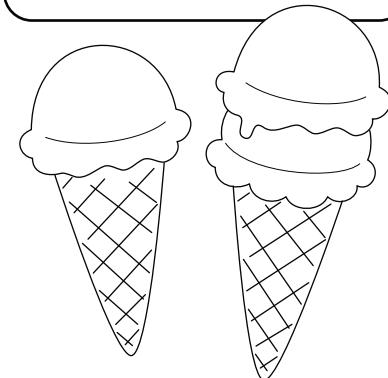


Oven mitts or towels (to keep hands warm)

## GOALS

★ Observe and better understand freezing point depression

★ Celebrate the end of the thermodynamics unit with a delicious treat!

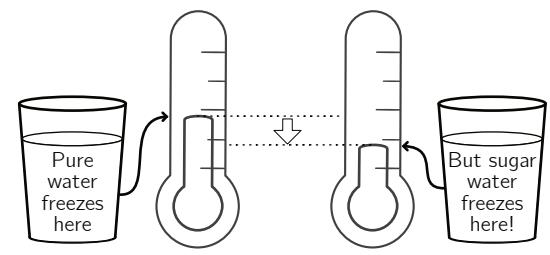


## Pre-lab Questions:

- ① Have you ever seen someone salt a driveway or sidewalk? If yes, did you see what happened after the salt was applied?

HAVE YOU EVER NOTICED... THE ORANGE JUICE CONCENTRATE IN YOUR FREEZER DOESN'T SEEM AS "FROZEN" AS THE ICE CUBES?

When another substance is dissolved in a liquid, the freezing point DROPS



This is called freezing point depression!

- ② Why do you think it's common for salt to be applied to roads in snowy climates?

- ③ When making homemade ice cream, salt is added to the ice. What is the purpose of adding salt? Will it increase or decrease the temperature? If you are unsure, do an experiment! Set up 2 sets of bags or cans. Then add salt to the ice in one of them but not the other. Observe what happens.

## INSTRUCTIONS:

- Prepare the Ice Cream Mixture:** In a small ziplock bag or a coffee can, mix the ingredients for your ice cream. Seal the bag or can and check to be sure the seal is water tight.
- Refrigerate for 1 hour:** This step is optional but it will help the ice cream making go much quicker!
- Add the Ice and Salt:** Place the small bag or can with the ice cream mixture inside the larger bag or can. Add ice and salt. If using bags, seal the large bag tightly. If using cans, use duct tape to attach the lid to the outer can.
- Chill and Shake:** If using bags, squeeze or shake the bag vigorously for about 10 minutes. Use towels or gloves to protect your hands from the cold. If using cans: Roll the can back and forth on the ground for about 10 minutes.
- Check and Adjust:** Open the large can or bag and drain out any melted water. Then check the inner bag or can to see if the ice cream is done. ***Be careful! You don't want to get salty water in the ice cream.*** If the ice cream mixture is still runny, add more ice and salt to the outer container. Mix or roll again for about 5 minutes. Check again. Adjust the ice and salt levels as needed. Keep rolling or squishing until the ice cream is firm.
- Complete Worksheets and Enjoy:** Finish filling out the worksheets and enjoy your delicious ice cream!

### INGREDIENTS FOR A DAIRY-BASED ICE CREAM

- 1 cup cream or half-and-half
- 2 Tbsp granulated sugar
- Flavorings of your choice such as:
  - 1 Tbsp chocolate syrup
  - ½ tsp vanilla extract
  - ½ tsp peppermint extract
  - ½ cup of your favorite candy, chopped
  - ½ cup berries or other fruit

### INGREDIENTS FOR A COCONUT-BASED ICE CREAM

- 1 can coconut milk
  - ¼ cup sugar
  - Flavorings of your choice such as:
    - Fresh dates (7-10) and cocoa powder
    - ½ tsp vanilla extract
    - ½ cup of your favorite candy, chopped
    - 1 cup fresh pineapple, cubed
- \*If using the pineapple or date versions, use a blender or food processor to thoroughly blend the mixture.

## CONNECTIONS AND EXTENSIONS

PICK ONE OF THESE QUESTIONS TO STUDY OR MAKE YOUR OWN. THEN LOOK UP ADDITIONAL INFORMATION AND MAKE NOTE OF WHAT YOU LEARNED!

### WHY DOES ICE CREAM CONTAIN AIR?

Air makes up between 30 to 50% of the volume of commercial ice cream!

### WHAT ABOUT SORBET?

Could this method be used to make sorbet or sherbet instead of ice cream?

### WHO INVENTED ICE CREAM?

The dessert is hundreds of years older than modern refrigeration methods. Can you discover some of the earliest recipes?

### PLASTIC VS METAL?

Would ice cream freeze faster in metal cans or plastic bags? Can you map the heat transfer in this activity?

Which question did you choose to study?

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**List 3 sources of information you found useful in answering your question.**

Then, for each source, list the publisher or author and at least one reason you believe the information is accurate.

If the source is a **book**, who is the publisher? Do you think they hired a fact checker or an expert reviewer to verify the contents of the book? For non-fiction books, this is standard practice with reputable publishers. Sometimes you might see mention of an expert reviewer or fact checker in the acknowledgements.

If the source is from a **website** or other online material, who wrote it? What type of reputation does the group, company, or person have? If it's from a personal story, what aspects of the story or person make them seem trustworthy? Is there any reason to suspect bias?

SOURCE 1: \_\_\_\_\_

PUBLISHER OR AUTHOR: \_\_\_\_\_

EVIDENCE OF ACCURACY? \_\_\_\_\_

ANY REASON TO SUSPECT BIAS OR MISINFORMATION? \_\_\_\_\_

SOURCE 2: \_\_\_\_\_

PUBLISHER OR AUTHOR: \_\_\_\_\_

EVIDENCE OF ACCURACY? \_\_\_\_\_

ANY REASON TO SUSPECT BIAS OR MISINFORMATION? \_\_\_\_\_

SOURCE 3: \_\_\_\_\_

PUBLISHER OR AUTHOR: \_\_\_\_\_

EVIDENCE OF ACCURACY? \_\_\_\_\_

ANY REASON TO SUSPECT BIAS OR MISINFORMATION? \_\_\_\_\_

What is the answer to your question? Summarize it here!

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# THERMODYNAMICS 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.

CONDUCTION: \_\_\_\_\_  
\_\_\_\_\_

CONVECTION: \_\_\_\_\_  
\_\_\_\_\_

ENTROPY: \_\_\_\_\_  
\_\_\_\_\_

HEAT: \_\_\_\_\_  
\_\_\_\_\_

Bob has a fancy new infrared thermometer. When he points the thermometer at a surface, it gives a digital reading of the temperature. Bob is very worried that his new device is broken because it gives the same temperature for the tile on the bathroom floor as it does for the rug. Yet, when Bob steps on the rug vs the tile, the tile feels cooler. Neither the rug nor the tile are being influenced by an outside power source such as sunlight or a heating vent.

What would you tell Bob? Should he return his new thermometer and demand a refund, or is the thermometer working?

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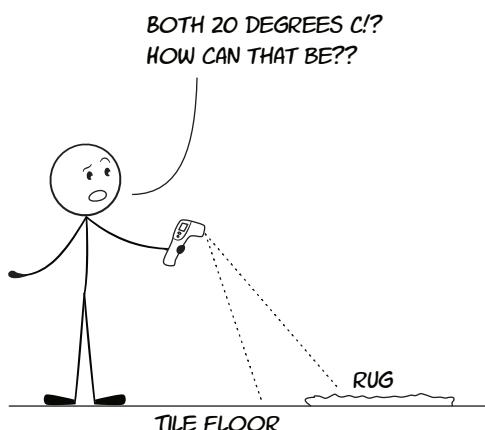
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# Thermodynamics Assessment

## 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.

HEAT CAPACITY: \_\_\_\_\_

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RADIATION: \_\_\_\_\_

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TEMPERATURE: \_\_\_\_\_

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INTERNAL ENERGY: \_\_\_\_\_

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① During melting:

- A. Particles stop moving
- B. Particles reach maximum movement
- C. Heat is absorbed
- D. Heat is released

② What is absolute zero?

- A. The temperature where water freezes
- B. The temperature where all molecular motion stops
- C. The lowest recorded temperature
- D. The highest recorded temperature

③ Which statements about heat are true?

- A. Heat is the transfer of thermal energy from one object to another
- B. The terms temperature and heat are synonymous and have the same meaning
- C. Heat always flows from an area of low energy to an area of high energy
- D. None of the above are true

# Thermodynamics Assessment

- 4 Thermal expansion occurs because:
- Particles lose energy when heated
  - Particles attract each other when heated
  - Heated particles move less and take up less space
  - Heated particles move more and take up more space
- 5 What is an example of conduction?
- Sunlight warming the earth
  - Hot water rising from a hydrothermal vent at the sea floor
  - A metal spoon becoming warmer after being in a pot of hot soup
- 6 What is thermal energy or internal energy?
- The total kinetic and potential energy of the particles in an object.
  - Only the kinetic energy of the particles in an object
  - Energy that is transferred to the object's surroundings
- 7 What is temperature?
- The transfer of thermal energy
  - The amount of coldness
  - The average kinetic energy of particles in a substance
  - The total potential energy of a substance
- 8 Circle the letter C if the material is a good thermal conductor and I if the material is a good thermal insulator:
- |   |   |            |
|---|---|------------|
| C | I | Air        |
| C | I | Copper     |
| C | I | Steel      |
| C | I | Wood       |
| C | I | Aluminum   |
| C | I | Fiberglass |
| C | I | Iron       |
| C | I | Styrofoam  |

- 9 Which of the following statements are true?

- Convection occurs in fluids (gas and liquids) but not solids.
- Heat transfer by radiation must involve direct contact between objects.
- Conduction is the fastest form of heat transfer
- A and C are both true
- None of the above statements are true

- 10 When a substance freezes, heat is:

- released
- absorbed
- There is no change in heat

- 11 When a liquid vaporizes, heat is:

- released
- absorbed
- There is no change in heat

- 12 The first law of thermodynamics states that:

- Entropy is always increasing
- In an isolated system, energy will always be conserved
- Heat flows from cold to hot objects

- 13 Which phase change below releases heat?

- Evaporation
- Sublimation
- Melting
- Freezing

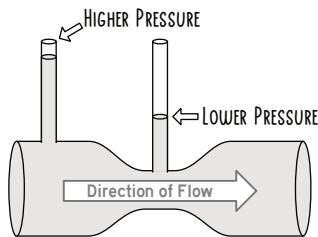
- 14 True or False? Heat capacity is the same for all states of matter.

- True
- False

## Unit 3: Fluids and Pressure

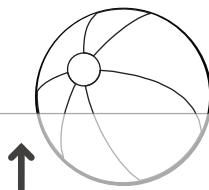
Liquids and gases are both fluids!

### BERNOULLI'S PRINCIPLE



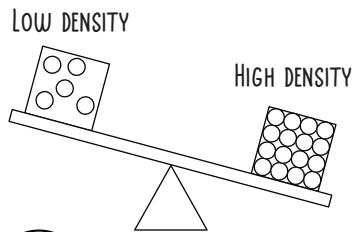
As the speed of a fluid increases,  
the pressure decreases

### BUOYANCY



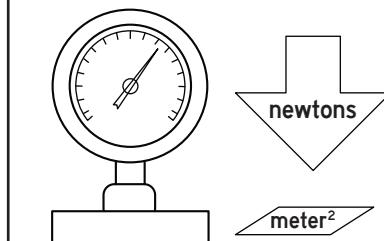
$\vec{F}_b = -\rho g V$  The upward force exerted by a fluid on an object

### DENSITY



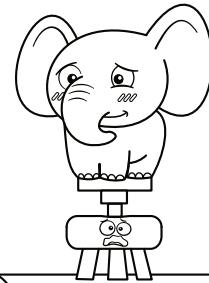
$\rho = \frac{m}{V}$  How compact something is or how much mass per unit of volume

### PASCALS



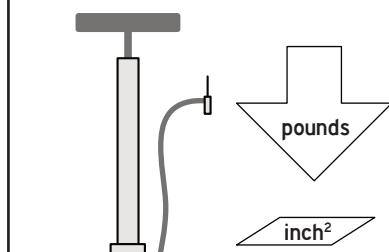
$\text{Pa}$  A measure of pressure:  
newtons per square meter

### PRESSURE



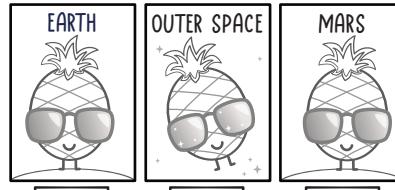
$P = \frac{F}{A}$  The amount of perpendicular force applied per unit of area

### PSI



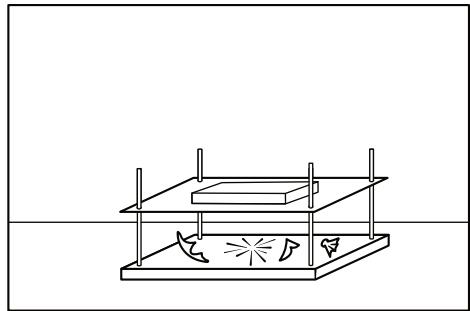
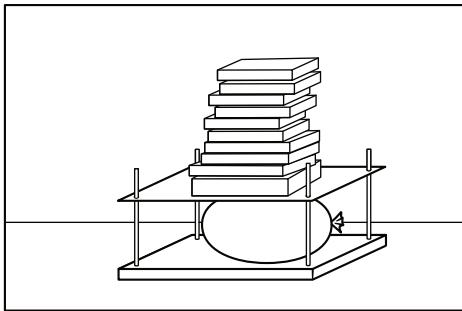
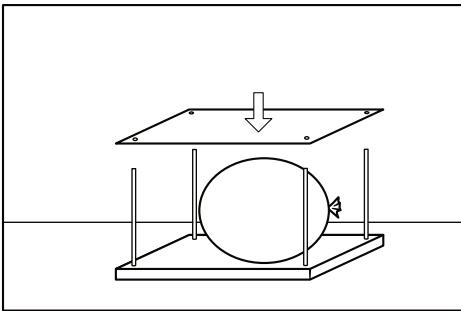
A measure of pressure:  
pounds per square inch

### 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?

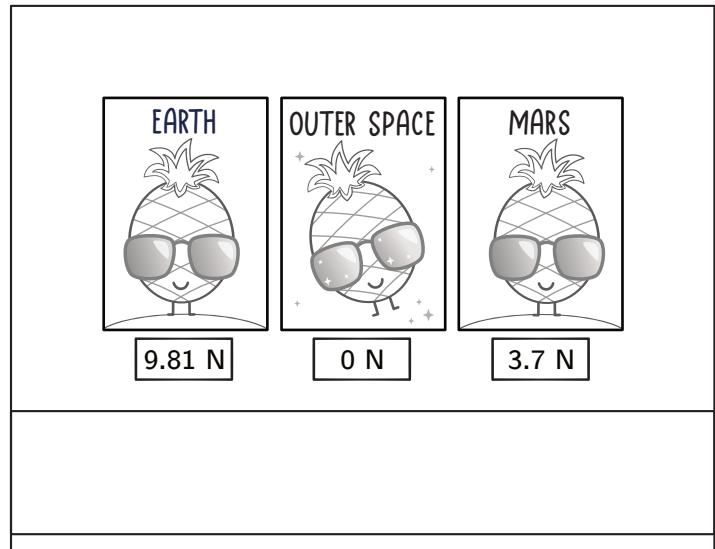
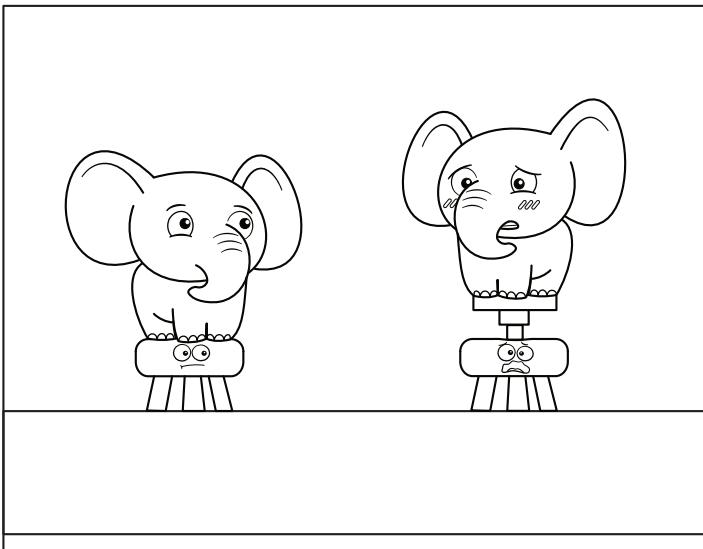
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## PRESSURE VS WEIGHT

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



SOMETHING SIMILAR:

---

SOMETHING DIFFERENT:

---

pressure is measured in many different units!

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

**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

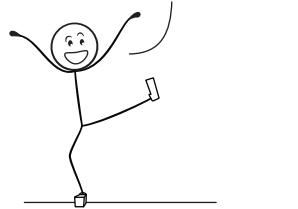
## 1 CALCULATING PRESSURE

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.

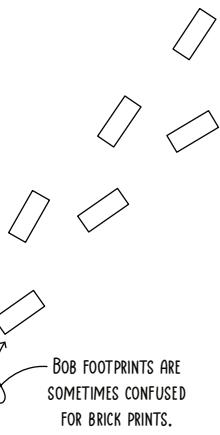
Bob weighs 140 lbs and wears shoes that have perfectly rectangular soles measuring 4 x 10 inches. How much pressure does Bob exert on the ground in PSI?

THESE SHOES  
ARE FABULOUS!



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

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



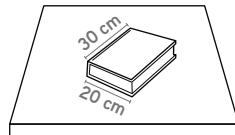
BOB FOOTPRINTS ARE  
SOMETIMES CONFUSED  
FOR BRICK PRINTS.

## 2 CALCULATING PRESSURE

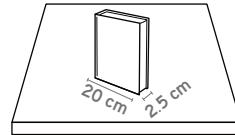
IN KPA

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<sup>2</sup>)? How much in kilopascals?



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.



### 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

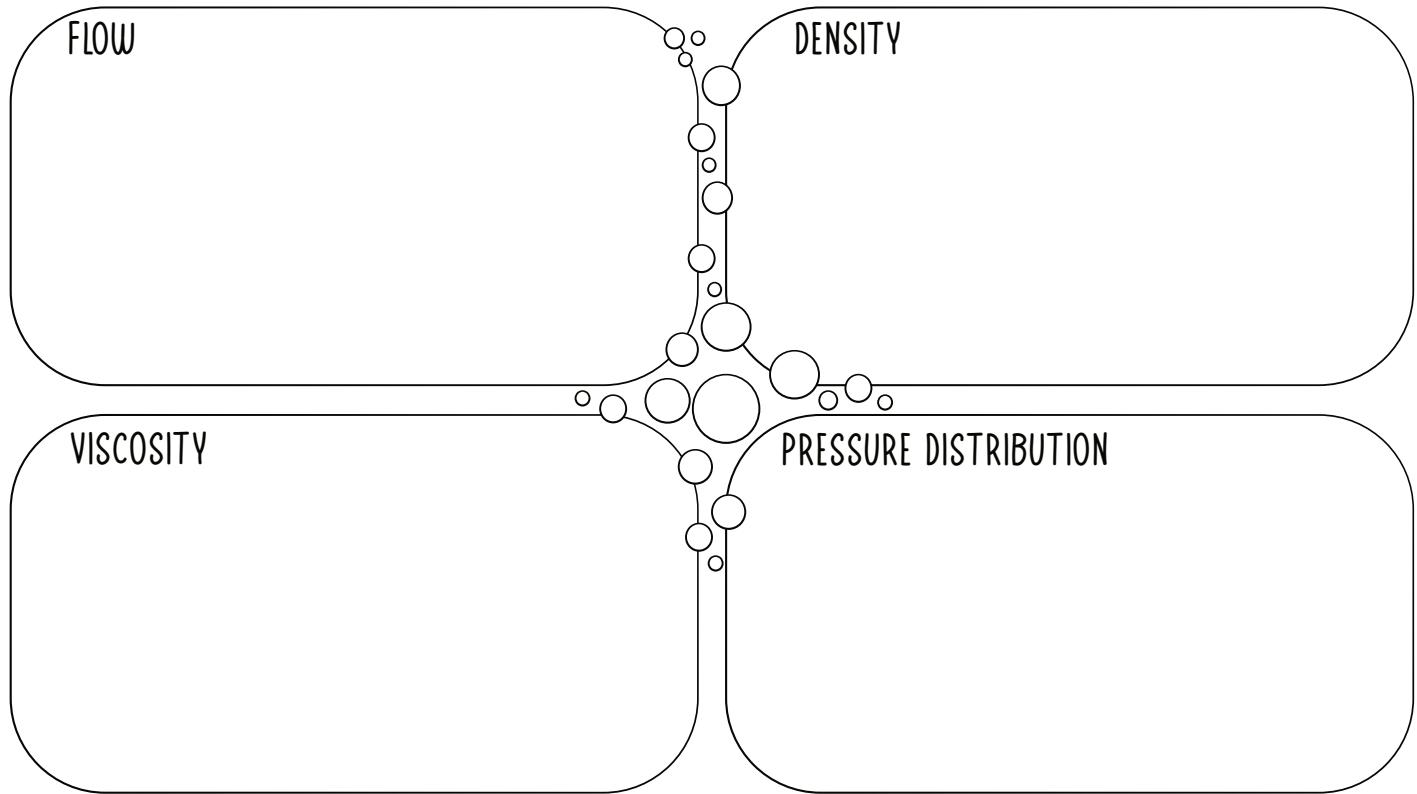
1 Pa = 1,000 kPa

1 atm = 101.3 kPa

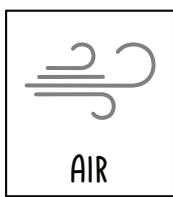
# FLUIDS



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:



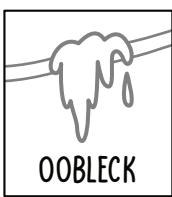
As with most categories and labels, some items fit within the norm and others do not conform! Draw lines to match each of the following fluids with their best description:



AIR



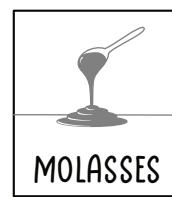
HONEY



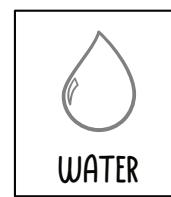
OOBLECK



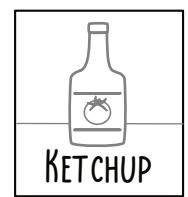
GASOLINE



MOLASSES



WATER



KETCHUP

Flows easily:  
has low  
viscosity

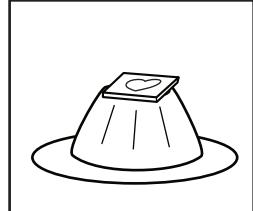
Resistance to  
flow: has high  
viscosity

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

## PRACTICE PROBLEMS – PRESSURE & FLUIDS

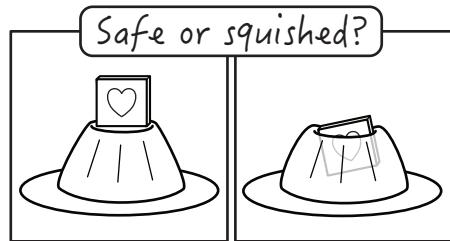
- ① If a force of 10 newtons is applied over an area of 2 square meters, what formula is needed to calculate the pressure? What will the units be?

- 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  $0.04 \text{ m}^2$ . How much pressure (in pascals) is the book applying on the gelatin dessert?



- ③ The gelatin dessert 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 dessert?

The base surface area when the book is upright is  $0.003 \text{ m}^2$ .

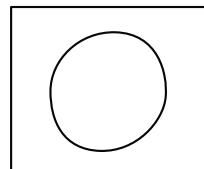


- ④ The pressure exerted by a fluid is evenly applied in all directions. Explain why this is the case.

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

## 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  $2 \text{ m}^2$  while a 20 N force is applied to a region of area  $4 \text{ m}^2$ . 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
- (9) What unit is used to measure tire pressure in the US, Canada, and the UK?
- (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.
- (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
- (13) Next the ice skater and elephant each balance on one foot.  
Who exerts more pressure on the ground?
- A. Ice skater
  - B. Elephant



Surface area of  
elephant footprint  
 $= 250 \text{ in}^2$



Surface area of  
single ice skate  
 $= 1.5 \text{ in}^2$

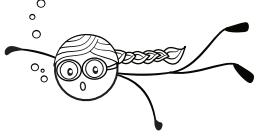
# GOING FOR A SWIM

Think about it:

AT SURFACE:  
EARS DON'T POP

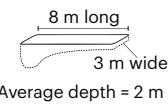


8 FEET DEEP:  
EARS POP



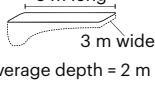
BACKYARD POOL:

48 CUBIC METERS



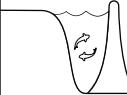
LAKE SUPERIOR:

12.1 TRILLION CUBIC METERS



WATER GOES ON FOR 30+ KILOMETERS THAT WAY!

LARGE LAKE, 3 METERS DEEP AND OVER 30 KM WIDE



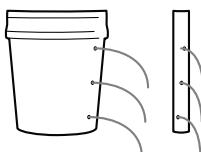
KOI POND, 3 METERS DEEP AND 1.5 METERS WIDE

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?

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

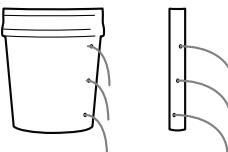
Holes are drilled in a 5 gallon bucket and a narrow piece of pipe. The holes are the same diameter and depth. Which of these drawings matches your prediction for how the water will flow out?

A



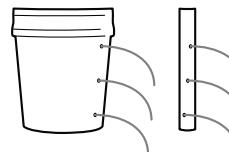
STRONGER SPOUTS FROM BUCKET  
BUT SAME FROM ALL HOLES.  
HOLE POSITION DOESN'T MATTER  
BUT CONTAINER SIZE DOES.

B



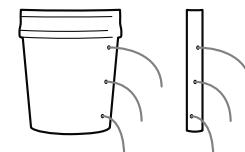
STRONGER SPOUTS FROM PIPE  
BUT SAME FROM ALL HOLES.  
HOLE POSITION DOESN'T MATTER  
BUT CONTAINER SIZE DOES.

C



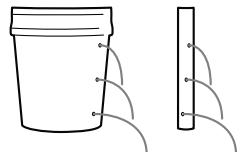
SAME-SIZED SPOUTS FROM ALL  
OF THE HOLES. POSITION AND  
CONTAINER SHAPE MAKE NO  
DIFFERENCE.

D



STRONGER SPOUTS FROM TOP  
BUT SAME PATTERN FROM  
BUCKET AND PIPE. HOLE POSITION  
MATTERS, NOT CONTAINER SIZE.

E

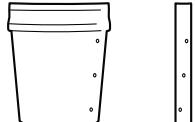


STRONGER SPOUTS FROM BOTTOM  
BUT SAME PATTERN FROM  
BUCKET AND PIPE. HOLE POSITION  
MATTERS, NOT CONTAINER SIZE.

Make a prediction and give a reason to support it.

Record the results:

F



SOMETHING DIFFERENT? DRAW  
YOUR PREDICTION HERE!

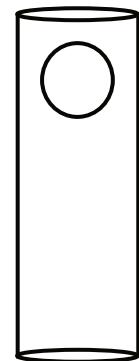
# GOING FOR A SWIM

WHAT SHAPE WOULD A BALLOON HAVE DEEP UNDER WATER?

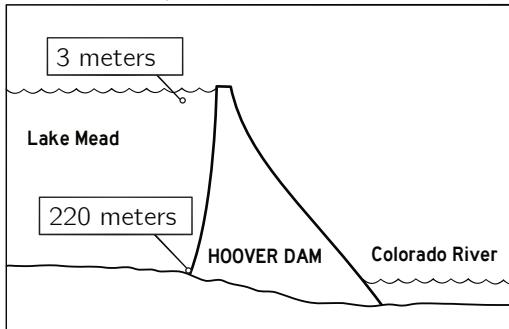
$$P_{\text{fluid}} = \rho g h$$

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

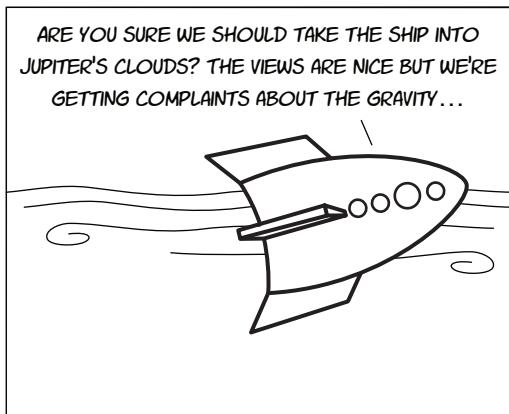
A CONFINED FLUID APPLIES PRESSURE \_\_\_\_\_ IN \_\_\_\_\_ DIRECTION.



Calculate the pressure:

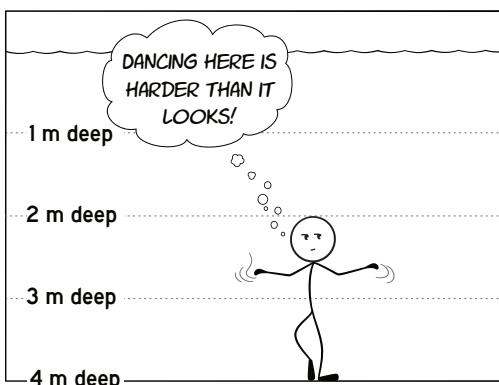


Calculate the water pressure behind Hoover Dam near the top of the dam (3 m deep) and at the bottom of the dam (220 m deep). The density of water is 1,000 kg/m<sup>3</sup>.



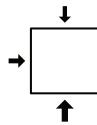
Calculate the pressure someone would experience if they were swimming at 3 m deep in a pool of water on Jupiter, where the acceleration due to gravity is 24.79 m/s<sup>2</sup>.

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



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).

# GOING FOR A SWIM

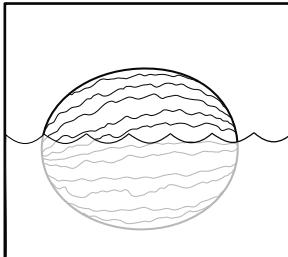


Because pressure increases with depth, the pressure against the bottom of an object in a fluid will always be greater than the pressure against the sides or top. This net upward force is called the **buoyant force**.

## 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

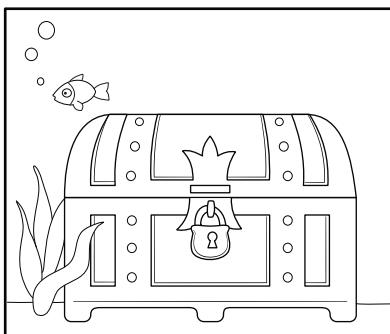


The melon displaces 5.91 kg of water. The weight of 5.91 kg of water is approximately 58 newtons.

WHAT IS THE BUOYANT FORCE ON THE WATERMELON?

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

### 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.

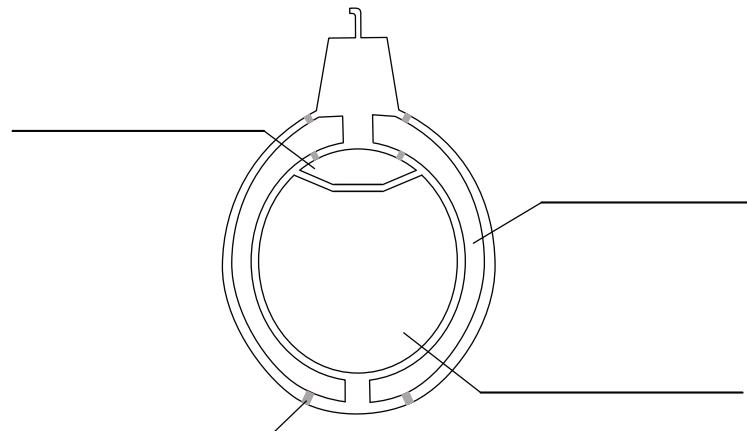
WHAT IS THE BUOYANT FORCE ON THE CHEST?

IS THE WEIGHT OF THE TREASURE CHEST MORE, LESS, OR EQUAL TO 4,660 NEWTONS?

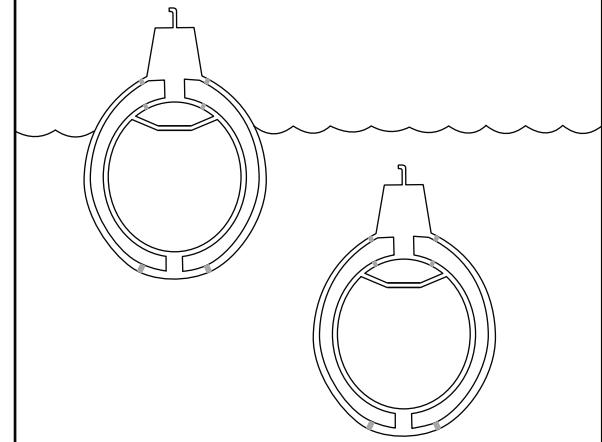
WHY DOES THE WATERMELON FLOAT WHILE THE TREASURE CHEST SINKS?

## 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



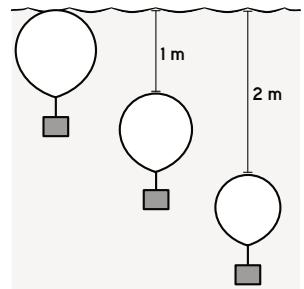
How do the ballast tanks differ when the sub is at the surface vs submerged?



## 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?

- 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.

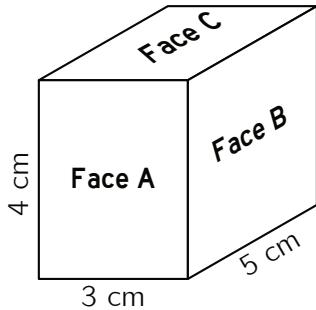


- ⑤ Will a basketball float higher in fresh or salt water, or will it have the same amount of ball floating above the water in each type? Explain.

- 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?

## PRACTICE PROBLEMS – GOING FOR A SWIM

- ⑦ Explain why most of an iceberg is underneath the water.
- 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?
- ⑨ Explain why a sharp knife cuts better than a dull knife.
- ⑩ A box measures  $3\text{ cm} \times 4\text{ cm} \times 5\text{ cm}$  and weighs 6 N. Calculate how much pressure it exerts on the table when it is laying on each of its faces.



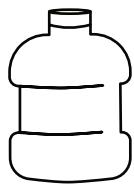
- ⑪ What would exert greater pressure, swimming 1 m deep (3.28 ft) in honey or swimming at a depth of 2 m (6.56 feet) deep in water? Both pools are located on Earth. The pool of water has a density of  $1,000\text{ kg/m}^3$  and the pool of honey has a density of  $1,400\text{ kg/m}^3$ .

# EGG IN A BOTTLE

## MATERIALS



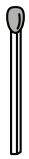
2 to 3 medium-size hard boiled eggs



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:

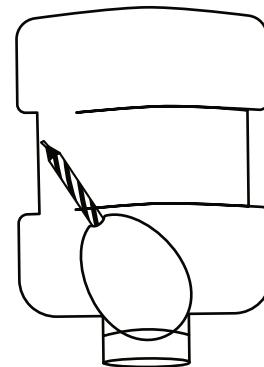
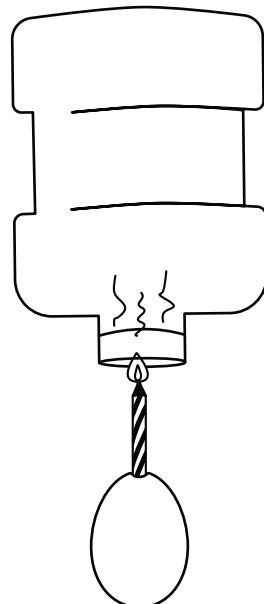
The hot flame heats up the air inside the bottle causing the air to expand as its molecules get excited. Without the heat of the flame, the air molecules cool quickly. Normally, other air would rush in to fill the bottle as the cooler air inside contracts, but the egg blocks the opening. The pressure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

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# RISING WATER

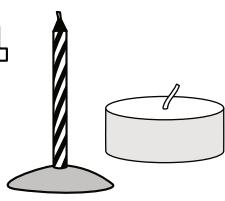
## MATERIALS



A dish or pie plate



water



A candle that will stand upright



A jar or a glass or a bottle



Food coloring



A lighter or a match

## 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?

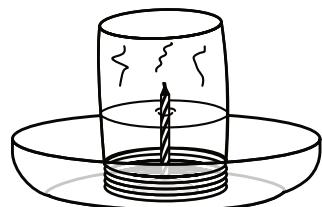
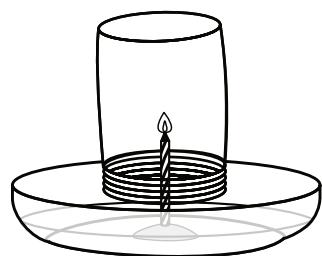
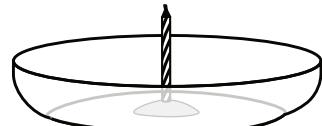
## INSTRUCTIONS:

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

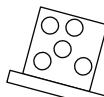
DENSITY IS A MEASURE OF HOW MUCH \_\_\_\_\_

IS IN A GIVEN AMOUNT OF \_\_\_\_\_.

Common units = g/cm<sup>3</sup> or kg/L or kg/m<sup>3</sup>. Note: 1 ml = 1 cm<sup>3</sup>

# DENSITY

LOW DENSITY



HIGH DENSITY



**Good to Know**

The density of water: 1 g/cm<sup>3</sup> or 1 kg/L or 1,000 kg/m<sup>3</sup>\*  
\*It's actually 0.9998395 g/ml at 4.0° Celsius or 39.2° Fahrenheit.  
But in most cases, 1 g/cm<sup>3</sup> is close enough!

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

Density =  $\frac{\text{mass}}{\text{volume}}$

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

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

## 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/m <sup>3</sup>	Aluminum 2,700 kg/m <sup>3</sup>	Apple 814 kg/m <sup>3</sup>
Gold 19,300 kg/m <sup>3</sup>	Frozen water 917 kg/m <sup>3</sup>	Lead 11,340 kg/m <sup>3</sup>
Platinum 21,090 kg/m <sup>3</sup>	Sea water at 25°C 1,024 kg/m <sup>3</sup>	Wood (maple) 700 kg/m <sup>3</sup>

Water at 4°C      Honey      Mercury

Platinum			
Gold			
Lead			
Aluminum			
Sea Water			
Frozen Water			
Wood (maple)			
Apple			
Air			

Density of water at 4 °C is 1,000 kg/m<sup>3</sup>

Density of honey is 1,400 kg/m<sup>3</sup>

Density of mercury is 13,590 kg/m<sup>3</sup>

# BUOYANCY

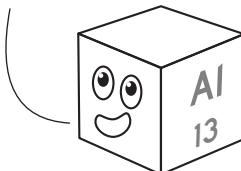
What has greater buoyancy and why?  
A cubic meter of aluminum or a cubic meter of iron?

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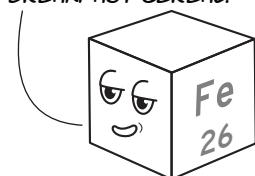
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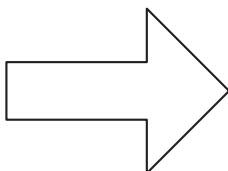
PICK ME! I'M LIGHTWEIGHT AND WHEN  
I WAS DISCOVERED IN 1825, I WAS  
MORE VALUABLE THAN GOLD! ALSO  
VERY RECYCLABLE.



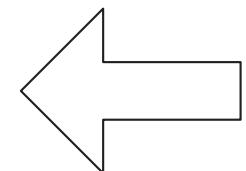
OH YEAH? WELL I'M THE MOST  
COMMON ELEMENT ON EARTH  
BY MASS AND I'M ADDED TO  
BREAKFAST CEREAL.



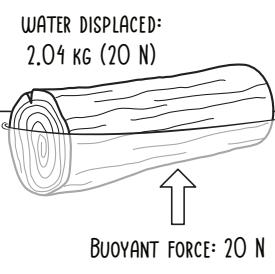
## MISCONCEPTION ALERT!



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!



WOW! NEWTON'S  
3<sup>RD</sup> LAW REALLY IS  
EVERYWHERE!

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

THIS ALUMINUM BOAT WEIGHS 500  
POUNDS (2,224 NEWTONS)

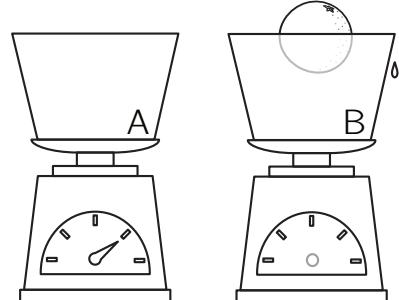


THE SAME BOAT WITH A HOLE IN  
THE BOTTOM STILL WEIGHS 500  
POUNDS (2,224 NEWTONS)

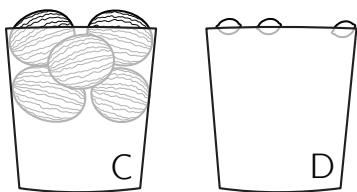


Use the floatation principle to answer the following questions:

- 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.



- 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)?



## 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.  $1 \text{ g/cm}^3$
  - B.  $1,000 \text{ kg/m}^3$
  - C. Both A and B
  - D. None of the above
- ③ Rank the following substances from most to least dense: air, gold, ice, wood, and water.

MOST DENSE

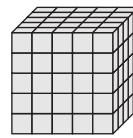
LEAST DENSE

- ④ What is more dense, 10 grams of gold or 500 grams of aluminum?
- ⑤ Is it possible that a hollow cube could be more dense than a solid cube? Explain.

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

## PRACTICE PROBLEMS – DENSITY & BUOYANCY

- (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.
- (8) A baseball has a volume of  $212 \text{ cm}^3$  and a mass of  $0.145 \text{ kg}$ . Is it more or less dense than water? Would you expect the baseball to float or sink in water?
- (9) Cork has a density of  $300 \text{ kg/m}^3$ . What would be the mass in grams of a sample of cork with a volume of  $100 \text{ cm}^3$ ?
- (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?
- (12) A rubber ball floats in water so that it is exactly half submerged. What is the density of the rubber ball?

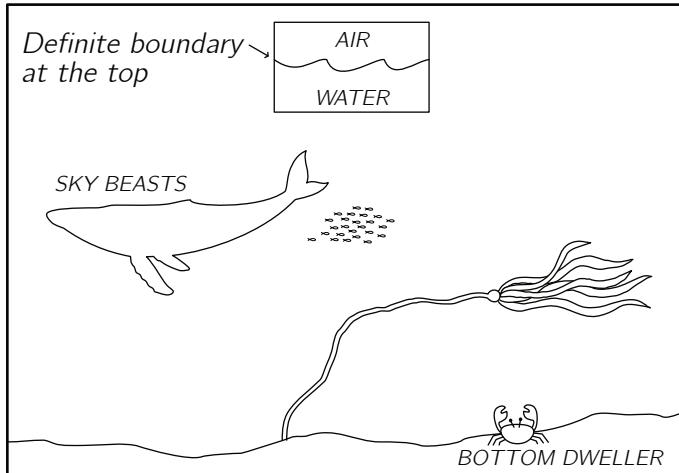
# AN OCEAN OF AIR

FILL IN THE BLANKS:

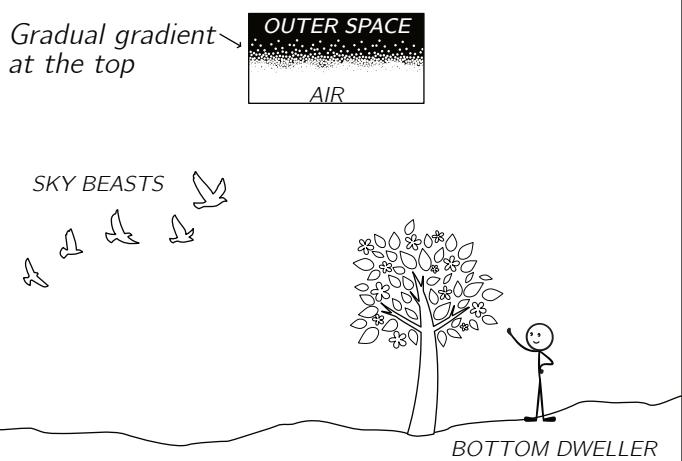
expand      pressure      fluids      decreasing      increasing

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

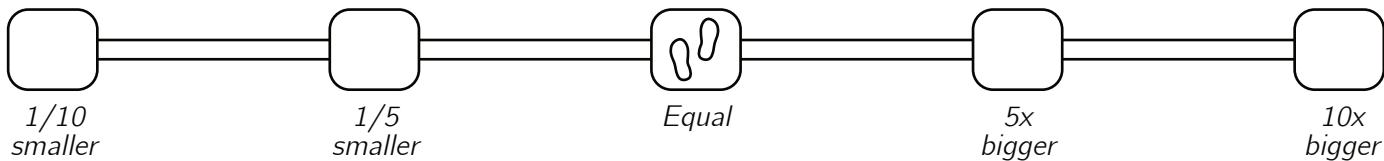
## OCEAN OF WATER



## OCEAN OF AIR

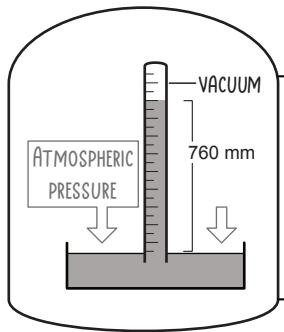


When Math Dad stands on two feet, he exerts a pressure of 2.51 PSI on the floor. Using that as a reference, how much pressure do you think the atmosphere is exerting on you right now?



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

# AN OCEAN OF AIR

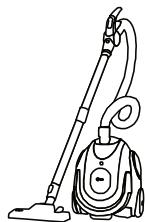


Italian physicist Evangelista Torricelli believed that air had weight and could apply pressure to support a column of water. To test this idea, he filled a glass tube with mercury and inverted it into a dish that was also filled with mercury. This groundbreaking experiment in 1693 led to the development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

WHAT IS WIND?

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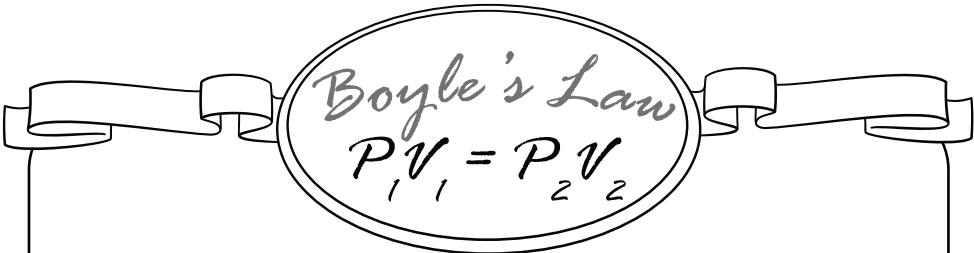
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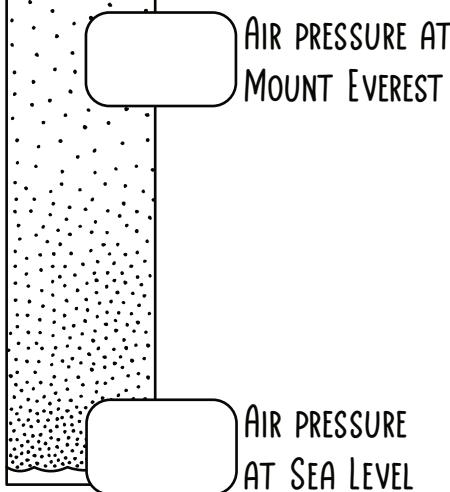
A PHYSICIST SAYS THERE'S NO SUCH THING AS SUCTION.  
IF THIS IS TRUE, HOW DOES A VACUUM WORK?

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AIR PRESSURE AT  
MOUNT EVEREST



## 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.
  
- (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.

## PRACTICE PROBLEMS – AN OCEAN OF AIR

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

- 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.

Elevation (ft)	Elevation (m)	Weight of 1 m <sup>3</sup> 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)*

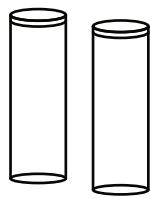
*R is the ideal gas constant (8.314 J/(mol·K))*

*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

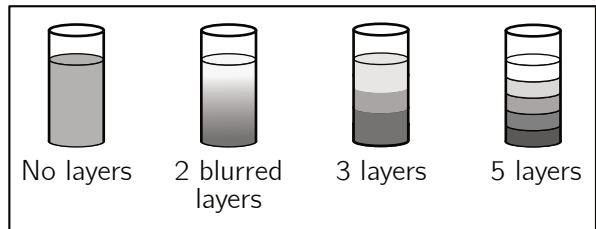
- ★ Better understand the concept of density
- ★ Make observations, record data, and communicate conclusions

### 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?

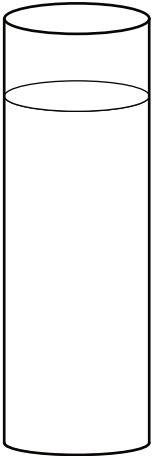
Draw and explain your prediction for when the liquids are layered from *most dense* on bottom to *least dense* on top (container 1). Also make a prediction for what you expect to see when they are layered from *least dense* on bottom to *most dense* on top (container 2).



### 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?*

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### CONCLUSIONS

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

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## OPTION 2: BOAT FLOAT

### MATERIALS



Aluminum foil



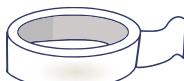
Rice



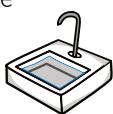
2 rolls of pennies or another weight



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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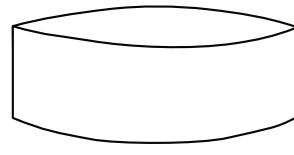
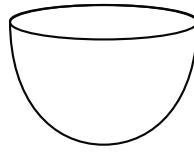
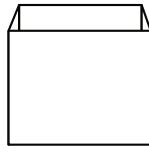
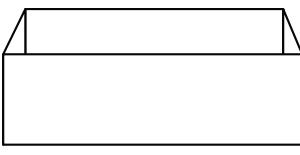
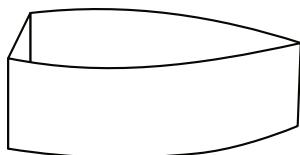
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### INSTRUCTIONS:

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  $\text{cm}^3$ . Note that  $1 \text{ mL} = 1 \text{ cm}^3$ .
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  $2.5 \text{ g/penny}$  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  $\text{cm}^3$ ).
6. Add bars to the bar chart to display the density of each boat.

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

The maximum density each boat could support



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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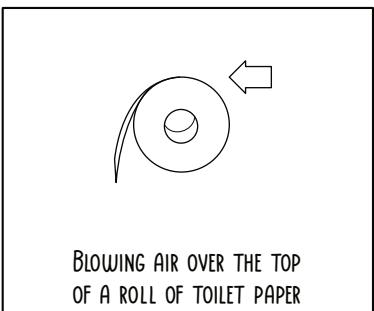
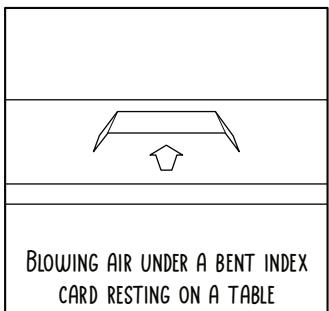
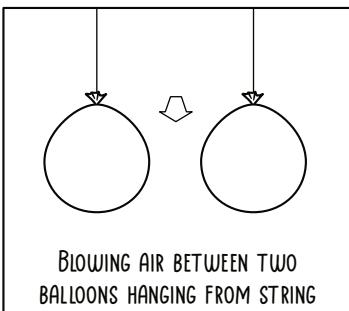
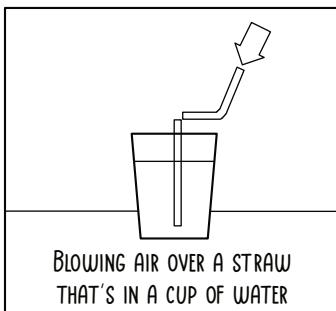


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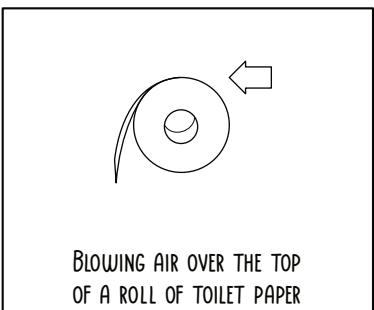
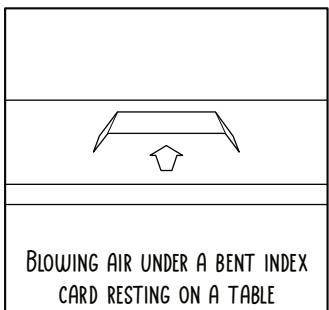
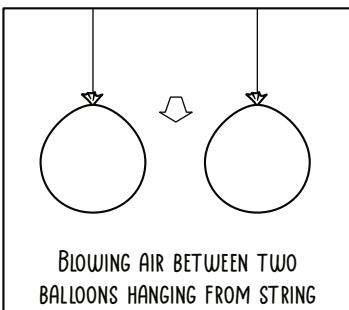
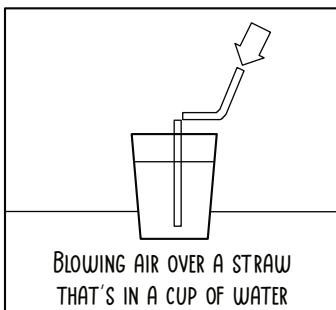
# FLUIDS IN MOTION

What will happen when the air moves fast in the direction the arrow is pointing?

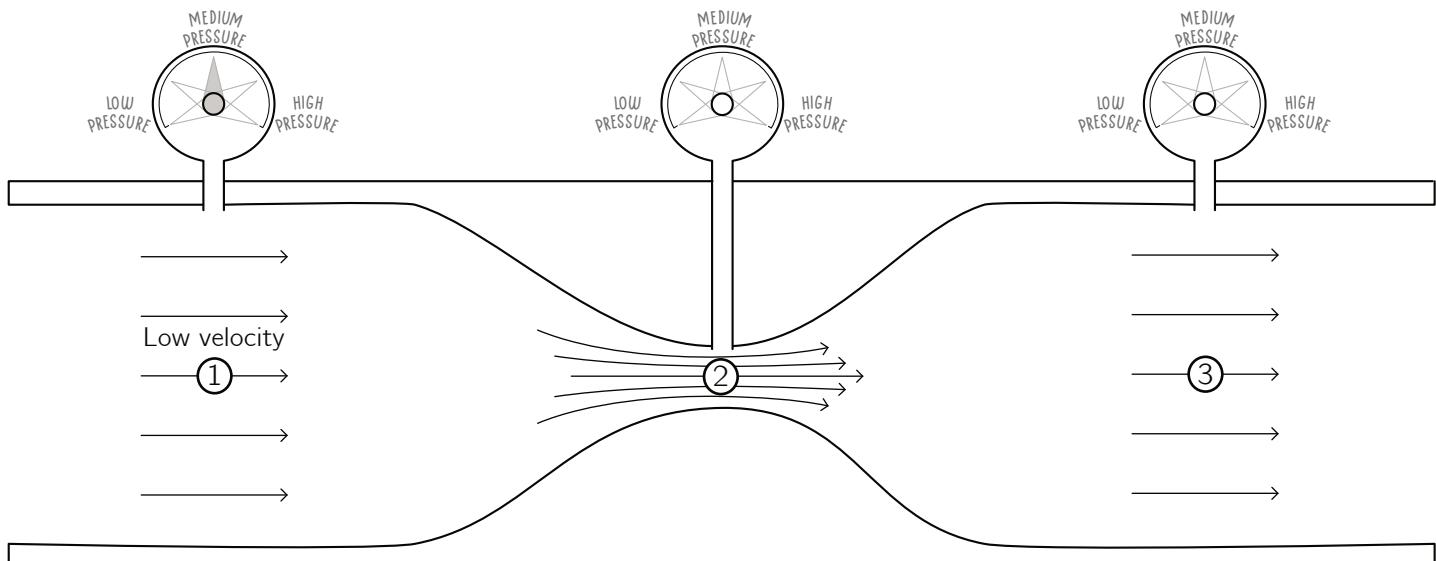
Draw or record your **prediction** below:



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



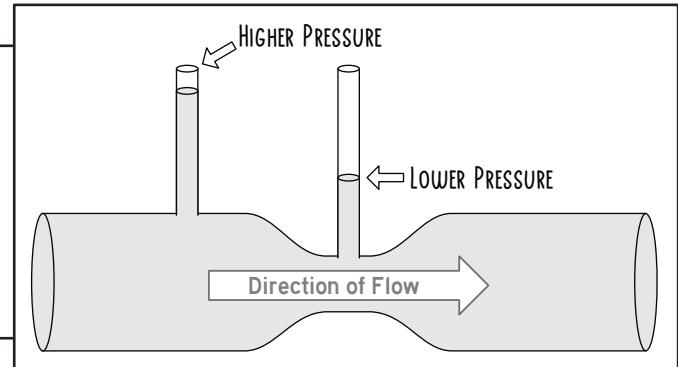
Fluid flows through a pipe with a narrow point. What will the pressure and velocity be at points 2 & 3?



# FLUIDS IN MOTION

## BERNOULLI'S PRINCIPLE

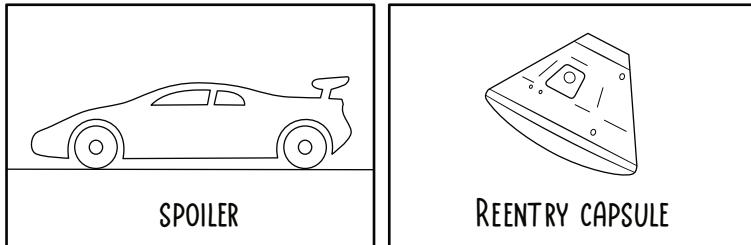
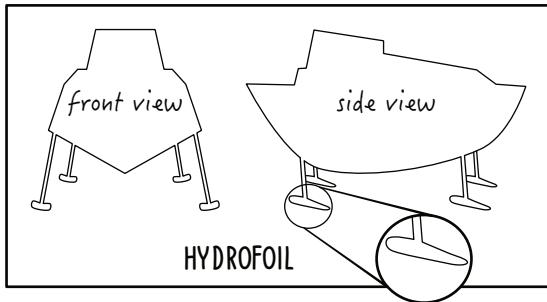
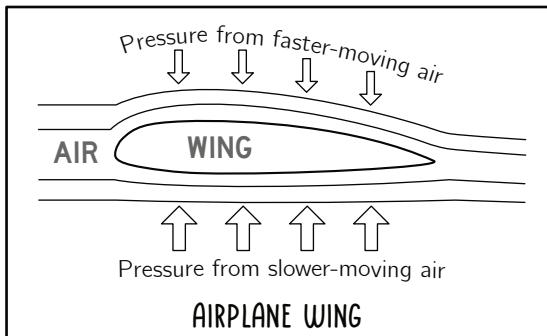
AS THE \_\_\_\_\_ OF A FLUID INCREASES,  
THE PRESSURE \_\_\_\_\_.



## Laminar Flow

## Turbulent Flow

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:



## 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.

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 3<sup>rd</sup> law
- B. Boyle's law
- C. Archimedes principle
- D. Bernoulli's principle

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?



- (8) In most cases, if the cross-sectional area of a pipe decreases, what happens to the flow speed of the fluid?

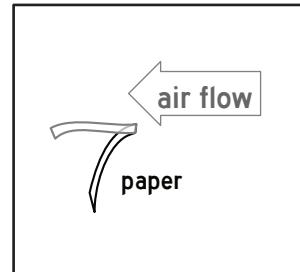
- A. It decreases
- B. It increases
- C. It remains the same
- D. It becomes turbulent

- (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



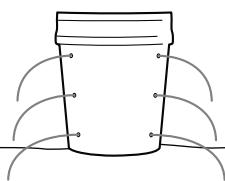
- (11) Explain Bernoulli's principle in your own words:

# 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 do you predict will happen and why?

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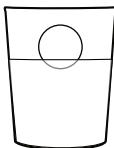
What will happen when the bucket is dropped?

---

What actually happened?

2

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



What do you predict will happen and why?

---

---

What will happen when the cup is dropped?

---

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?**

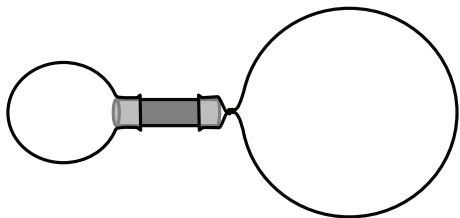
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4

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 do you predict will happen and why?**

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*What will happen when air is allowed to flow?*

## 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?
  
  
  
  
  
  
- 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?
  
  
  
  
  
  
- 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?

# 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?

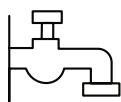


# A BALL ON A STRING

## 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: \_\_\_\_\_

**BUOYANCY:** The ability of a material to float in water.

FLUID:

PASCAL S:

PRESSURE:



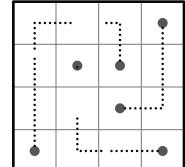
## PIPE FLOW MATCHING



A				D
3	C		B	4
			1	5
	2			E

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. $\text{m}^2$           |
| 2. temperature | B. $\text{kg}/\text{m}^3$ |
| 3. heat        | C. K                      |
| 4. area        | D. $\text{N}/\text{m}^2$  |
| 5. density     | E. J                      |



# FLUIDS & PRESSURE ASSESSMENT

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  $\frac{1}{4}$  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<sup>3</sup>
- B. An ice cube with density 0.92 g/cm<sup>3</sup>
- C. A piece of metal with density 7.8 g/cm<sup>3</sup>
- D. A rubber ball with density 1.5 g/cm<sup>3</sup>

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

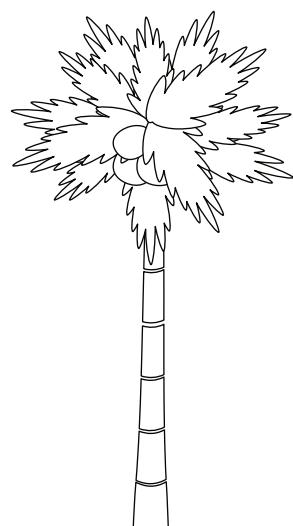
## FLUIDS & PRESSURE ASSESSMENT

- 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.

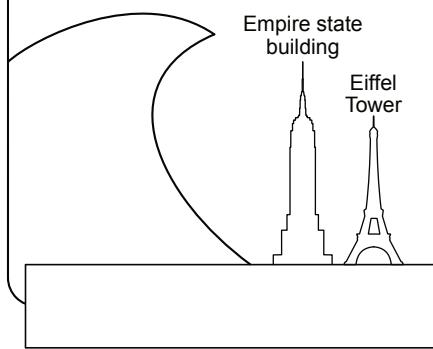
- 16 Why does a diver feel more pressure as they dive deeper?
- A. Because water temperature decreases with depth, increasing pressure
  - B. Because the volume of water above the diver increases, increasing pressure
  - C. Because the density of water increases with depth
  - D. Because of increased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



# MAKING WAVES

**FACT OR FICTION?** Write your verdict below each statement:

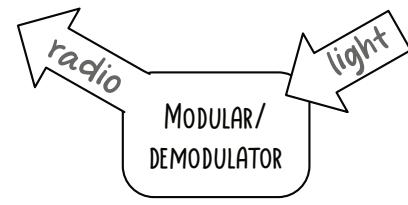
The largest recorded ocean wave had a height more than 1,000 ft above sea level.



It's possible to do brain surgery using only sound.



Most modern homes contain a machine that converts light into radio waves.

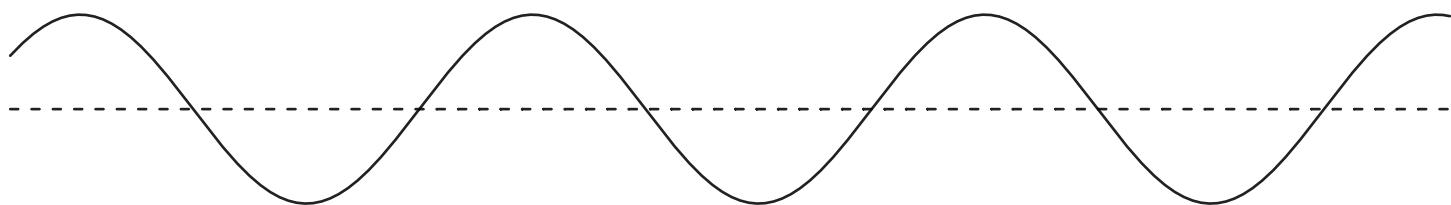


**FILL IN THE BLANKS:**

energy      disturbance      medium      transmitted

A wave is a \_\_\_\_\_ that transfers \_\_\_\_\_ from one place to another without transferring matter. Some waves, such as sound, require a \_\_\_\_\_. This means they can only travel or be \_\_\_\_\_ through physical materials such as air, water, or rock.

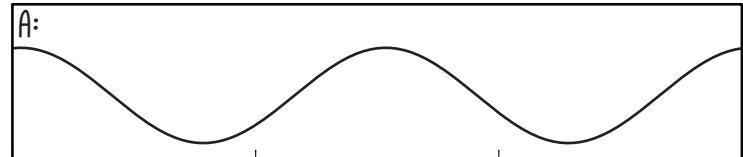
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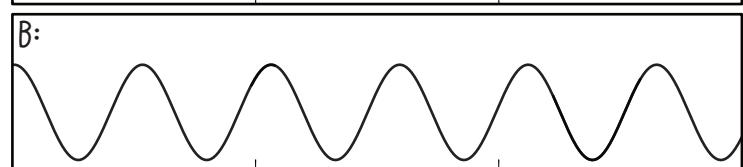
**AMPLITUDE:**

THE IMAGES BELOW SHOW HOW MANY OSCILLATIONS OCCUR IN 3 SECONDS.  
WHICH WAVE HAS A HIGHER FREQUENCY?

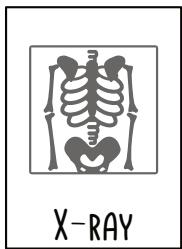
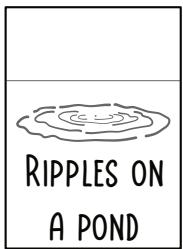
**WAVELENGTH:**



**FREQUENCY:**



Draw lines to categorize each of these as either a mechanical or electromagnetic wave:

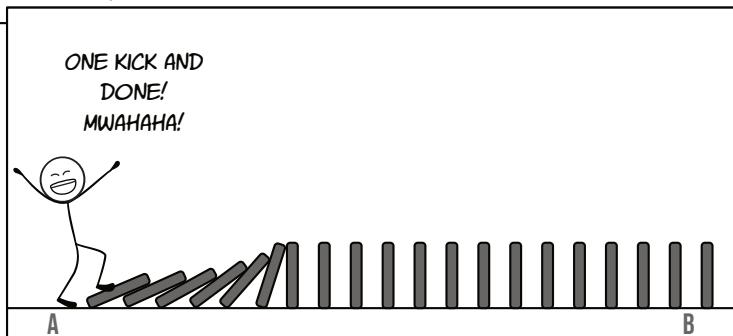
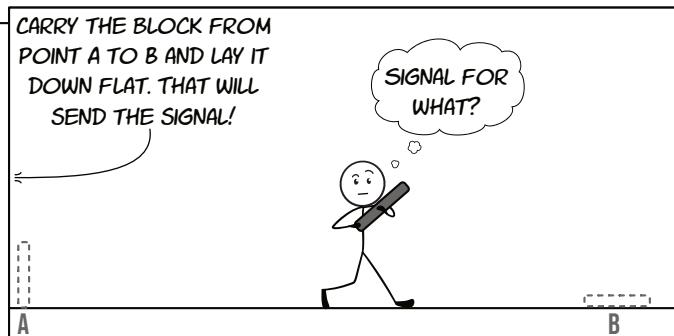


Mechanical wave:  
requires a medium

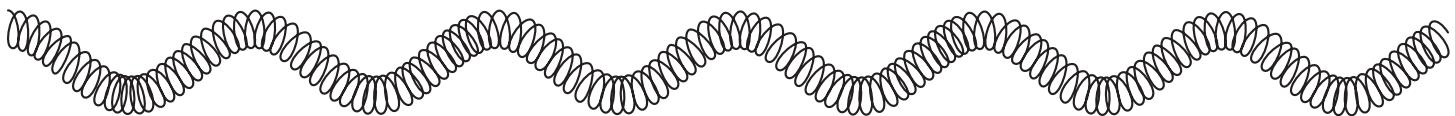
Electromagnetic wave: can travel through a vacuum of empty space.

## **THINK ABOUT IT:**

There are 2 primary ways to send energy or information from one place to another: by transporting physical matter or by creating a disturbance or wave that travels through space. With a wave, any matter involved moves very little. What really travels through space is the disturbance/wave itself.



## TRANSVERSE WAVE:

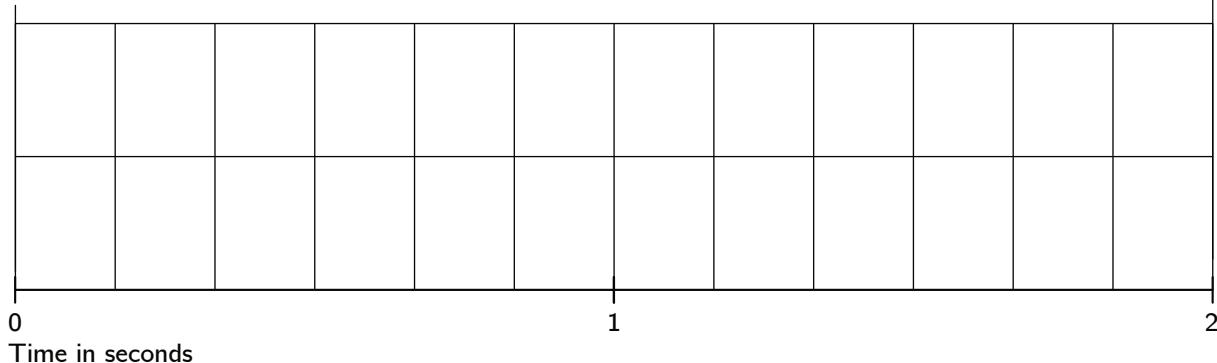


## LONGITUDINAL WAVE:



## PRACTICE PROBLEMS – MAKING WAVES

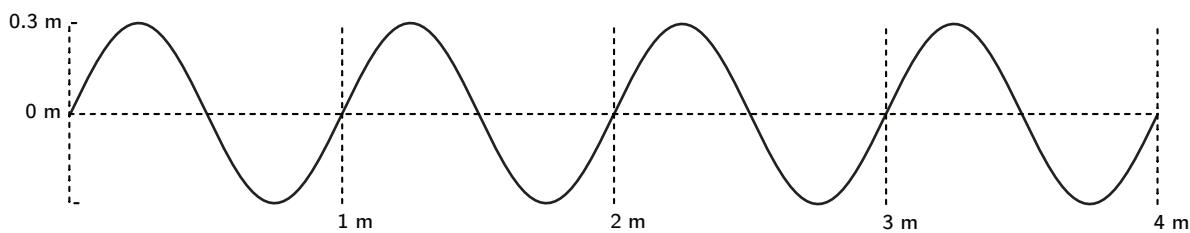
- ① Draw a wave with a frequency of 3 Hz (1 Hertz = 1 oscillation or 1 wave per second).



- ② Explain the difference between a mechanical wave and an electromagnetic wave and give an example of each.

- ③ A wave represented in the diagram below travels 4 meters in 2 seconds. Answer the following questions about the wave:

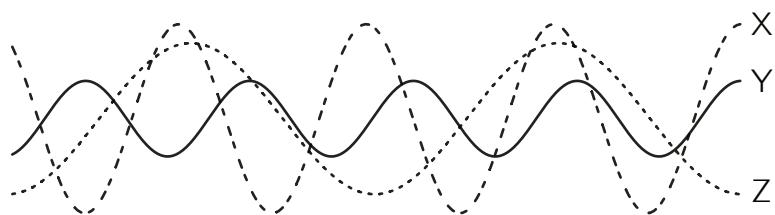
- A. What is the wavelength in meters? \_\_\_\_\_  
B. What is the amplitude? \_\_\_\_\_  
C. What is the speed of the wave in meters per second? \_\_\_\_\_



- ④ Three waves labeled X, Y, and Z are shown below.

- A. Rank curves X, Y, and Z below from smallest to largest amplitude:

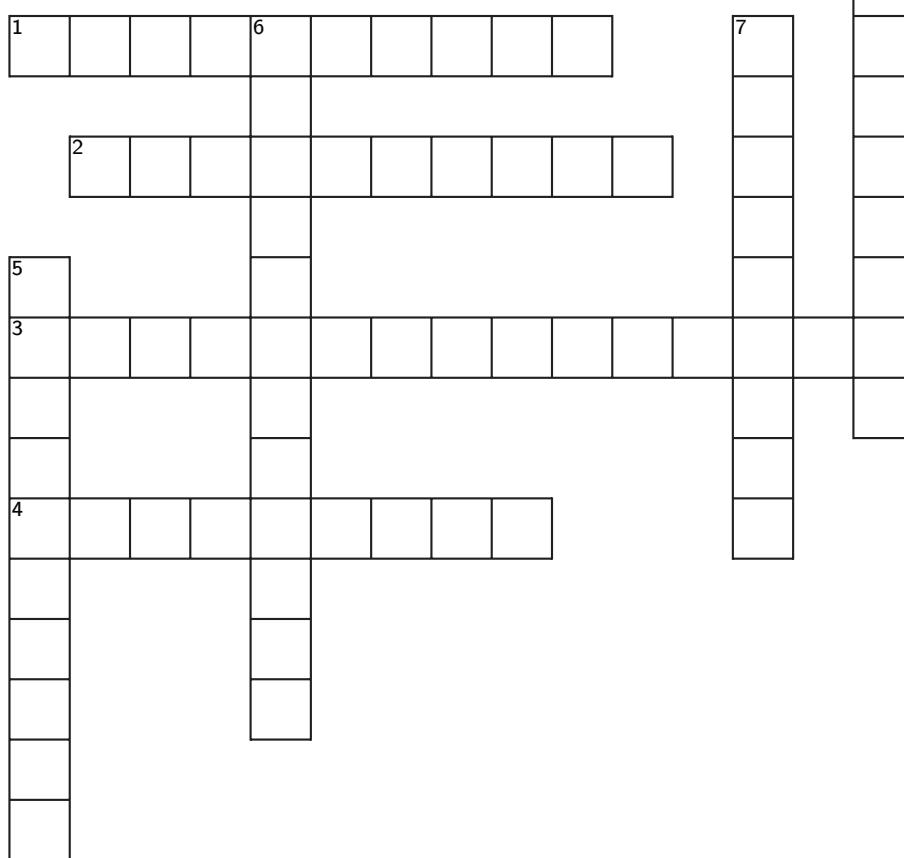
- B. Rank curves X, Y, and Z below from smallest to largest wavelength:



## PRACTICE PROBLEMS – MAKING WAVES

- (5) Are earthquake waves mechanical or electromagnetic? Explain.
- (6) What wave has motion that moves in the same direction the wave travels?
- (7) What type of wave has motion that moves perpendicular to the direction the wave travels?

### Wave Vocabulary Crossword Puzzle



#### Horizontal Words

1. The distance between crests of the wave
2. A wave that moves perpendicular to the direction of the wave speed
3. The type of wave that can travel through a vacuum of empty space
4. The distance from rest to the top of the wave (the distance from crest to peak)

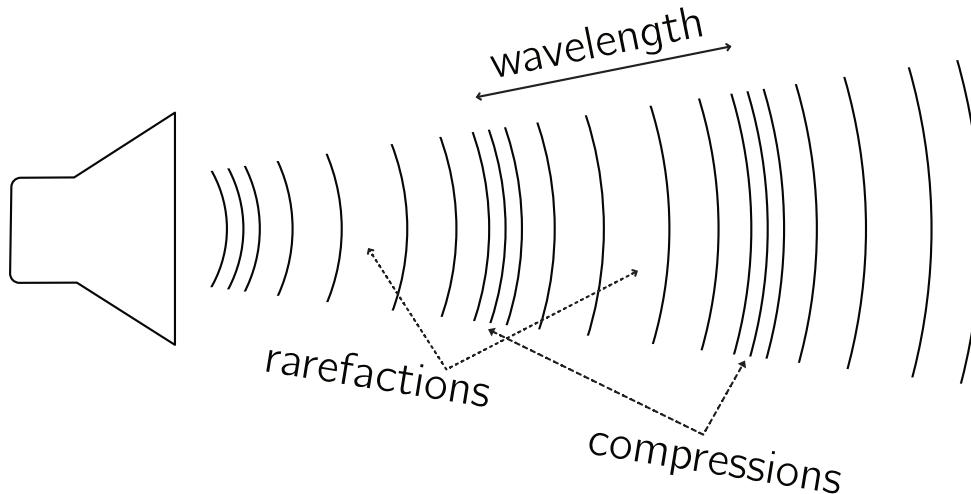
#### Vertical Words

5. A type of energy-carrying wave that always travels through material matter
6. A wave that moves along the same direction as the wave speed.
7. An oscillation, a wiggle repeated over time
8. How often a wave repeats itself.

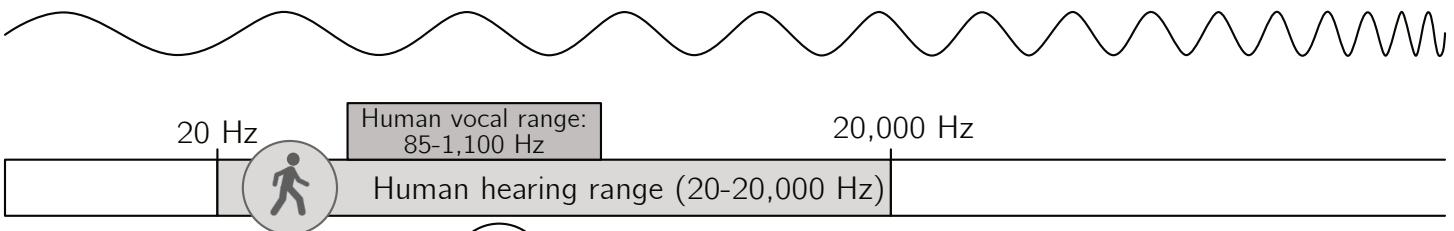
# GOOD VIBRATIONS

Fill in the blanks! Options for words include density, longitudinal, temperature, transverse

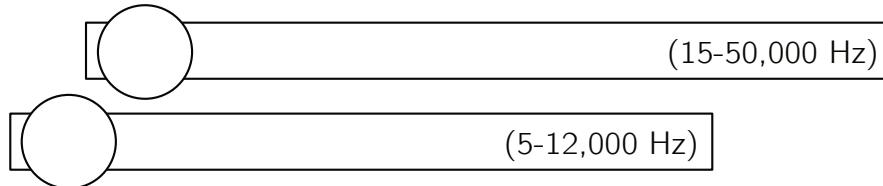
Sound is a \_\_\_\_\_ wave created by a vibrating source. These waves or compressions travel at varying speeds depending on the \_\_\_\_\_ of the medium.



Humans have a specific range of sound frequencies they can hear, typically between 20 hertz and 20,000 hertz. This range varies and tends to decrease with age. Frequencies below 20 Hz are called **infrasound** or **infra-sonic** and are too low for human ears to detect. Frequencies too high for human hearing are called **ultrasound**.



WHICH 3 ANIMALS HAVE THESE HEARING RANGES? BAT,  CAT, DOG, DOLPHIN, ELEPHANT, SNAKE, OR WHALE?



**PITCH:**

**VOLUME:**

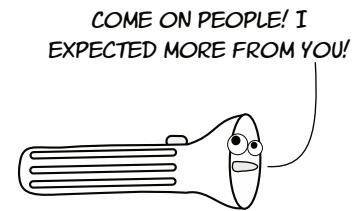
$$\lambda = \frac{V}{f}$$

Bats emit ultrasonic sounds at 40 kHz to navigate and locate prey. If the speed of sound in air is approximately 340 m/s, what is the wavelength of these ultrasonic sounds?

If the wavelength of a WiFi signal is 0.12 meters and the speed of electromagnetic waves is  $3 \times 10^8$  meters per second, what frequency band is the WiFi signal using?

### FACT OR FICTION? Write your verdict below each statement:

10 million people talking at once would barely produce enough energy to operate a flashlight.



Sound can make objects levitate in the air.

BRAIN SURGERY  
BY DAY, MUSICAL  
JUGGLER BY  
NIGHT!



The first sonic boom in history happened on Oct 14, 1947 when Chuck Yeager flew a Bell X-1 jet at an altitude of 45,000 ft.

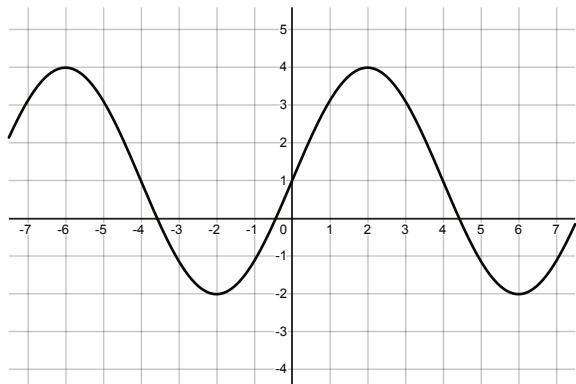


## PRACTICE PROBLEMS – GOOD VIBRATIONS

- ① How does the speed of sound change in a gas as temperature increases?
  
  
  
  
- ② How are microwaves different than sound waves?
  - A. Sound waves are longitudinal waves while microwaves are transverse waves
  - B. Sound waves are transverse waves while microwaves are longitudinal waves
  - C. Sound waves can travel through a vacuum of empty space but microwaves can't
  - D. Microwaves always have larger amplitude than sound waves
  
- ③ What formula is useful for determining the relationship between the frequency, wavelength, and speed of a wave?
  - A.  $\lambda = v / f$
  - B.  $f = v / \lambda$
  - C.  $\lambda = f \cdot v$
  - D.  $f = \lambda \cdot v$
  
  
  
  
- ④ Which form of water would sound travel the fastest through?
  - A. Ice
  - B. Liquid water
  - C. Steam
  - D. Sound would travel at the same speed through water no matter what state it was in.
  
  
  
  
- ⑤ The larger the amplitude, the \_\_\_\_\_ the sound will be.
  - A. Quieter
  - B. Louder
  - C. Sound waves with different amplitudes will have same volume
  
  
  
  
- ⑥ The pitch of a sound is primarily determined by the:
  - A. Amplitude
  - B. Frequency
  - C. Wavelength

## PRACTICE PROBLEMS – GOOD VIBRATIONS

- (7) Find the amplitude and wavelength of the graph on the right. (For units, count the number of squares)



- (8) A lightning bolt strikes, and it takes 6 seconds before you can hear the thunder from the lightning strike. Approximately how far away was the lightning strike from your location?
- (9) Explain how a sound is produced when you strike a drum.
- (10) The longer a guitar string is, the:
- A. Higher its pitch
  - B. Lower its pitch
  - C. Louder its sound
  - D. Softer its sound
- (11) Plucking a guitar string harder will do what to the sound wave it creates?
- A. Increase the wavelength
  - B. Increase the frequency
  - C. Increase the amplitude
  - D. All of the above

# MAKE YOUR OWN INSTRUMENT

## MATERIALS (WILL VARY DEPENDING ON WHAT TYPE OF INSTRUMENT YOU MAKE)

### Panpipes

- scissors
- duct tape
- 8 pieces of pipe OR 8 straws cut to different lengths

### Straw Flute or Trombone

- scissors
- 2 straws\* or 1 straw and a piece of paper and tape

\*If using 2 straws, one straw needs to be able to slide inside of the other.

### Rubber Band Banjo

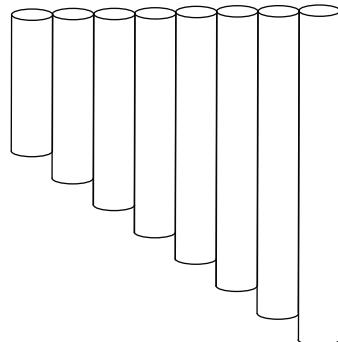
- scissors
- rubber bands
- stapler or tape
- a cardboard container (an empty tissue box works well)

### Bucket Drums

- buckets or metal cooking pots of several different sizes
- a wooden spoon or mallet

## INSTRUCTIONS for Panpipes:

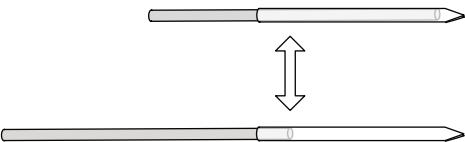
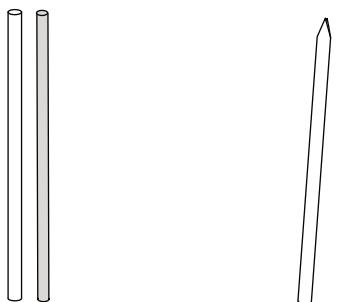
1. Cut the straws or pipes to different lengths.\* For better sound quality, cap the bottoms by covering them securely with tape or (in the case of actual pipe) capping them with pipe fittings.
2. Use glue or tape to secure the tubes together in a straight line.
3. Blow over the top of each tube and listen to the pitch of the notes.
4. Optional: cover the bottoms of each tube with tape or paper and see how that changes the sound.



*\*The pitch depends on both the width and the length. But straw pipes cut to the following lengths in centimeters will usually produce a nice set of tunes: 9.5, 10, 11.5, 13, 14.5, 15.5, 17, and 19.5 cm. Err on the side of cutting too long because it's easier to trim a pipe shorter than to make it longer.*

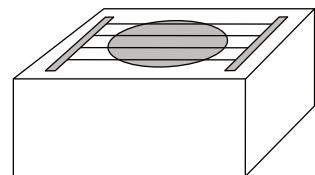
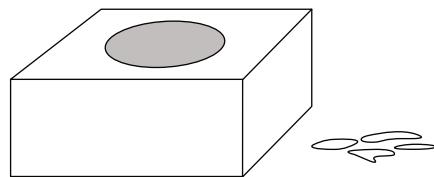
## INSTRUCTIONS for Straw Flute or Straw Trombone:

1. Blow into a straw and observe the sound made.
2. Flatten one end of the straw and then use scissors to trim that end to a point.
3. Place the flattened end of the straw in your mouth and blow again. Observe the sound made.
4. The flute is now complete. To make a Trombone, you may want to trim your straw flute with scissors to be shorter in length. Whether trimmed or not, make your trombone by fitting a smaller straw inside the straw flute OR make a cylindrical tube of paper that fits inside or just over the straw flute. Adjust the length by sliding the paper forward and back and observe how the sound changes.



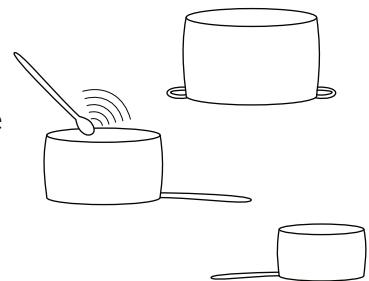
## INSTRUCTIONS for Rubber Band Banjo:

1. Find a container made of cardboard or another material that can be used to amplify the sound of the rubber bands. An empty tissue box or cereal box with a hole cut in one end works well.
2. Stretch rubber bands over the opening of the container. Depending on the size of your rubber bands and container, you might be able to stretch them over or you may need to cut them with scissors and secure them to the box with a stapler. Placing a popsicle stick or pencil under the rubber bands at each end may help improve the sound.
3. Experiment with the placement of the rubber bands. Stretch them differently or change the sizes to get



## INSTRUCTIONS for Bucket Drums:

1. Gather bucket-shaped objects of different sizes such as cans or pots.
2. Using a wooden spoon or an actual mallet, tap the buckets and notice the pitch of the sound made.
3. Arrange the bucket drums from highest to lowest pitch. Can you find shapes that correspond to pitches so you can play a song?



## Questions to consider and explore:

There are 3 main types of instruments: wind, string, and percussion. Why does a note of the same pitch sound different when played on a violin versus a trumpet? How can someone tell the difference between a middle C being played on a flute vs a harp vs a xylophone?

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What happens to the pitch of a stringed instrument when you shorten the string?

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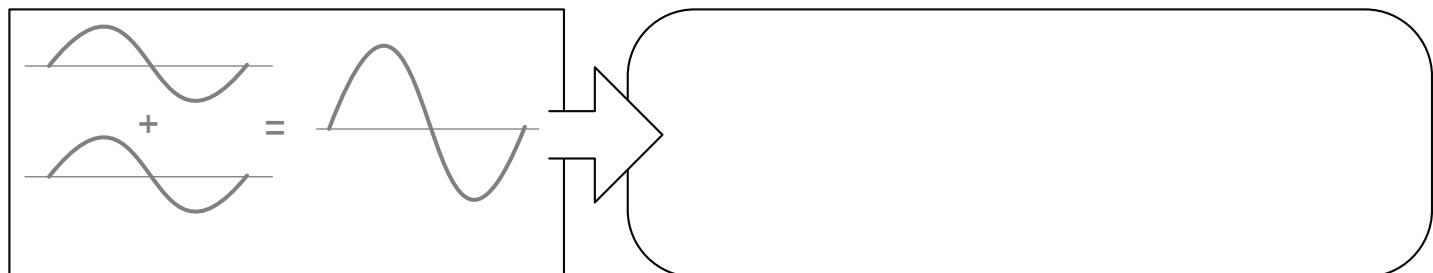
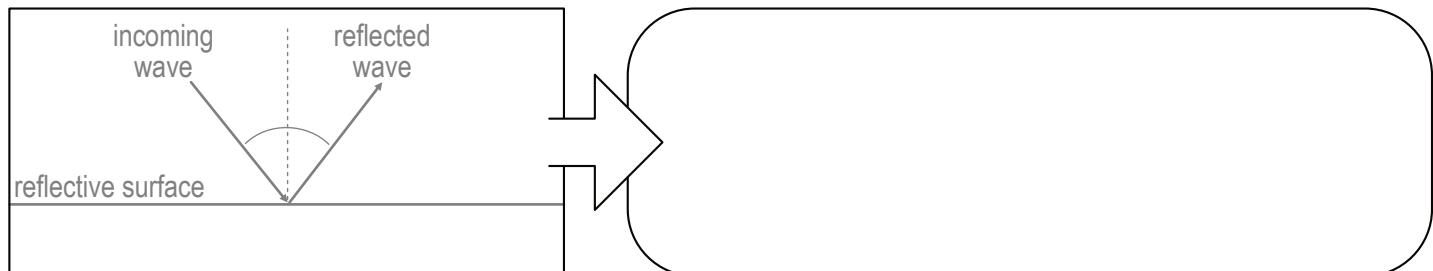
In the instrument(s) you made, what part of the instrument vibrated and created sound waves?

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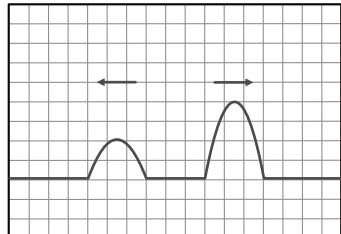
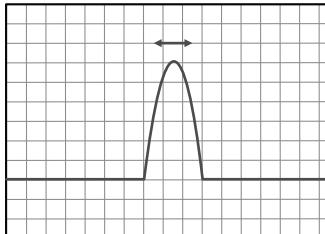
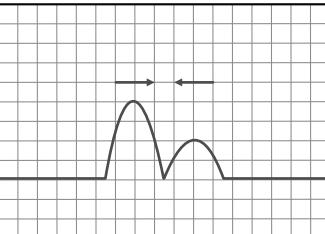
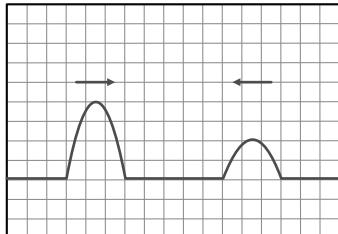
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# RESONANCE & DECIBELS

Interesting things happen when waves collide with objects or with other waves. When two waves collides, they don't destroy each other! Instead they pass *through* each other.

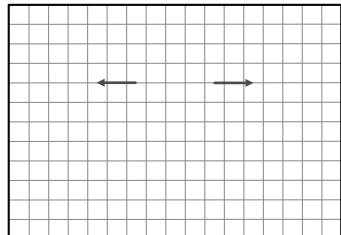
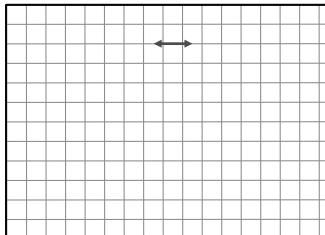
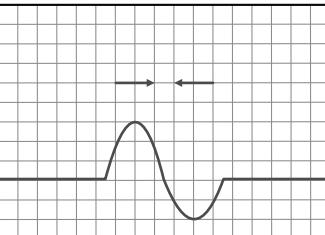
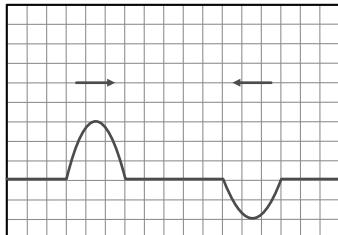


## Constructive Interference

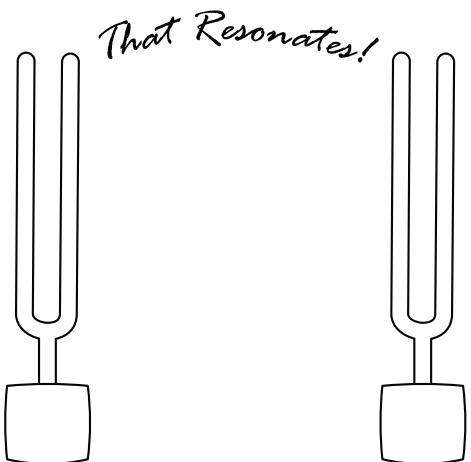


Two pulses with positive amplitude are moving towards each other. When they overlap, the resulting amplitude increases significantly. After passing through each other they return to their original shape and size.

## Deconstructive Interference



Two pulses with opposite amplitude are moving towards each other. Draw the resulting amplitude when they overlap and after the waves pass each other. (After passing, these waves will also return to their original shape and size.)

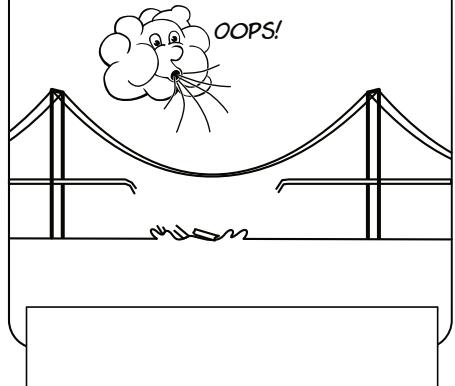


**Natural frequency:**

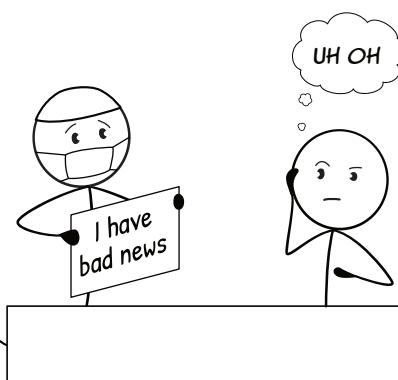
**Resonance:**

## FACT OR FICTION? Write your verdict below each statement:

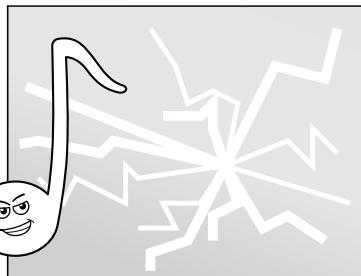
In 1940, a mile-long bridge collapsed because of a moderate wind.



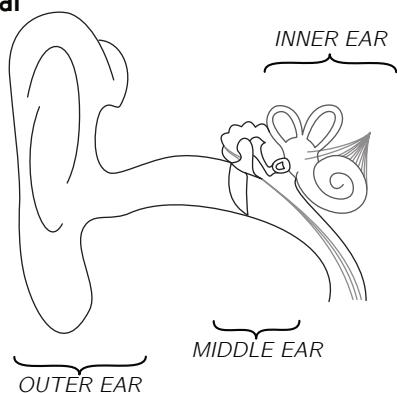
A broken eardrum will result in permanent hearing loss.



If you sing loudly enough, you can break glass using just your voice!

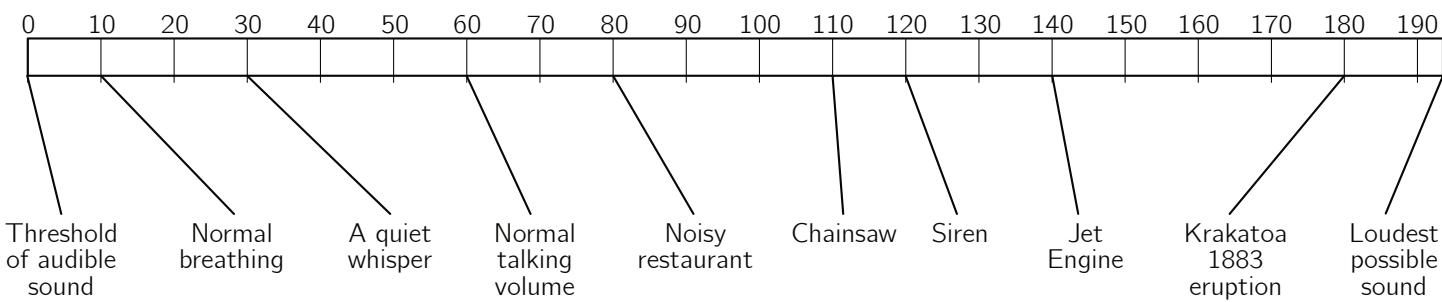


### The Human Ear



Label the earlobe, eardrum, and cochlea. Which parts of the ear collect, transfer, and sort or interpret sound waves?

### The Decibel Scale



Color the decibel scale above to show the range of decibels associated with the following:

**GREEN**: Safe. Little or no risk of hearing loss.

**YELLOW**: Caution. Sustained exposure will result in permanent hearing loss.

**RED**: Danger. Short term exposure causes pain and hearing loss.

FILL IN THE BLANKS: 10    100    1,000    logarithmic

The decibel scale is a \_\_\_\_\_ scale, which means that an increase of 10 dB changes the sound intensity by a factor of \_\_\_\_\_. An increase of 20 dB changes the sound intensity by a factor of \_\_\_\_\_, and an increase of 30 dB means the sound is \_\_\_\_\_ times more intense!

## PRACTICE PROBLEMS – RESONANCE AND DECIBELS

- ① Bob is standing 100 meters away from a large wall with a stopwatch. He bangs a pair of cymbals together and records the time until he hears an echo. Today he hears the echo in 0.6 seconds. What is the speed of sound through the air today?
  
- ② The speed of a wave depends on:
  - A. The medium through which it is traveling
  - B. The wavelength. Shorter wavelengths travel faster than longer wavelengths.
  - C. The frequency. Higher frequency waves travel at higher speeds.
  
- ③ Which of these has a bigger impact on the frequency of a wave?
  - A. The medium through which it travels
  - B. The source producing the wave
  
- ④ Which of the following are examples of resonance?
  - A. The 1850 collapse of the Angers Bridge in France
  - B. A child pumping their legs to move higher on a swing
  - C. The balance wheel in a mechanical clock
  - D. All of the above
  - E. None of the above
  
- ⑤ What does the decibel scale measure?
  - A. The pitch of a sound
  - B. The frequency of a sound
  - C. The intensity of a sound
  - D. The duration of a sound
  
- ⑥ Prolonged exposure to sounds above which decibel level can lead to hearing loss?
  - A. 50 decibels
  - B. 60 decibels
  - C. 85 decibels
  - D. 100 decibels

## PRACTICE PROBLEMS – RESONANCE AND DECIBELS

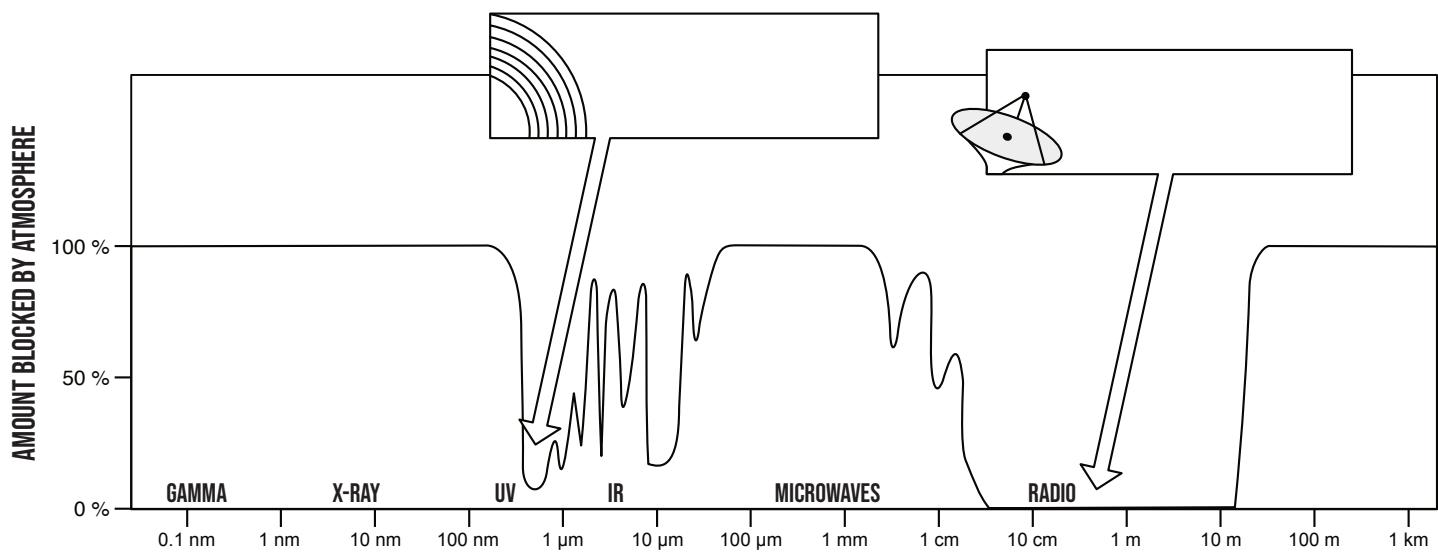
- (7) What is the approximate threshold of human hearing? Or in other words, what is the quietest sound a human can hear?
- (8) On the decibel scale, a sound that is 30 decibels is \_\_\_\_\_ times more intense than a sound that is 20 decibels.
- A. 2 times
  - B. 5 times
  - C. 10 times
  - D. 100 times
- (9) What statement about resonance is true?
- A. When resonance happens, more energy is being added to the object or system
  - B. Tuning forks vibrate in the presence of any sound
  - C. When an oscillating force is applied at a frequency that matches the natural frequency of an object, this vibration will cause the system to vibrate at a lower amplitude
  - D. Objects must be completely still for resonance to occur.
- (10) Give two examples of situations where you might encounter superposition or interference in everyday life. One example should be for constructive interference. The other example should be deconstructive interference.

# THE ELECTROMAGNETIC SPECTRUM

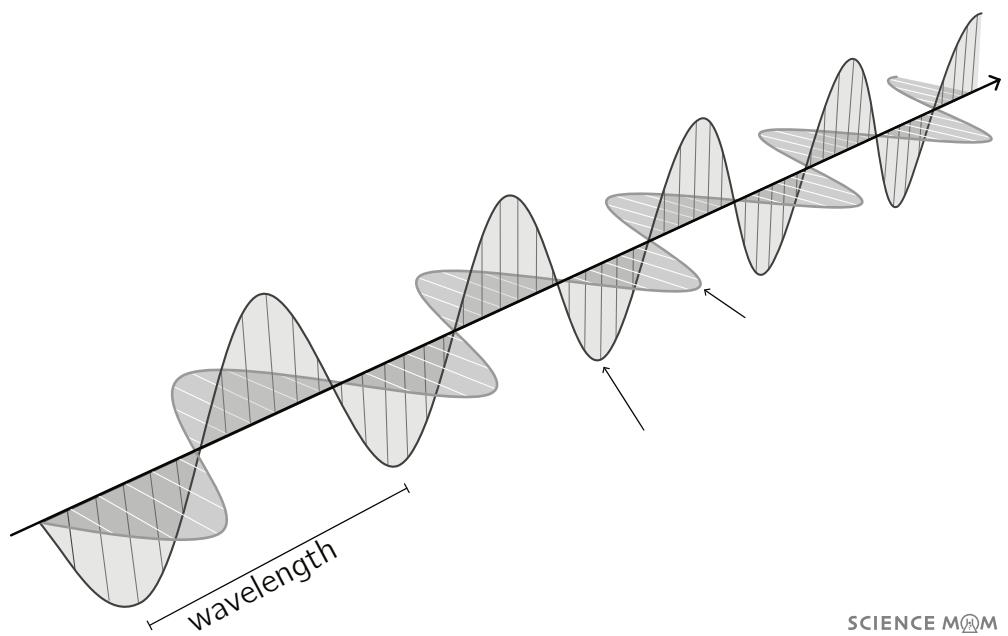
FILL IN THE BLANKS:

visible wavelengths eyes radiation radio gamma

The electromagnetic spectrum is the full range of electromagnetic \_\_\_\_\_ organized by frequency or wavelength. \_\_\_\_\_ waves have wavelengths longer than a football field. The shortest wavelengths are found in \_\_\_\_\_ waves, which have a wavelengths as small as the width of an atomic nuclei. Human \_\_\_\_\_ can only perceive a narrow band of radiation with \_\_\_\_\_ from 400 to 700 nm. This radiation is called \_\_\_\_\_ light.



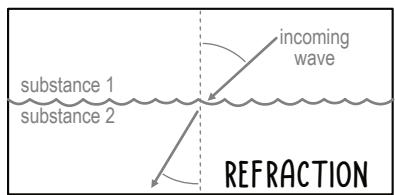
Why are these waves called electromagnetic?



## MATCH EACH DEFINITION AND EXAMPLE WITH THE CORRECT TERM:

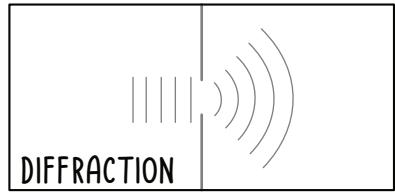
When a wave strikes a reflective surface it bounces back at the same angle.

Ex: echoes, mirrors



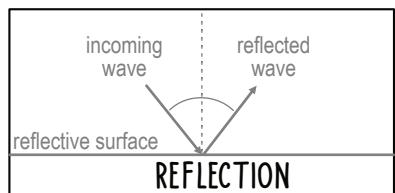
The apparent speed of a wave changes as it moves from one medium to another.

Ex: underwater objects look distorted, rainbows

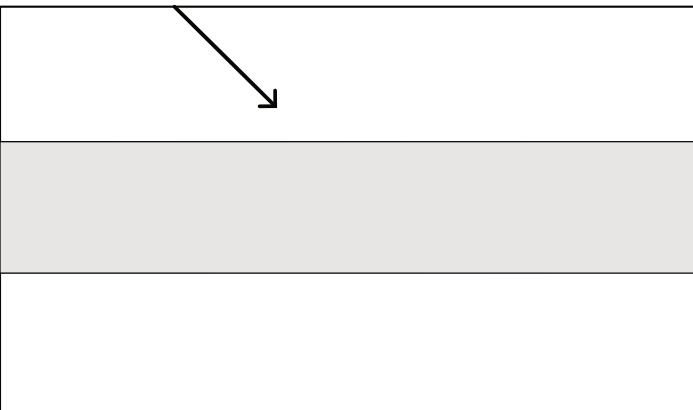


A wave spreads out around obstacles.

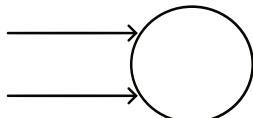
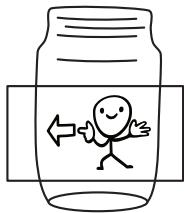
Ex: hearing someone on other side of door, light shining through a pinhole



### What path does light take through glass?



### The image reverser - how it works!



### The disappearing coin trick - how it works!



## PRACTICE PROBLEMS – THE ELECTROMAGNETIC SPECTRUM

- ① “Microwaves are just another color that humans can’t see.”

Do you agree with this statement? Why or why not?

- ② Rank the following from shortest wavelength to longest wavelength. Then label which one is most energetic and which has the least amount of energy. EM wavelengths: *gamma, infrared, microwave, radio, ultraviolet, visible light, x-ray*.

\_\_\_\_\_ *SHORTEST WAVELENGTH* \_\_\_\_\_ *LONGEST WAVELENGTH*

- ③ X-rays are used in medicine because:

- A. They can easily pass through soft tissues but not through bones
- B. They are completely safe and have no side effects
- C. They are easily visible to the human eye
- D. They provide warmth and help with healing

- ④ Which of the following are made of photons traveling at the speed of light in a vacuum?

- A. s-waves in an earthquake
- B. Microwaves
- C. Green light
- D. Radio waves
- E. Infrared light (heat) emitted from a sleeping marmoset
- F. The sound of middle C (a frequency of 261.62 hertz)

- ⑤ The Sun emits all of the following. Which wavelengths are blocked by Earth's atmosphere?

- A. Red light
- B. Microwaves
- C. X-rays
- D. Gamma rays
- E. Radio waves

## PRACTICE PROBLEMS – THE ELECTROMAGNETIC SPECTRUM

- (6) A remote control uses a pulse of electromagnetic radiation of 940 nanometers to turn on a television screen. This wavelength is invisible to human eyes but picked up by a cell phone camera. What type of electromagnetic radiation is used by this remote control?

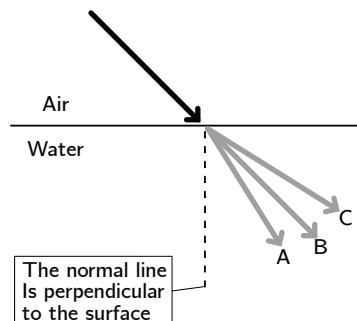
- A. Ultraviolet
- B. X-ray
- C. Infrared
- D. Microwave
- E. Radio

- (7) What type of wave is a radio wave?

- A. Sound wave
- B. Light wave

- (8) How would light bend when it travels from air to water?

- A. It would bend toward the normal line (line A)
- B. It would not bend (line B)
- C. It would bend away from the normal line (line C)
- D. All of these options (the light would spread out in a cone)
- E. None of these options

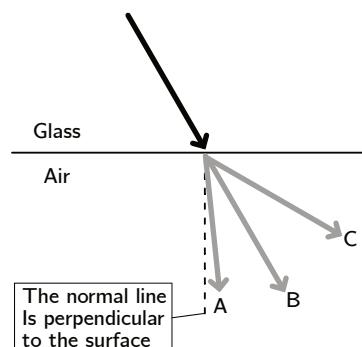


- (9) When driving on a highway, Bob sees a mirage. It looks like there is a puddle of water in the middle of the highway. But as Bob continues driving the puddle moves. No matter how fast or slow Bob drives, the puddle is always about 100 meters in front of the car. This mirage is primarily caused by:

- A. Reflection
- B. Refraction
- C. Water on the road quickly evaporating and then condensing

- (10) How would light bend when it travels from glass to air?

- A. It would bend toward the normal line (line A)
- B. It would not bend (line B)
- C. It would bend away from the normal line (line C)
- D. All of these options (the light would spread out in a cone)
- E. None of these options

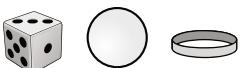


# TABLETOP KALEIDOSCOPE

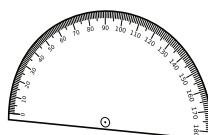
## MATERIALS



2 flat mirrors \*



A small object to place in front of the mirror such as a pebble, ring, dice, or small figurine



Protractor



Tape

## GOALS

★ Create a kaleidoscope effect with mirrors.

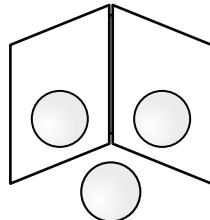
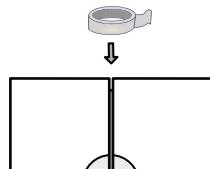
★ Explore the angle of reflection of light in a mirror.

\* If you only have one hand mirror available, you can hold it up to a bathroom mirror and get the same effects. It works best if your mirror has no border.

## INSTRUCTIONS:

1. Tape two mirrors side-by-side with a little space between them and add tape along the back creating the spine of a mirror-book.
2. Place an object up on a table.
3. Stand the mirrors vertically upright so they form a  $180^\circ$  angle with each other. You should see exactly two copies of your object (one mirrored across the spine of the mirror-book).
4. How many objects do you predict you will see if the mirrors are rotated to form a  $120^\circ$  angle? Make a prediction before trying it. If you don't have a protractor, print the following page and use it as a guide.
5. Continue rotating the mirrors to form other angles, and try viewing different objects.

At what angle should you use to see exactly 4 copies of your object?



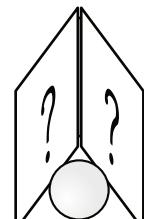
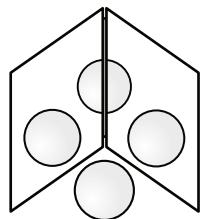
Is it possible to get exactly 5 copies of your object?

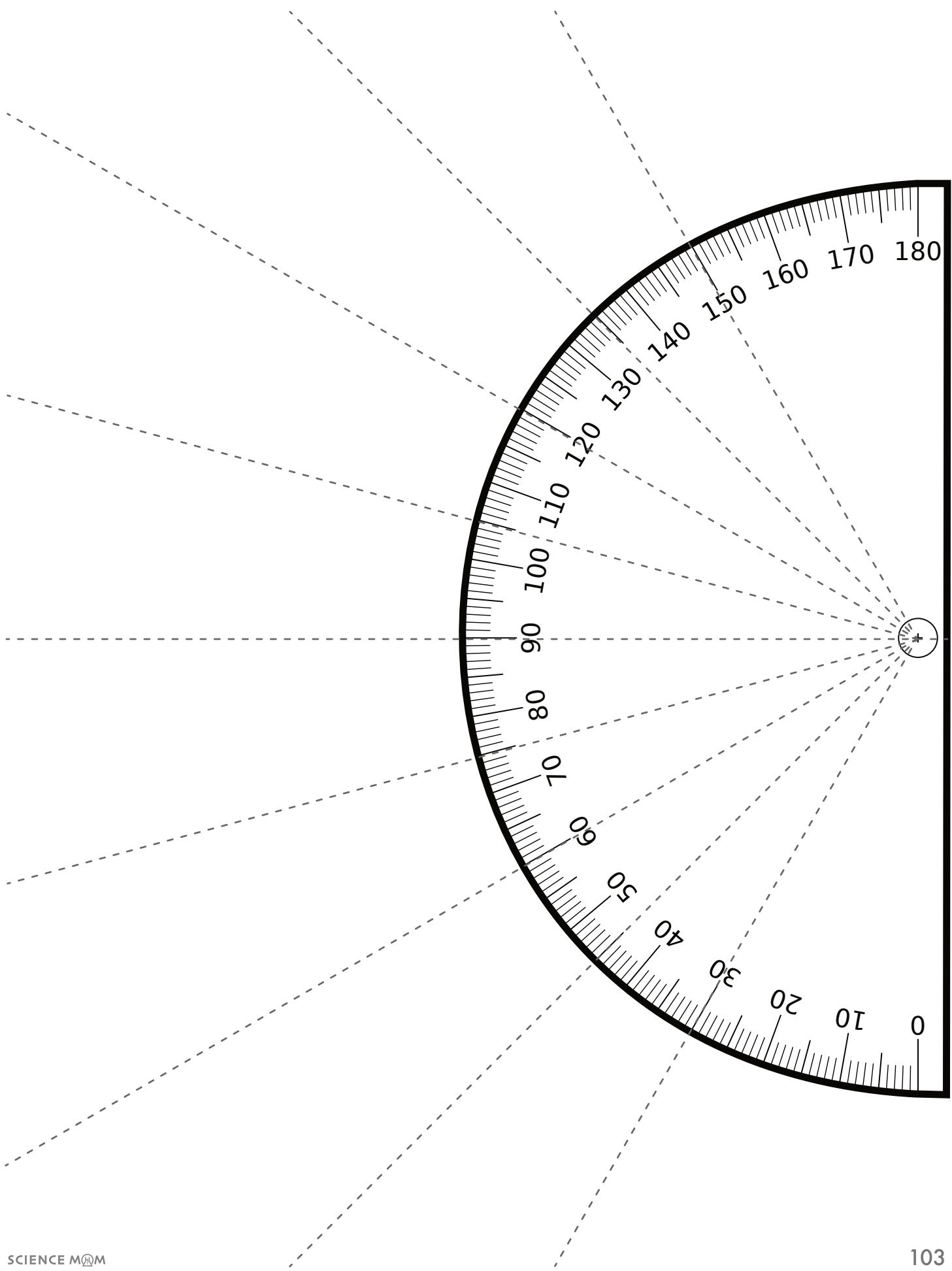
Fill in the table below to match the size of the angle with the number of objects you can see.

Describe any patterns you see.

angle	objects
$180^\circ$	2
$120^\circ$	3
	4
	5
	6
	8
	9
	10

Would it be possible to make 100 copies of an object visible using two mirrors? Explain.





# COLORS & SENDING SIGNALS

In reflection and refraction, light can change direction after interacting with an object, but there's another option we haven't talked much about yet: absorption! Draw your own comic or diagrams to go along with the text below:

WHEN LIGHT IS ABSORBED, THE ENERGY IS CONVERTED INTO OTHER FORMS LIKE HEAT.

EVERYTHING WE CAN SEE IS BEING HEATED UP?!?

YEP! THE AMOUNT OF TEMPERATURE INCREASE DEPENDS ON THE LIGHT INTENSITY. OFTEN IT'S VERY SMALL.

ALSO... MOST OBJECTS DON'T ABSORB ALL VISIBLE LIGHT. THEY REFLECT AT LEAST A FEW WAVELENGTHS.

White Light Contains These Wavelengths:

380-450 nm:

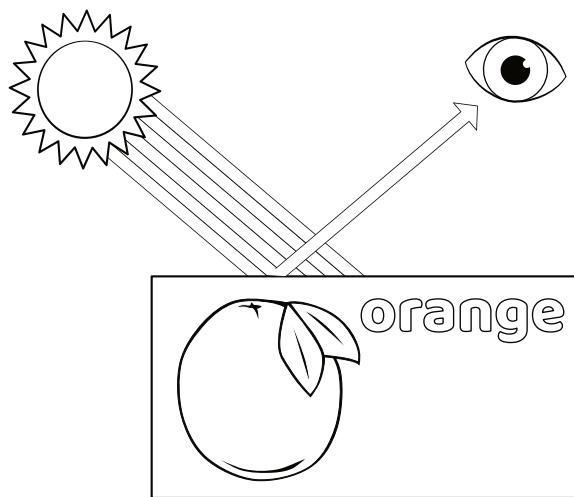
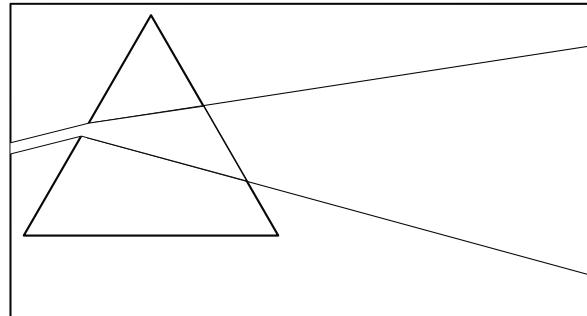
450-500 nm:

500-570 nm:

570-590 nm:

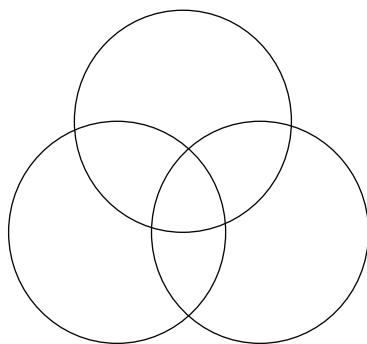
590-610 nm:

610-760 nm:



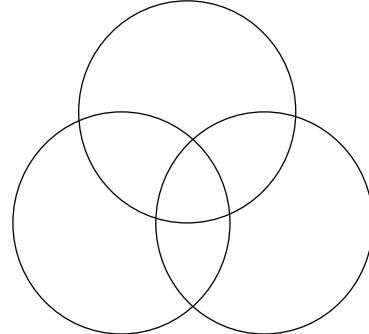
## MIXING LIGHT

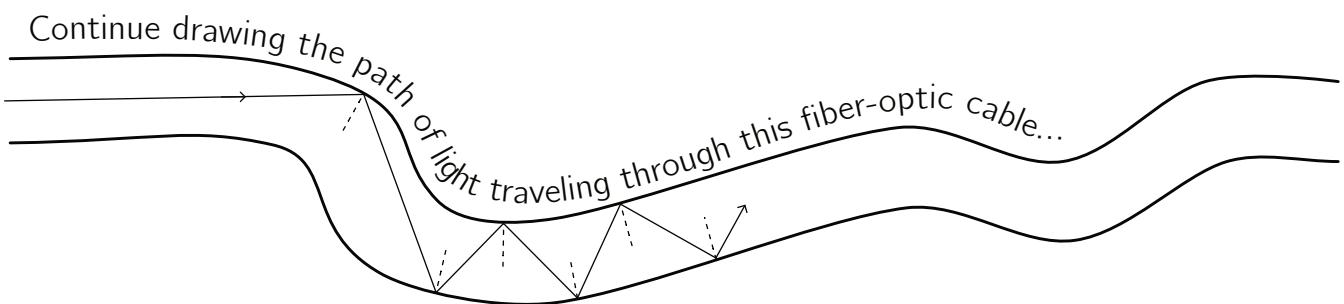
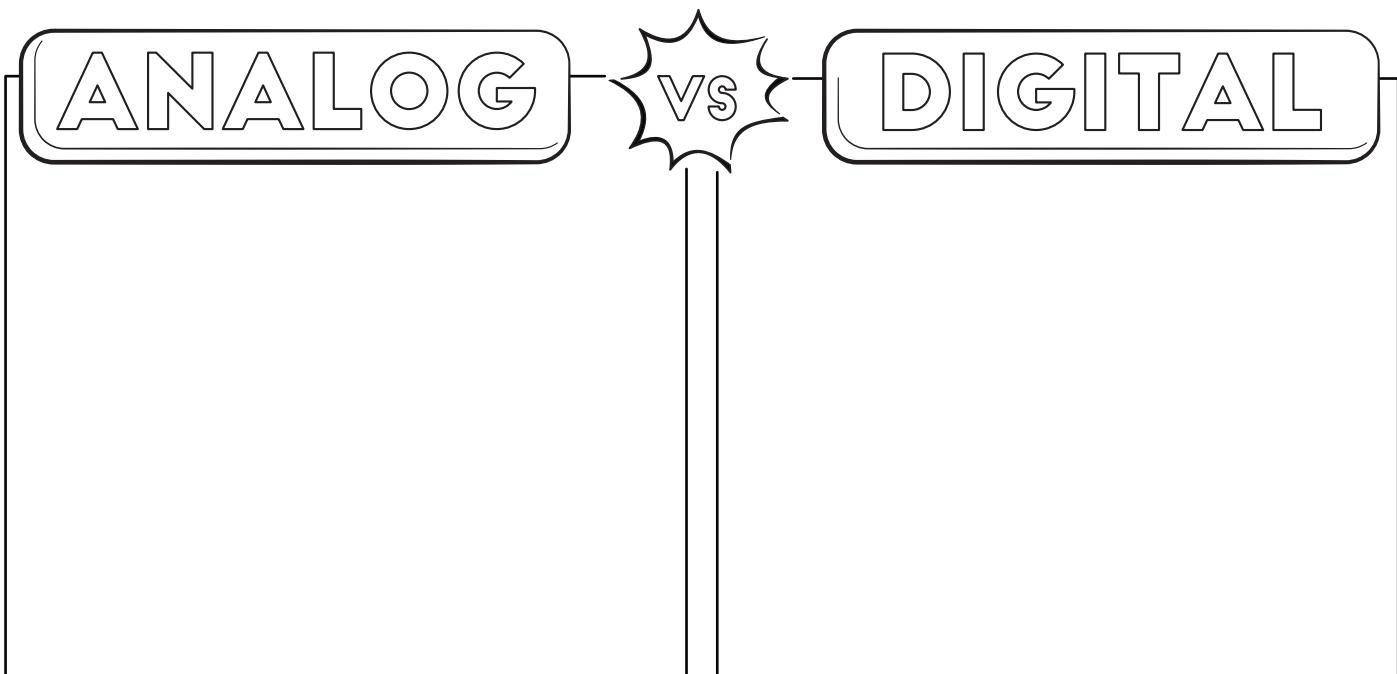
*The Additive Color Model*



## MIXING PIGMENTS

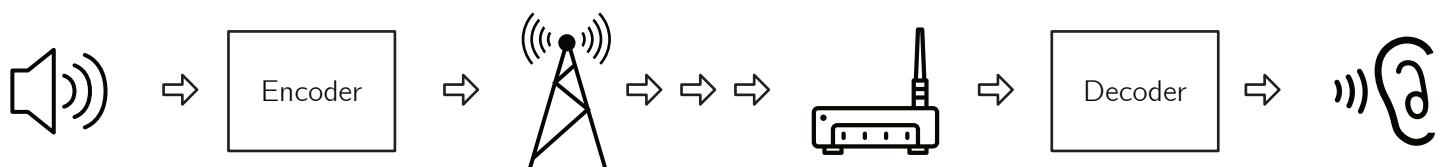
*The Subtractive Color Model*





### Communicating with waves

Bob uses a cell phone to call to a friend. What waves are involved? Label them and then describe whether the signals involved are analog or digital.



## PRACTICE PROBLEMS – COLOR & SENDING SIGNALS

- ① Emily sends a text message to her brother. What type of electromagnetic wave is most likely used to send the text message?
- A. Infrared
  - B. Microwave
  - C. Ultraviolet
  - D. Violet
- ② Which color of light has more energy, red light or blue light?
- A. Red light because it has a higher frequency
  - B. Red light because it has a lower frequency
  - C. Blue light because it has a higher frequency
  - D. Blue light because it has a lower frequency
- ③ Why are most plants green?
- A. They absorb green light.
  - B. They reflect green light but absorb other wavelengths of color.
- ④ What color is produced when all wavelengths of light overlap or are “mixed” together?
- A. White
  - B. Brown
  - C. Black
  - D. Magenta
- ⑤ A color printer can print photographs and other complex color images quickly and easily. It only has 4 ink cartridges. What color are the ink cartridges?
- A. Red, Yellow, Blue, and Brown
  - B. Red, Green, Blue, and White
  - C. Cyan, Yellow, Magenta, and Black
  - D. Each of the cartridges contains many colors of ink
- ⑥ Which of the following statements is true?
- A. We don’t see color in moonlight because only one wavelength is reflected from the Moon.
  - B. Objects still have color in moonlight, it’s just too faint for our eyes to detect.
- ⑦ Of the colors below, which has the longest wavelength?
- A. Violet
  - B. Orange
  - C. Green
  - D. Yellow

# WAVES UNIT ASSESSMENT

## IN YOUR OWN WORDS!

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

MECHANICAL WAVE: \_\_\_\_\_  
\_\_\_\_\_

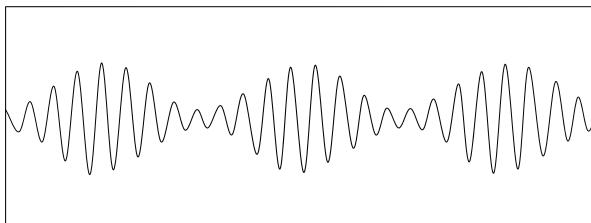
ELECTROMAGNETIC WAVE: \_\_\_\_\_  
\_\_\_\_\_

AMPLITUDE: \_\_\_\_\_  
\_\_\_\_\_

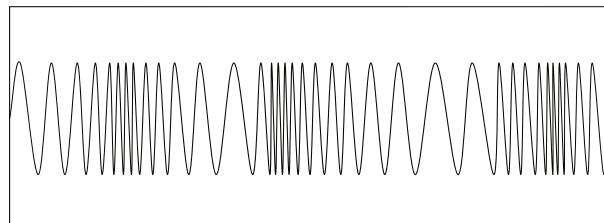
FREQUENCY: \_\_\_\_\_  
\_\_\_\_\_

HERTZ: \_\_\_\_\_  
\_\_\_\_\_

Below are two diagrams of radio wave signals. One of them is an FM signal (Frequency Modulated) and one of them is an AM (Amplitude Modulated) signal. Which is which and why?



SIGNAL TYPE: \_\_\_\_\_  
\_\_\_\_\_



SIGNAL TYPE: \_\_\_\_\_  
\_\_\_\_\_

## WAVES UNIT ASSESSMENT

1 What type of waves do NOT require matter to transport energy?

- A. Mechanical waves
- B. Electromagnetic waves
- C. Longitudinal waves
- D. Ocean waves

2 As the frequency of a wave *increases* its energy

- A. decreases
- B. increases
- C. remains the same

3 Why can't sound waves travel through the vacuum of outer space?

- A. It's too cold in outer space.
- B. Radiation from the Sun destroys them.
- C. Sound waves need physical matter to exist.
- D. There are sound waves in space, but no one is there to hear them.

4 What is the primary difference between radio waves and visible light?

- A. One travels faster than the other.
- B. One light is made of photons.
- C. One travels longer distances than the other.
- D. One has a longer wavelength than the other.

5 As the wavelength of a wave gets longer its energy will \_\_\_\_\_.

- A. decrease
- B. increase
- C. remain the same

6 What part of the electromagnetic spectrum can be seen by people?

- A. Infrared radiation
- B. Microwaves
- C. Ultraviolet light
- D. Visible light

7 What type of signal is made of continuously varying data or information?

- A. Analog
- B. Digital

8 What type of signal is commonly used in computers?

- A. Analog
- B. Digital

9 Which of the following statements is **false**?

- A. Digital signals are recorded and stored more easily than analog.
- B. Analog signals maintain their quality over long distances.
- C. Digital signals are considered more reliable than analog.
- D. Analog signals can be converted into digital signals.

10 When a straight pencil is placed in a glass that is half-full of water, it appears bent when viewed from the side. Which of these phenomena best explains why?

- A. Light being refracted
- B. Light being absorbed
- C. Light being reflected
- D. Light being diffracted

11 The \_\_\_\_\_ of a wave is how many wavelengths pass a certain point each second.

- A. amplitude
- B. frequency
- C. wavelength

11 If a marmoset sees lightning strike a tree one mile away, which of the following is true?

- A. They will hear thunder at the same time they see lightning because sound and light travel at the same speed.
- B. They will hear thunder after seeing the lightning because sound travels more slowly than light.
- C. They will not hear any thunder because the lightning strike is too far away.

12 Why does a green ball appear green?

- A. It absorbs all wavelengths of light except for green.
- B. It only absorbs green light.

13 What are the primary colors of light?

- A. Red, Yellow, and Blue
- B. Red, Blue, and Green
- C. Orange, Green, and Purple
- D. Cyan, Magenta, and Yellow

## WAVES UNIT ASSESSMENT

14 Of the colors listed below, which has the shortest wavelength?

- A. Red
- B. Yellow
- C. Blue
- D. Orange
- E. Green

15 Look at the graphs of waves A and B drawn at the right. Which has greater energy and why?

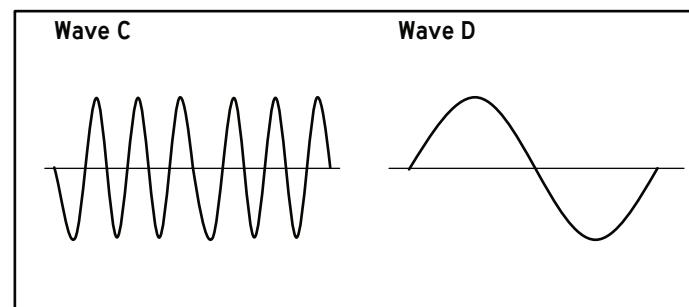
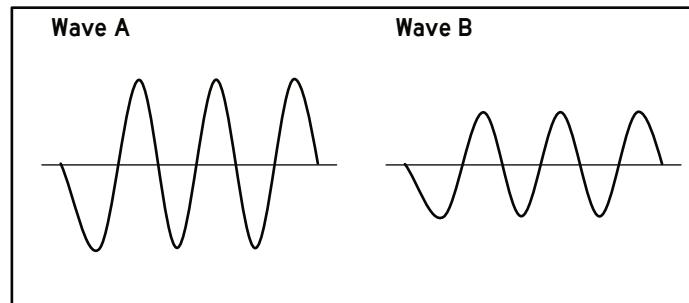
- A. Wave A carries more energy because it has higher amplitude.
- B. Wave A carries more energy because it has higher frequency.
- C. Wave B carries more energy because it has a shorter wavelength.
- D. Wave B carries more energy because it has a lower amplitude.

16 Look at the graphs of sound waves C and D. What differs between these waves?

- A. C has higher frequency than D.
- B. D has lower amplitude than C.
- C. C has shorter wavelength than D.
- D. Both A and C
- E. None of the above

17 Would you be able to see a full-body reflection of yourself in a mirror that is only half as tall as you? If so, how?

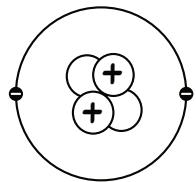
18 Bob wants to know why a red apple appears to be red during the day but looks grey at night when the light is dim. How would you explain it to him?



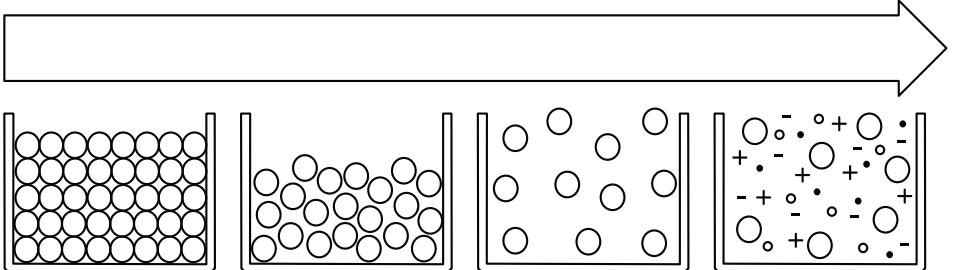
# ELECTROSTATICS

The study of stationary charges

Quick Review:



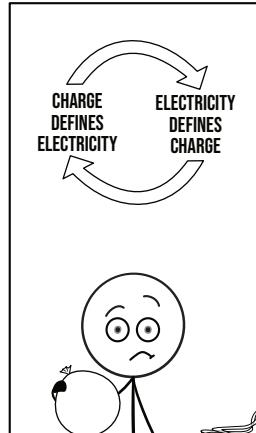
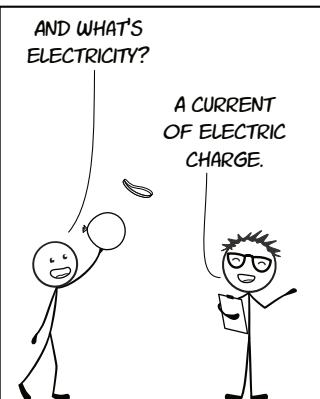
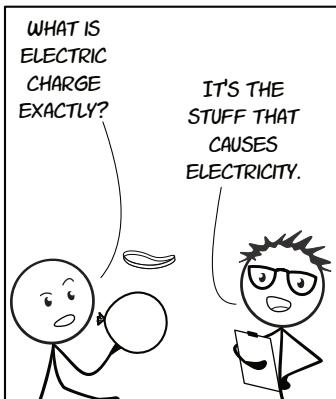
Proton:



Neutron:

Electron:

## How Bob Became an Arborist

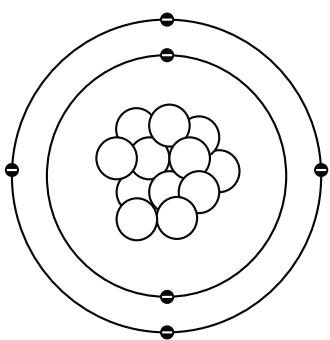


DON'T WORRY, THIS ISN'T YOUR FIRST TIME USING A CIRCULAR DEFINITION! TREES ARE PLANTS THAT CONTAIN WOOD. AND WOOD IS A MATERIAL THAT COMES FROM TREES. SEE? NOW YOU KNOW HOW TO RECOGNIZE TREES!



## 3 Important Facts About Charges:

CHARGE IS A PROPERTY OF SUBATOMIC PARTICLES.



PROTONS HAVE \_\_\_\_\_ CHARGE.

ELECTRONS HAVE \_\_\_\_\_ CHARGE.

IN AN ISOLATED SYSTEM, CHARGE IS \_\_\_\_\_. IT CAN BE

TRANSFERRED BUT CANNOT BE CREATED OR DESTROYED.

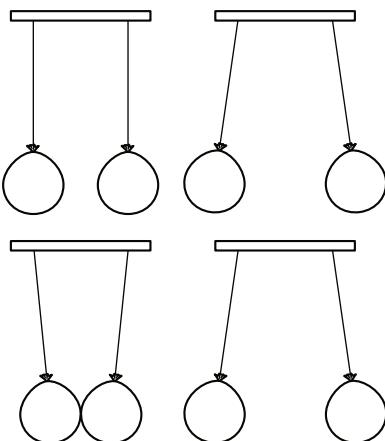
CONSERVATION OF MATTER,  
CONSERVATION OF ENERGY,  
CONSERVATION OF CHARGE...  
I'M SENSING A THEME.



CHARGES REPEL

EACH OTHER AND

CHARGES ATTRACT EACH OTHER.



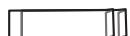
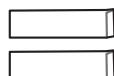
FILL IN THE BLANKS:

negative    positive    neutral    charge    fundamental

Charge is a \_\_\_\_\_ property of matter. There are two types of \_\_\_\_\_ which we call positive and negative. When an object has a \_\_\_\_\_ charge, it possesses an excess of electrons compared to protons. When an object that has a net \_\_\_\_\_ charge it has fewer electrons than protons. When an object has an equal number of protons and electrons, the result is a \_\_\_\_\_ state with no net charge.

## Separating charges!

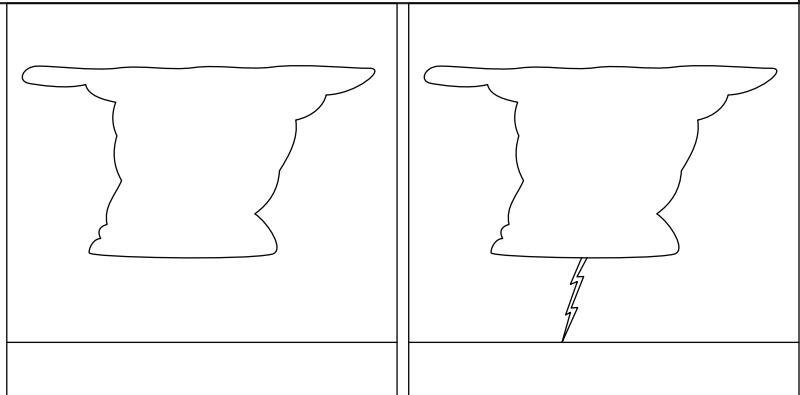
1. PEELING SCOTCH TAPE



2. RUBBING A BALLOON ON HAIR

3. RUBBING A BALLOON ON A SWEATER

Lightning!

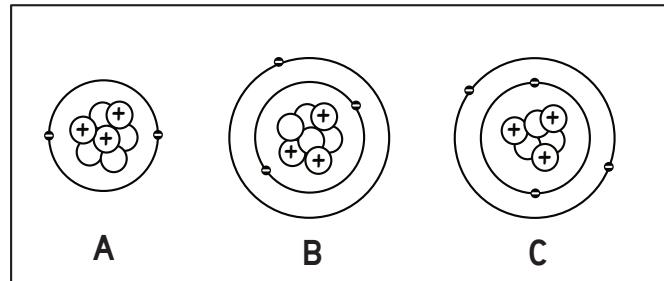


## PRACTICE PROBLEMS – ELECTROSTATICS

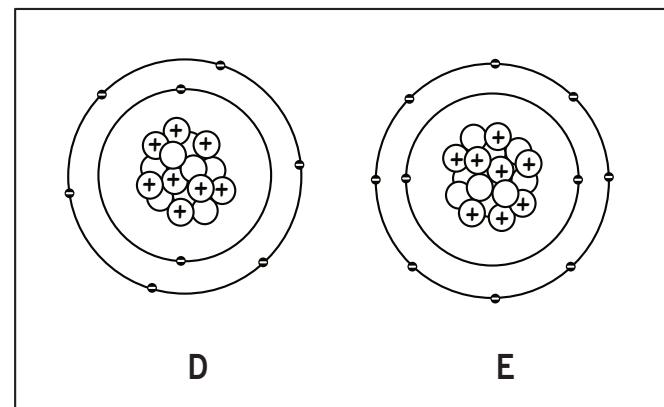
- 1) Two charged spheres are brought closer together. What happens to the electrostatic force between them?
  - A. It increases.
  - B. It decreases.
  - C. It stays the same.
- 2) If the number of protons is equal to the number of electrons, the object will have:
  - A. Negative charge
  - B. Positive charge
  - C. No charge
  - D. Oscillating charge
- 3) Lightning is caused by
  - A. friction from clouds rubbing against each other
  - B. rapid temperature fluctuations inside storm clouds creating electrons
  - C. air pressure differences between the upper and lower atmosphere
  - D. the discharge of electrical charges between clouds or between clouds and the ground
- 4) Which of the following are examples of plasma?
  - A. Super-cooled nitrogen
  - B. Blood
  - C. Neon lights
  - D. Lasers
- 5) Two charged objects repel each other due to their charge. What could the charges of the objects be? (Select all that apply.)
  - A. Positive and Positive
  - B. Negative and Positive
  - C. Negative and Negative
- 6) Two charged objects attract each other due to their charge. What could the charges of the objects be? (Select all that apply.)
  - A. Positive and Positive
  - B. Negative and Positive
  - C. Negative and Negative
- 7) What happens to electrons when something is getting electrically charged?

## PRACTICE PROBLEMS – ELECTROSTATICS

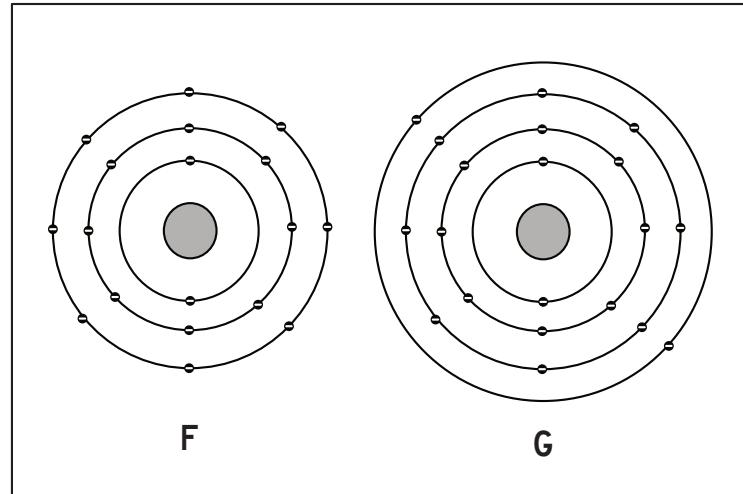
- ⑧ Lithium has 3 protons. Examples of lithium atoms are drawn in the figure below. Explain which atom is positive, which is negative, and which one has a neutral charge.



- ⑨ Oxygen has 8 protons. Two examples of oxygen atoms are drawn in the figure below. Explain why each atom has a positive, negative, or neutral charge.

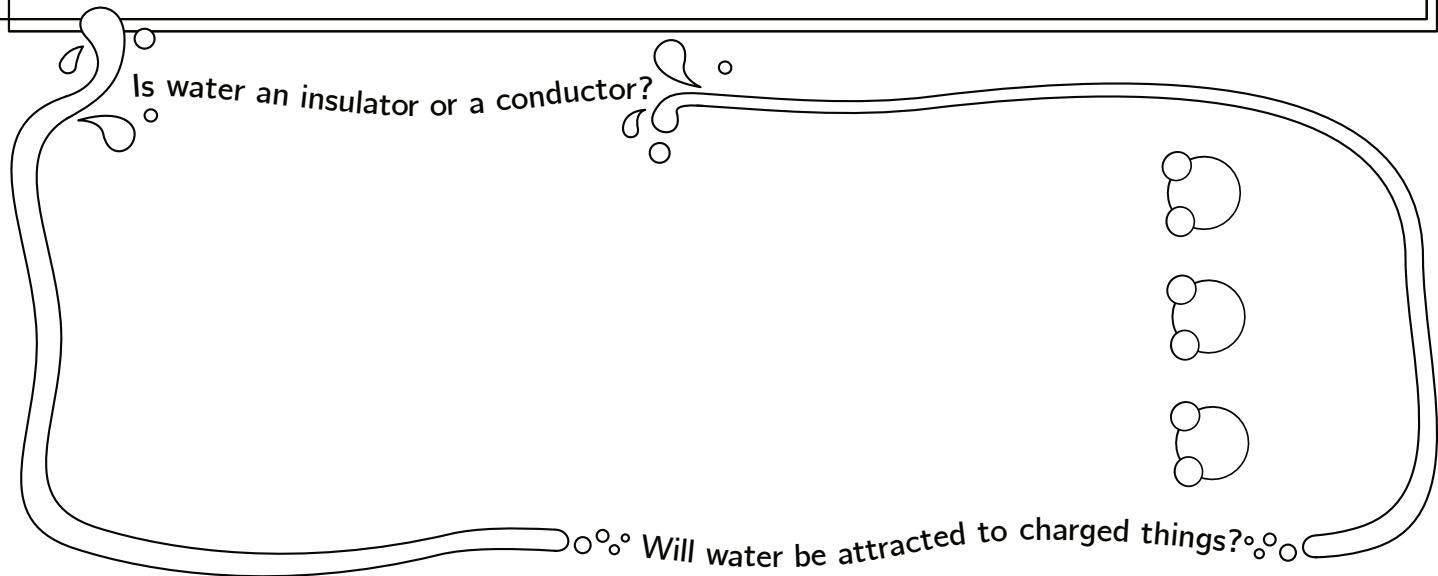
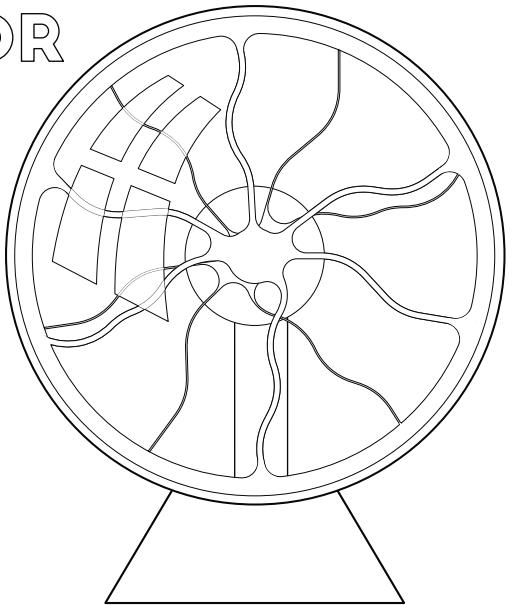


- ⑩ The filled-in circles in the diagram below represents the nucleus of calcium, which has 20 protons. Explain why each atom below has a positive, negative, or neutral charge.

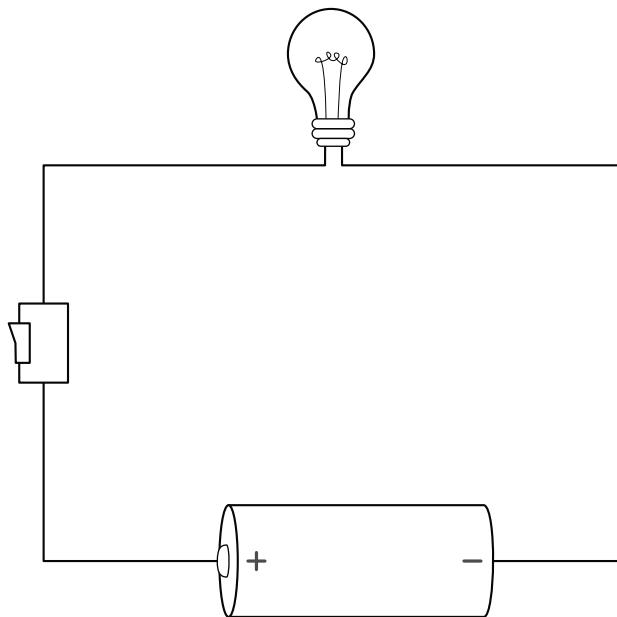


# THE CURRENT EVENT

## CONDUCTOR vs INSULATOR



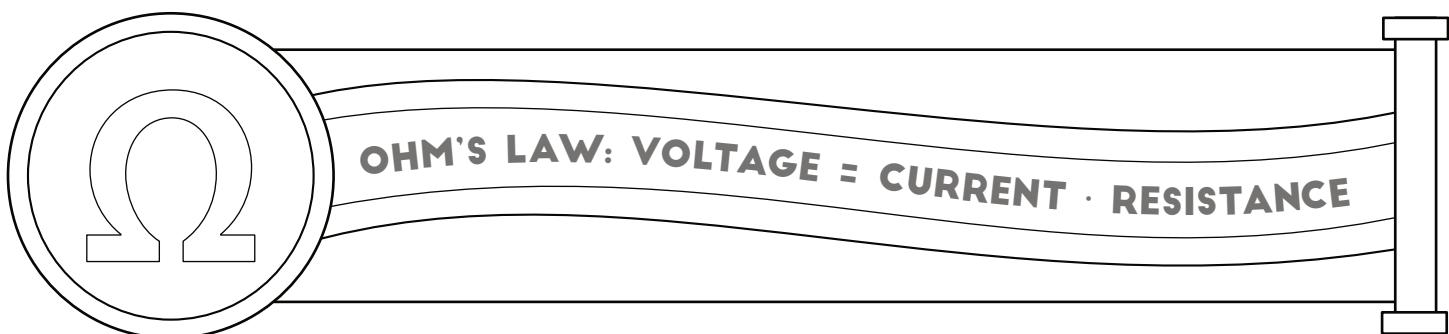
## CIRCUITS



VOLTAGE (VOLT):

CURRENT (AMPERE OR AMP):

RESISTANCE:



$$V=IR$$

Sasha needs to charge her phone but the only charging cable available doesn't have visible specifications for the voltage. It only lists the cable's resistance, which is 1.8 ohms. When Sasha uses her multimeter, she measures a current of 0.9 amperes flowing through the cable while charging. To charge her phone safely, the voltage needs to be below 5V. Is it safe for Sasha to use the cable?

### WHAT IS A COULOMB?

The coulomb (C) is the SI unit for electric charge.

It's named after Charles-Augustin de Coulomb, a French scientist who calculated the amount of force between two electrically charged particles (Coulombs inverse-square law).

1 COULOMB = THE ELECTRIC CHARGE DELIVERED  
BY 1 AMP OF CURRENT IN 1 SECOND.

## PRACTICE PROBLEMS – THE CURRENT EVENT

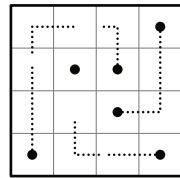
- ① Select each substance that is an electrical insulator.
- Plastic
  - Copper
  - Glass
  - Wood
- ② A material is made of atoms that loosely hold onto their electrons, leaving the ones in the outer shell free to wander around. This material will be a
- Conductor
  - Insulator
- ③ What happens when a charged object such as a balloon comes close to an uncharged insulator, such as a piece of paper? (but does not touch the object)
- The paper becomes charged as well by induction
  - The paper is repelled and moves away from the balloon
  - There is no change; the paper remains uncharged
  - The paper is attracted to the balloon because all insulators have the same charge
- ④ Electrical potential is called:
- Voltage
  - Current
  - Resistance
  - Amp
- ⑤ The flow of electrons in an electrical current is called:
- Voltage
  - Current
  - Resistance
  - Amp

### PIPE FLOW MATCHING

6	5	B			
		E			
		D			
C			3	1	
2		4			A

Match each numbered word with its lettered description by joining the number and letter with a continuous stroke (pipe).

Each square in the grid should be visited by exactly one pipe.



- Electrostatics
- Conductor
- Insulator
- Ion
- Coulomb
- A charged atom
- Electricity at rest
- SI unit of electric charge
- Allows charged particles to flow
- contains no free charged particles

## PRACTICE PROBLEMS – THE CURRENT EVENT

(7) What unit is used to measure electrical current?

- A. Ohm
- B. Volt
- C. Ampere
- D. Watt

(8) What does  $\Omega$  stand for in physics?

- A. Ohms
- B. Amps
- C. Volts/Amps
- D. Coulombs

(9) What is required for current to flow in a circuit?

- A. A resistor
- B. An insulator
- C. A light bulb
- D. A closed loop

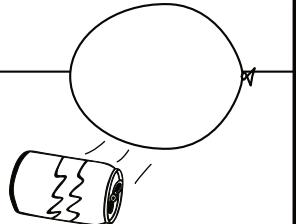
(10) Why do birds sitting on power lines not get electrocuted?

- A. They are too small to complete the circuit.
- B. Their bodies do not provide a path to the ground
- C. They wear natural insulating materials.
- D. They are immune to electricity.

(11) What is voltage equal to?

- A) the inverse of resistance
- B) Current
- C) Current multiplied by resistance
- D) Resistance divided by current

-EXPLAIN THE ROLLING CAN:



# SUPER STATIC

## MATERIALS (WILL VARY DEPENDING ON WHICH ACTIVITIES YOU CHOOSE TO DO)

### Sticky Balloons

- two balloons
- a soft cloth for charging the balloon
- a wall, a window, and various furniture items

### Levitating Ring

- balloon or a short length of PVC pipe
- a soft cloth for charging the balloon
- a very thin plastic bag (such as the type used grocery stores in the produce department)
- scissors

### Paper Vacuum & Scooting Bubbles

- balloon or short length of PVC pipe
- a soft cloth for charging the balloon
- tissue paper
- scissors
- bubble solution or water and dish soap
- a flat counter or table

### Bending Water

- balloon or short length of PVC pipe
- a soft cloth for charging the balloon
- a faucet or container that can create a thin stream of water

### STICKY BALLOON:

1. Blow up two balloons by the same amount and tie them off.
2. Charge the balloons. Ideally, try to charge them by the same amount by rubbing them the same number of times on a large blanket (in practice, it will be very difficult to charge them by *exactly* the same amount, but if you are careful you should be able to develop similar charges)
3. Make a prediction! Will the balloons “stick” to a wall or to glass?
4. Hold one balloon next to a wall made of sheetrock or plaster. SLOWLY let go and observe whether the balloon stays on the wall or falls to the ground.
5. Hold the other balloon next to a window made of glass. SLOWLY let go and observe whether the balloon stays on the window or falls to the ground.
6. Record how long each balloon stayed on its surface.

*Extension: Try different materials! Does the balloon stick to metal, plastic, glass, wood, fabric? Does it stick better on cold days than warm days? Does the weather make a difference?*

### LEVITATING RING:

1. Blow up a balloon and tie it off OR get a short length of plastic PVC pipe.
2. Use scissors to cut a small ring from a very thin plastic bag. The produce bags in US supermarkets usually work very well. Tip: Make sure the bag is not wet. It will only be able to acquire a static charge if it is dry.
3. Charge the balloon or pipe by rubbing it with a material such as a soft fuzzy blanket.
4. Charge the ring of thin plastic by rubbing it gently in a soft cloth or someone's hair.
5. Hold the ring of plastic above the balloon or length of pipe.
6. Drop it and observe!

*With practice, you can keep the plastic ring floating for many seconds by moving the balloon so that it stays underneath.*

## PAPER VACUUM and SCOOTING BUBBLES:

1. Blow up a balloon and tie it off OR get a short length of plastic PVC pipe.
2. Use scissors to cut tissue paper into very small pieces and scatter them on a table or countertop. (An alternative option if you don't have thin wrapping paper or tissue paper is to sprinkle some salt and pepper on a plate)
3. Charge the balloon or pipe by rubbing it on a blanket, coat, or hair.
4. Hold the balloon or PVC pipe above the small pieces of paper or the salt and pepper and observe!
5. Next, clean the table or counter and get it slightly wet with soapy water.
6. Blow bubbles using a bubble wand or your thumb and finger to form a loop. Let them land on the wet surface. With some practice, you should end up with several bubbles that are resting on the surface as hemispheres.
7. Charge the balloon or pipe again by rubbing it on a soft cloth.
8. Bring the balloon or pipe close to the bubble hemispheres and observe how they react. Do they move toward or away from the charge?

*Extensions: Is there a limit to how large a piece of paper you can lift up? If you trace and make some paper figures and tape one side of them to the plate, can you use the balloon to get them to stand up? If you blow a bubble in the air can you change how the bubble drifts using the balloon?*

## BENDING WATER:

1. Blow up a balloon and tie it off OR get a short length of plastic PVC pipe.
2. Arrange a faucet or a jug with a hole so that you have water flowing with a very narrow and calm stream.
3. Charge the balloon or pipe by rubbing it on a soft cloth.
4. Bring the balloon or pipe close to the stream of water and observe how it reacts. Do they move toward or away from the charged object?

## GOALS

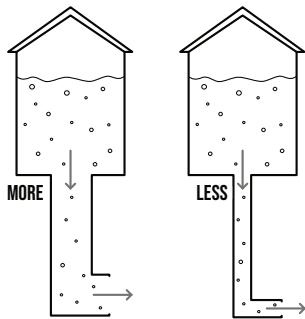
-  Explore conductors and insulators.
-  Collect and observe static charge.



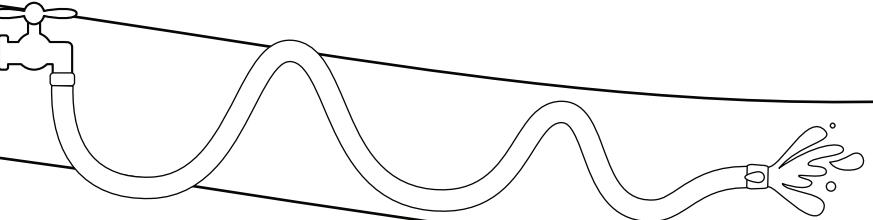
## THE UNIT OF ELECTRICAL POWER:

### THE WATER PIPE ANALOGY\*

Where the flow of electrons is likened to water flowing in a pipe or hose

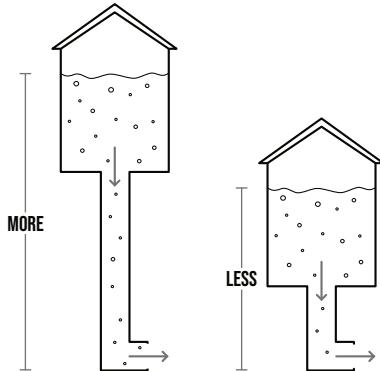


FLOW RATE IS LIKE:



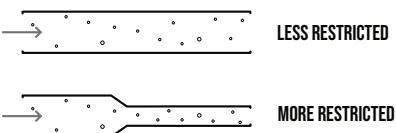
\* Electrons don't actually push each other through the wire. They are propelled by an electric field which is created by the charges on the battery and/or wires. The energy is actually carried by these fields rather than the electrons themselves. This is why it's possible to charge something with a wireless charger.

While electrons don't flow through wire like water through a pipe, the analogy is still helpful for learning the terms.



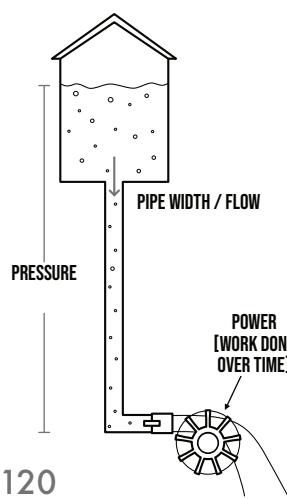
WATER PRESSURE IS LIKE:

A RESTRICTION IN PIPE SIZE IS LIKE A CHANGE IN:

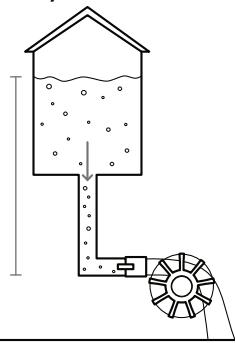


THE AMOUNT OF POWER A WATER SYSTEM HAS IS LIKE:

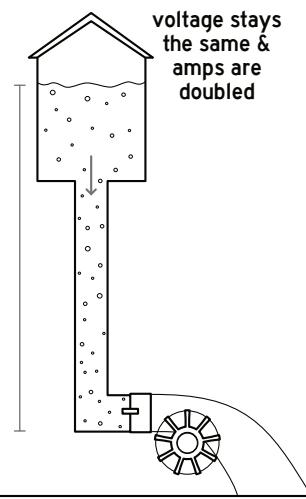
WHAT WILL HAPPEN TO POWER (WATTS) IN EACH OF THESE CASES? COMPARED TO THE FIRST TOWER WITH A WATER WHEEL, WILL THE POWER/WATTAGE INCREASE, DECREASE, OR STAY THE SAME?



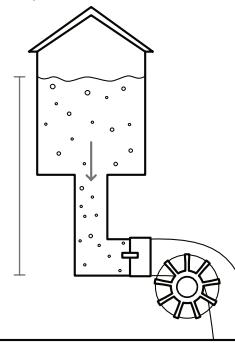
voltage is cut in half & current (amps) stay the same



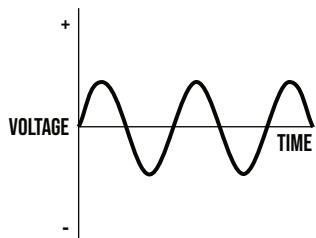
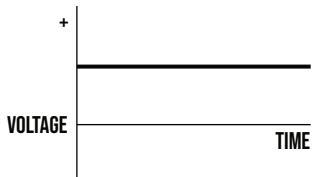
voltage stays the same & amps are doubled



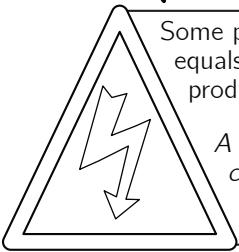
voltage is cut in half & amps are doubled



## ALTERNATING CURRENT VS DIRECT CURRENT



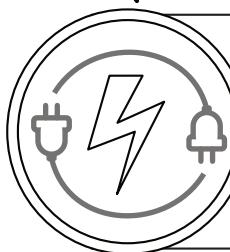
### MISCONCEPTION ALERT #1



Some people think higher voltage automatically equals more power, but remember power is a product of voltage AND current!

A device with high voltage but low current could use less power than a device with low voltage and high current (amps).

### MISCONCEPTION ALERT #2



Some people think voltage and watts mean the same thing. Or they think that any situation with low voltage is safe.

*Remember that watts and voltage measure different things! High levels of either one can be dangerous.*

### INCANDESCENT VS LED LIGHTBULB

### LAPTOP CHARGER VS HAIR DRYER

### CAR BATTERY

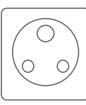
### WELDING EQUIPMENT



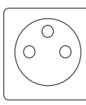
TYPE A



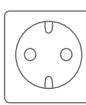
TYPE B



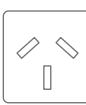
TYPE D



TYPE E



TYPE F

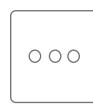


TYPE I

### TESLA COIL



TYPE K



TYPE L

### How many volts from the outlet?

The plug design and voltage of power outlets vary by country! Power outlets in the US and Canada deliver 120 volts. Much of Europe and India use 230V outlets. China typically uses 220 volts. When traveling to another country, be careful about how and what you plug in!

## PRACTICE PROBLEMS – WHATS A WATT?

- ① The volume of electrical charge flowing through a wire is best described as the:
  - A. Amperage (current)
  - B. Voltage
  - C. Resistance
  - D. Wattage
- ② What does DC stand for in electricity?
  - A. Direct Current
  - B. Dual Current
  - C. Direct Circuit
  - D. Dynamic Current
- ③ What is the best course of action if an electrical fire starts in the wiring of your kitchen wall?
  - A. Pour water on it
  - B. Use a standard fire extinguisher
  - C. Turn off the electricity if possible
  - D. Smother the fire by covering it with a towel
- ④ What is the main difference between AC and DC?
  - A) AC can only flow in a vacuum
  - B) DC is faster than AC
  - C) AC changes direction periodically while DC flows in one direction
  - D) DC cannot be used in homes
- ⑤ What does a watt measure?
  - A. Force
  - B. Resistance
  - C. Power
  - D. Current
- ⑥ If a device draws a current of 2 amperes from a 120 volt source, how many watts does it use?
  - A. 60 watts
  - B. 120 watts
  - C. 240 watts
  - D. 100 watts
- ⑦ How does the resistance of a circuit affect the current?
  - A. Higher resistance increases the current
  - B. Higher resistance decreases the current
  - C. Resistance does not affect the current
- ⑧ True or false: Batteries use AC current.
  - A. True
  - B. False

## PRACTICE PROBLEMS – WHATS A WATT?

- (9) What does it mean if a light bulb is rated at 60 watts?
- It uses 60 volts of electricity
  - It draws a current of 60 amperes
  - It uses 60 joules of energy per second
  - None of the above
- (10) Amil uses an 800 watt microwave at work and a 1200 watt microwave at home. Which one will cook food faster?
- The 800 watt microwave
  - The 1200 watt microwave
  - There will be no difference in cook time between the two microwaves
- (11) What would happen if you plug a device rated for 220 volts into a 120 volt socket?
- The device will operate more efficiently
  - The device will operate faster
  - The device will overheat because it is receive too much current
  - The device might not operate correctly or at all
- (12) A new appliance is advertised as being low voltage, but it uses a lot of watts. How could this mystery appliance be both high wattage and low voltage?
- By using a high amount of current
  - By using a low amount of current
  - By having incredible resistance
  - There is no such thing as a high wattage but low voltage device
- (13) If an LED lightbulb and an incandescent lightbulb both produce the same amount of light but the LED light is 8 watts and the incandescent is 60 watts, what does this mean?
- The LED uses higher voltage
  - The incandescent bulb is more efficient
  - They use the same amount of electrical current
  - The LED bulb uses less current
- (14) True or false: A 120V appliance is safer than a 240V appliance. Provide an example to justify your answer.
- True
  - False
- (15) Which of these appliances would use the most electric current (amperes) when operating?
- A 10-watt LED bulb running on a 120 volt supply
  - A 1,500-watt hair dryer running on a 120-volt supply
  - A 1,000-watt electric stove burner running on a 240-volt supply
  - A 5-watt phone charger on a 120-volt supply

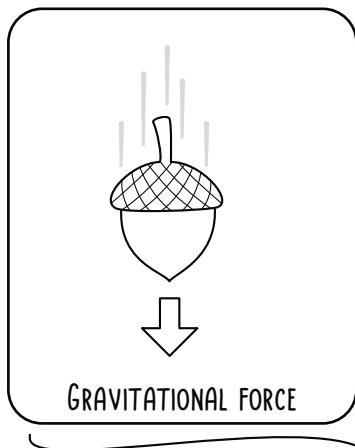
# MARVELOUS MAGNETS

FILL IN THE BLANKS:

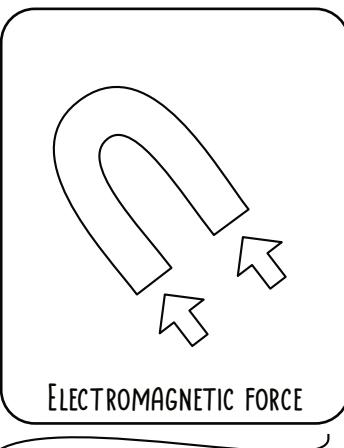
gravity electrostatics repel force

In magnetism, like charges \_\_\_\_\_ each other and opposite charges attract. If this sounds reminiscent of electrostatics, it's because \_\_\_\_\_ and magnetism are closely linked! They both occur because of the electromagnetic \_\_\_\_\_, which, like \_\_\_\_\_, is one of the fundamental forces at work in the universe.

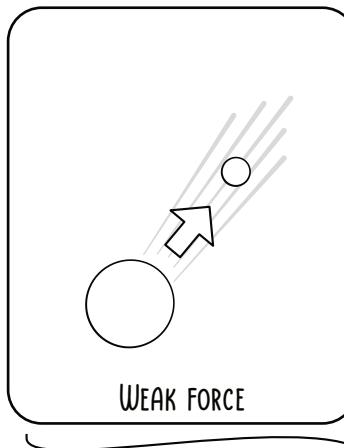
THE 4 FUNDAMENTAL FORCES:



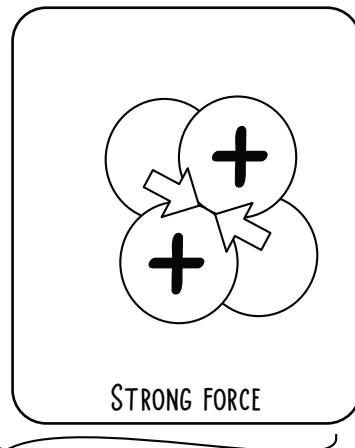
GRAVITATIONAL FORCE



ELECTROMAGNETIC FORCE



WEAK FORCE



STRONG FORCE

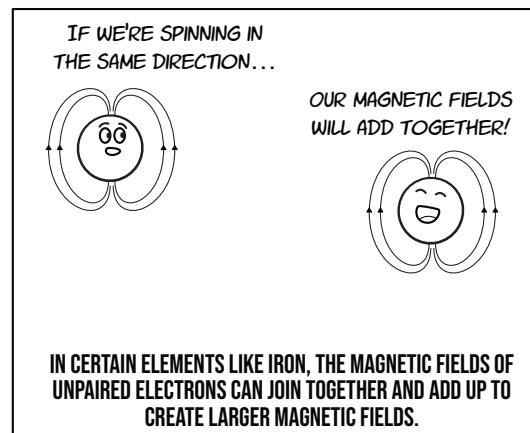
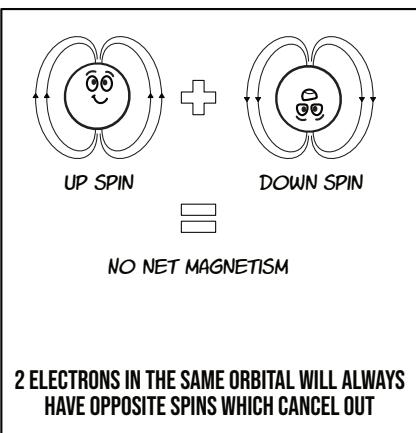
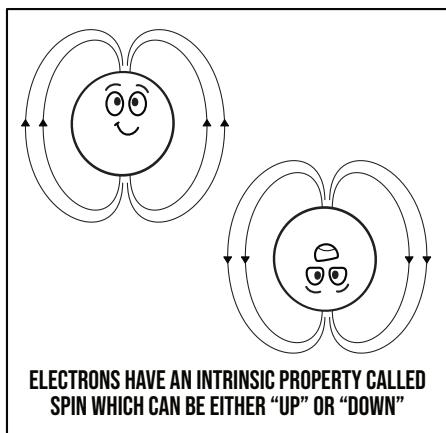
*Infinite range but strength very strongly linked with distance*

*Only effective at short range, the dominant forces at subatomic level*

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



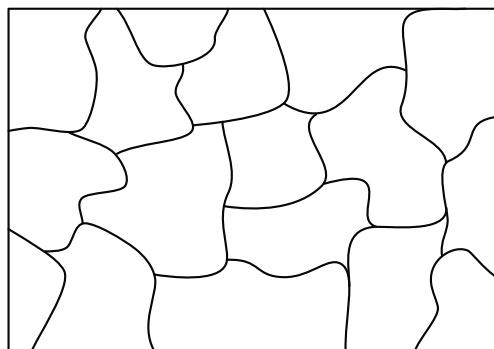
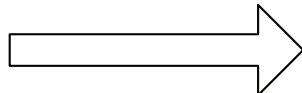
**But what is magnetism?** It's a force produced by the movement of charges! Since electrons are charged particles that move... they create small magnetic fields.



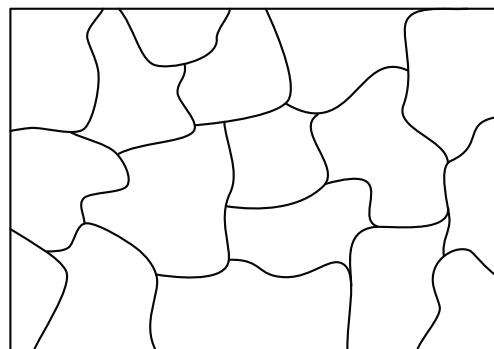
Most atoms have electrons which are paired in a way that cancels out their magnetic fields. Certain elements (like iron) have atoms with magnetic fields that can join together and add up instead of canceling out.

A piece of iron has domains where electrons spinning in the same direction align, producing a stronger magnetic field. When magnetized, all of the domains will align in the same direction.

HERE ARE DIAGRAMS OF THE DOMAINS IN 2 BLOCKS OF IRON. DRAW ARROWS TO SHOW HOW THE MAGNETIC FIELDS ARE ALIGNED IN EACH.

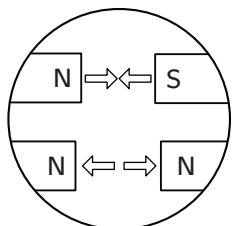
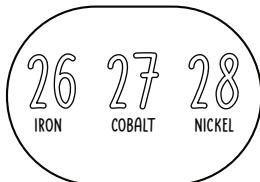
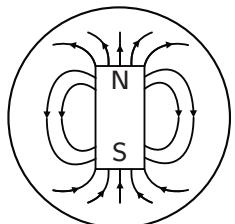


weak magnet / not magnetic



strong magnet

### PROPERTIES OF PERMANENT MAGNETS:



## PRACTICE PROBLEMS – MARVELOUS MAGNETS

- ① What happens when you bring the north pole of one magnet close to the south pole of another magnet?
  - A. They repel each other.
  - B. They attract each other.
  - C. They become demagnetized.
  - D. Nothing happens.
- ② Which of these materials are NOT attracted to a magnet?
  - A. Aluminum
  - B. Copper
  - C. Cobalt
  - D. Iron
- ③ What is the term for the invisible area around a magnet where forces are felt?
  - A. Magnetic aura
  - B. Magnetic bubble
  - C. Magnetic field
  - D. Magnetic zone
- ④ Why does a compass point north?
  - A. Because of gravity
  - B. Because the Earth is a giant magnet
  - C. Because of the Sun's magnetic field
  - D. Because of the orientation of the Moon
- ⑤ What would happen to the electric field of a magnet if it were broken in half?
  - A. The magnetic field would disappear. The pieces would no longer be magnetic.
  - B. The magnetic field would weaken. Each of the pieces would be weakly magnetic.
  - C. Each piece would become a separate magnet with its own north and south poles.
- ⑥ What can happen to a magnet if it is heated up to a very high temperature?
  - A. It becomes stronger and attracts magnetic material with more force.
  - B. It loses its magnetic properties and is no longer magnetic.
- ⑦ What is the most likely result of a nail being placed next to a magnet for an extended period of time?  
(Assume the nail is made of iron and is not magnetized before being placed next to the magnet)
  - A. The nail is temporarily magnetized and will exert its own magnetic field.
  - B. The nail is now a permanent magnet.
  - C. The nail experiences no change.
- ⑧ True or False: Magnets can attract any type of metal.
  - A. True
  - B. False
- ⑨ True or False: Magnets work in air, water, and the vacuum of outer space.
  - A. True
  - B. False

## PRACTICE PROBLEMS – MARVELOUS MAGNETS

(10) True or False: Holding papers to a fridge is one of the most practical uses for magnets. They don't have many other applications or uses.

- A. True
- B. False

What statement is true about the force responsible for the interaction between two magnets?

(11) A. The force between magnets is not related to the force responsible for electric charge  
B. The force between magnets decreases with proximity  
C. The force between magnets increases with proximity  
D. The force between magnets is dependent on gravity

(12) What is the term used to describe materials that are attracted to magnets?

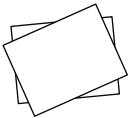
(13) Draw lines to represent the magnetic field surrounding a bar magnet.



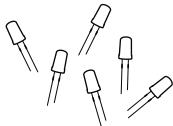
(14) List 3 examples of devices that use magnets:

# LED HOLIDAY CARD

## MATERIALS (TO MAKE 2 CARDS)



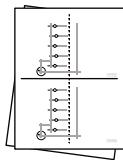
1 piece of cardstock



Between 3 to 20 LED lights (3 mm)



Scissors



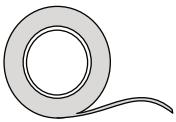
Printed templates OR pencil and pen to create your own design



A small piece of cardboard (optional)



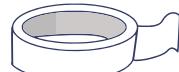
2 Button batteries (CR2032 3-volt batteries work well)



0.5 meters of conductive maker tape



Push pin OR sewing needle



Glue stick and tape



Coloring supplies

## FOR BEST RESULTS:

Be careful when using different colors! Blue/whites LED bulbs often use a different voltage than red/green/yellow. Mixing all the colors will only work if you have them come on one-at-a-time or you use resistors.

## INSTRUCTIONS FOR A “PRESS & LIGHT” CARD:

Matches the string of lights template.

1. Print the template (front and back) on cardstock and then cut the paper in half along the solid line.
2. Color the string of lights and write a phrase of your choice such as Merry Christmas, Happy Diwali, Eid Mubarak, Happy Hanukkah, Happy New Year, or You LIGHT up my day!
3. Fold the paper along the dotted line so that the diagram for the conductive tape is on the inside of the card.
4. Using the pin or sewing needle, poke two small holes where each LED light will be placed. *TIP: For poking the holes, it helps to have a piece of cardboard on the other side.*
5. Insert the LED lights so the wires are on the inside of the card. Bend the wires out so the long wires go toward the + symbols and that the short ends are toward the - symbols.
6. Create your circuit by placing conductive tape along the lines.
7. Tape the battery to the card so that the negative side of the battery is connected to the short wires and the positive side is connected by the tape to the long wires (figure A). If the battery orientation is reversed (figure B), the LED bulb will not light up! If needed, use additional pieces of regular tape to secure the battery to the card.
8. Close the card. Press along the wire above the lights and watch them light up!

## GOALS

- ★ Create an LED circuit card
- ★ Gain increased understanding of how circuits work
- ★ Persevere and troubleshoot any problems that emerge.

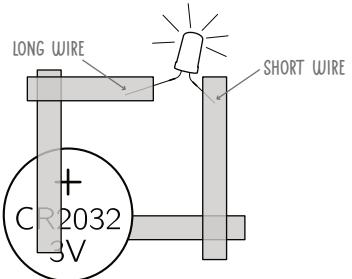


Figure A

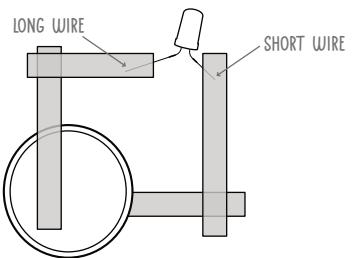


Figure B

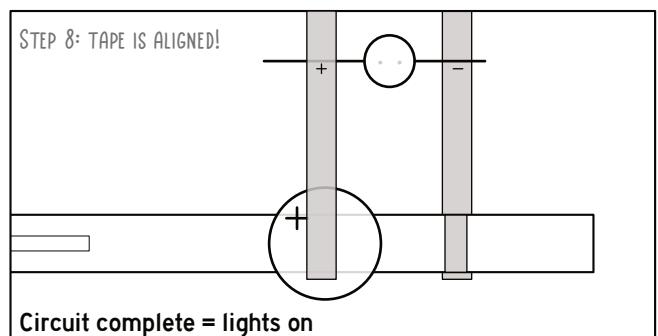
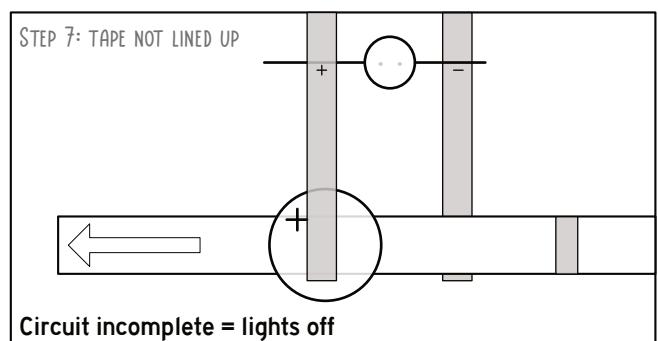
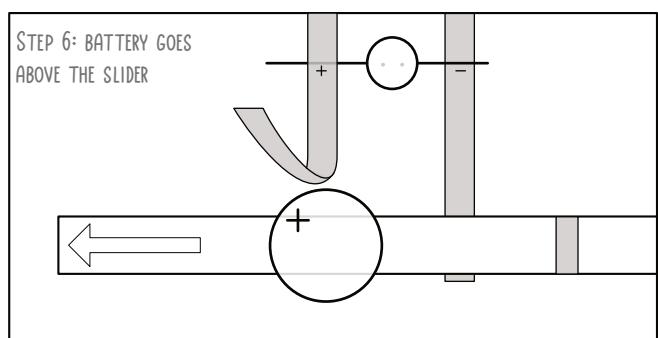
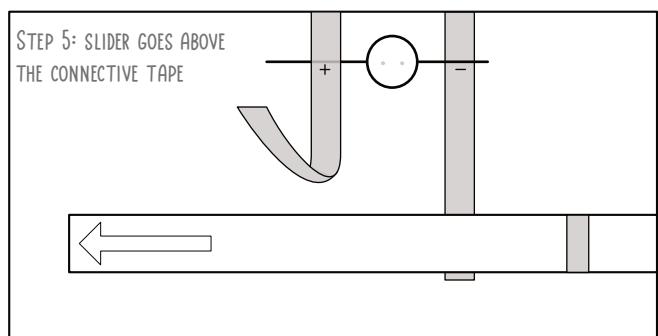
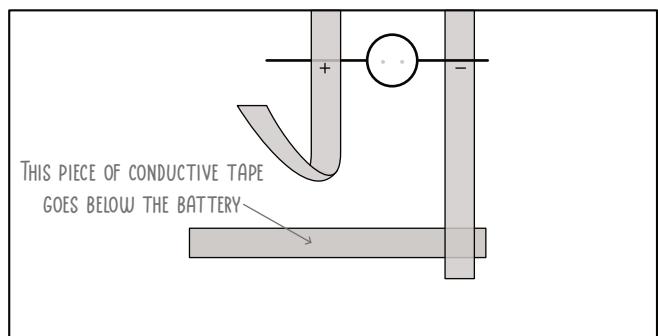
## INSTRUCTIONS FOR A “SLIDER” CARD:

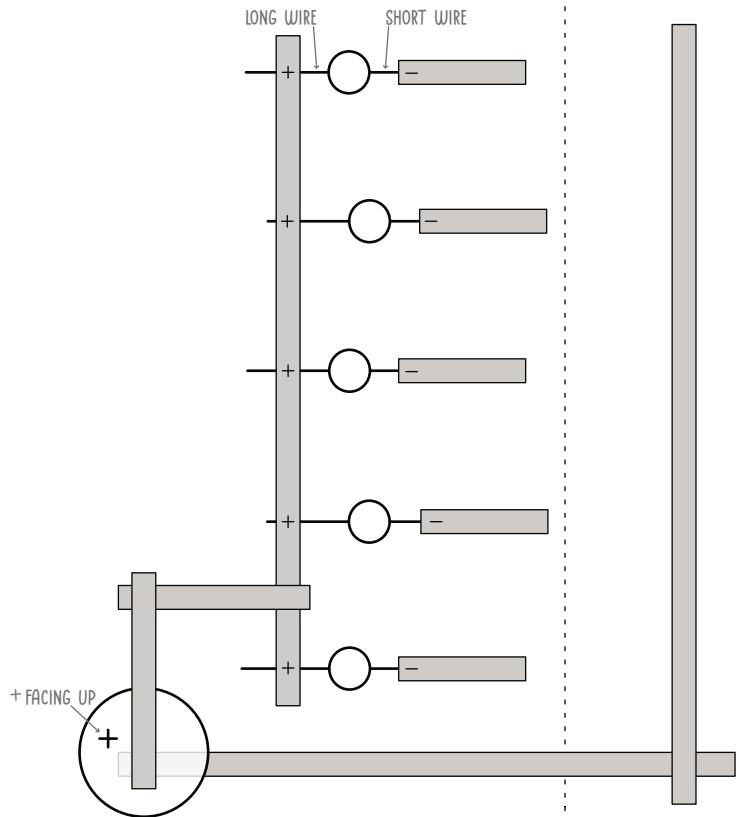
*Matches the paper slider card template.*

1. Print the page with the flowers and leaves, color them, and carefully cut them out. Glue the leaves on the front of the card so that the center hole matches the markings for the LED bulb. Tip: poke holes where the LED wires will go so that its easier to line up the leaves with the holes.
2. Use a glue stick to glue the petal templates together so that they are offset and make a full flower. Glue the center circle to each flower so that there are 3 flowers in total. Glue them over the leaves.
3. Place the card on a thick piece of cardboard. Use the pin or sewing needle to poke holes where each LED light will be placed.
4. Insert the LED light so that the wires are on the inside of the card. Bend the wires out so the long wires go toward the + symbols and that the short ends are toward the - symbols. Apply conductive tape to match the circuit lines and keep the wires in place.
5. Make the slider by wrapping a strip of connective tape around a piece of cardstock. Place the slider above the conductive tape.
6. Place the battery on top of the slider (positive side facing up). Use tape to connect the battery to the line of tape that is labeled with + symbols.
7. Adjust the slider so that the line of tape is not lined up with the circuit. The lights should be off.
8. Pull the slider so that the line of tape touches the circuit. The lights should come on!
9. Close the card and move the slider back and forth.

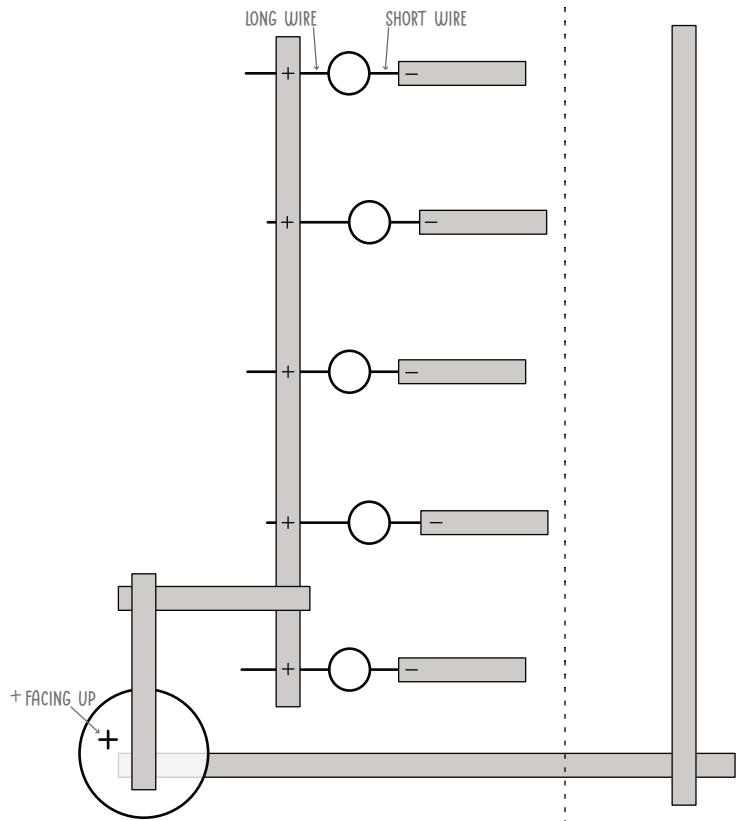
## TO MAKE YOUR OWN CARD:

1. Design a circuit so that the circuit will be complete either when the card is closed or when a slider is moved into place.
2. Arrange the LED lights so that the long wires and short wires are all on the same sides.
3. Connect a button battery to the conductive tape so that the positive side connects to the long wires of the LED bulbs. The negative side of the battery should connect to the short wires.
4. Test your card and see if it works! If needed, adjust the design of the circuit or add more tape to get a better connection.

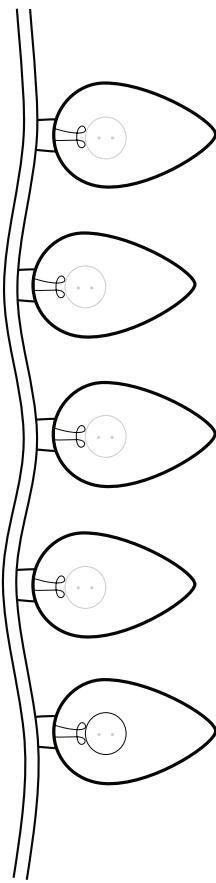
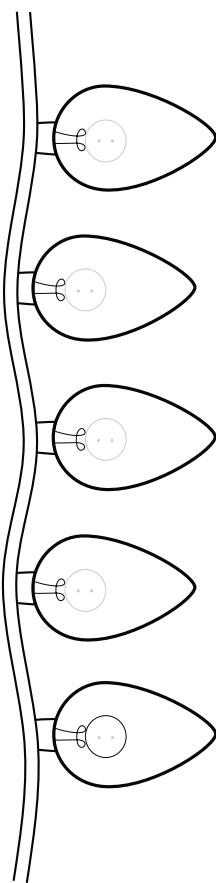


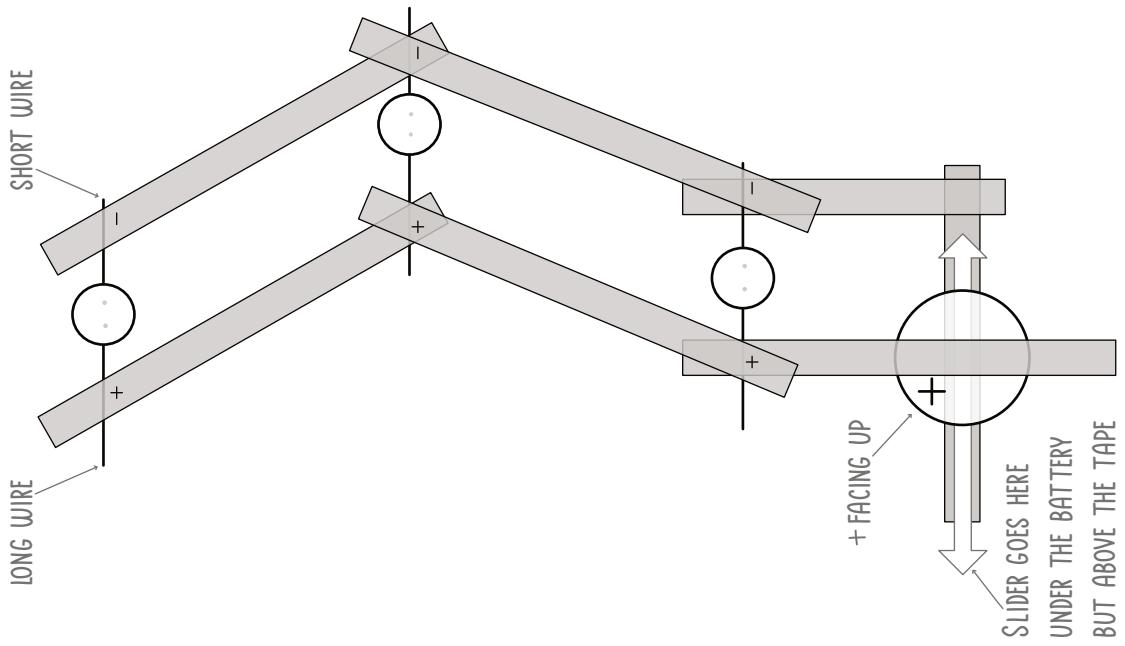


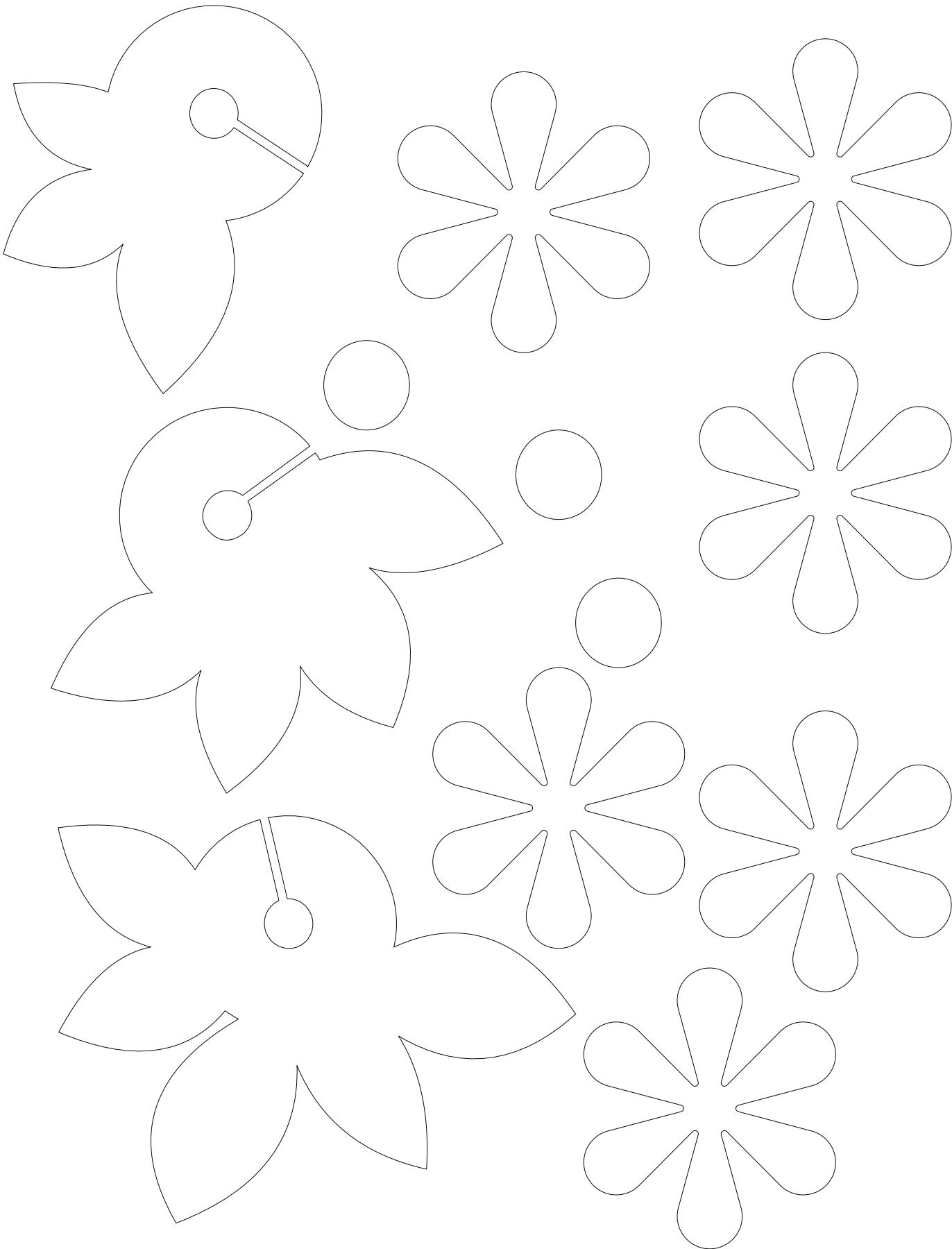
String of Lights LED  
Circuit Card Template  
**SCIENCE MAM**



String of Lights LED  
Circuit Card Template  
**SCIENCE MAM**





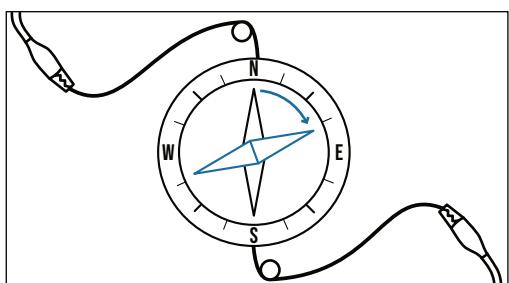


Flowers and slider for  
Paper Slider LED  
Circuit Card

# ELECTROMAGNETISM!

What do you expect to happen to a magnet or ferromagnetic objects when they are around wire carrying electric current? Make predictions for each of these demonstrations. Then record what happens!

1.



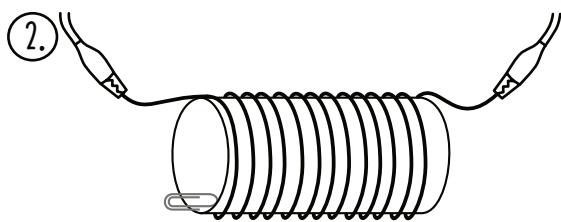
CURRENT FLOWS THROUGH A WIRE.  
HOW WILL THE COMPASS BEHAVE?

PREDICTION:

- Compass remains pointing north
- Compass points different direction
- Compass oscillates back and forth
- Something else

RESULT:

2.

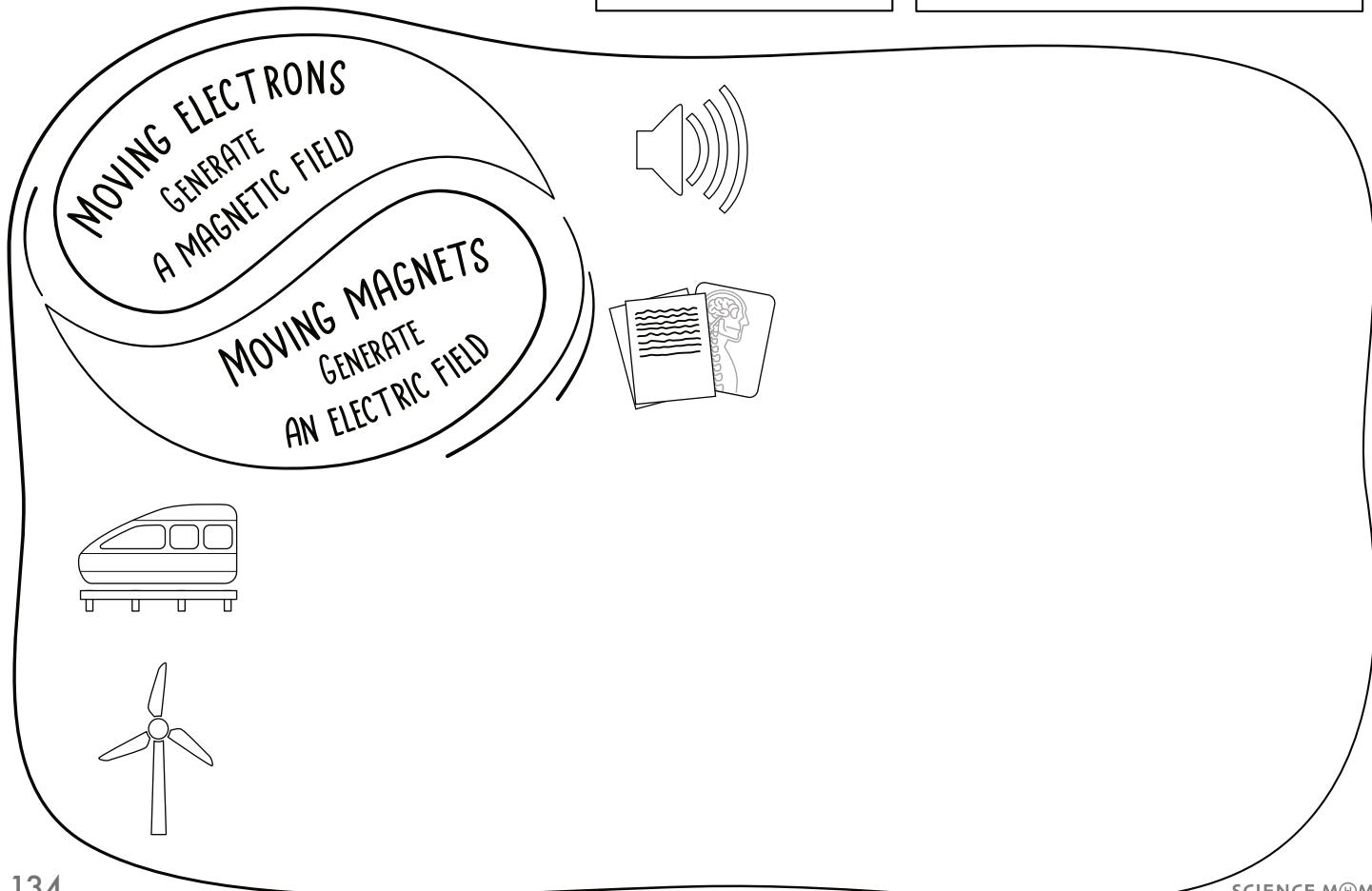


CURRENT FLOWS THROUGH A COIL OF WIRE.  
A PAPERCLIP IS PLACED AT THE INNER EDGE  
OF THE COIL. WHAT WILL HAPPEN?

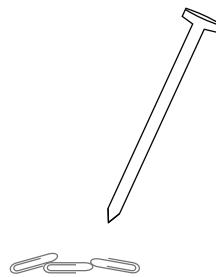
PREDICTION:

- Paperclip remains in place
- Paperclip is repelled by coil
- Paperclip moves through the coil
- Something else

RESULT:

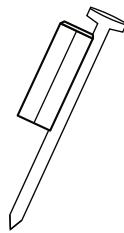


A LARGE ORDINARY IRON NAIL COMES NEAR PAPERCLIPS. THE NAIL IS NOT MAGNETIC, SO NOTHING HAPPENS.

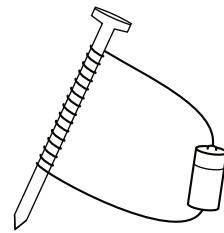


What would happen to the nail & paperclips in each of these scenarios and why?

SCENARIO 1: STRONG MAGNET ON TOP OF THE NAIL



SCENARIO 2: WIRE IS COILED AROUND THE NAIL WITH AN ELECTRIC CURRENT RUNNING THRU IT



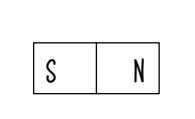
MAGNET ON NAIL:

WIRE CONNECTED TO BATTERY:

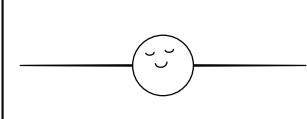
Draw lines to match each of these descriptions as belonging to a permanent magnet or electromagnet.



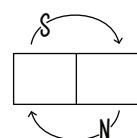
VARIABLE MAGNETIC FIELD  
STRENGTH CAN BE EASILY  
ADJUSTED OR CHANGED



FIXED POLARITY  
FIXED NORTH AND  
SOUTH POLES



CONSTANT MAGNETIC FIELD  
HAVE CONSTANT FIELD THAT  
DOESN'T NEED A POWER SOURCE



ADJUSTABLE POLARITY  
DIRECTION OF MAGNETIC  
CURRENT EASILY REVERSED



CAN BE STRONGER  
CAN HAVE MORE MAGNETIC  
PULL GIVEN THEIR SIZE

PERMANENT  
MAGNET

ELECTROMAGNET

## PRACTICE PROBLEMS – ELECTROMAGNETISM

- 1) What is an electromagnet? Describe it briefly and draw a diagram. Then list 2 examples of devices or machines that use electromagnets.
- 2) A magnet that can be repeatedly turned on and off is called:
- A bipolar magnet
  - An electromagnet
  - A permanent magnet
  - A temporary magnet
- 3) What is always created when an electric current flows through a wire?
- A vacuum
  - High temperature
  - A magnetic field
  - Sound waves
- 4) What happens to the magnetic field of an electromagnet when more current is put through the coil?
- The magnetic field increases
  - The magnetic field decreases
  - The direction of the magnetic field reverses
  - The magnetic field becomes unstable
- 5) An electric generator does which of the following?
- Converts mechanical energy into sound energy
  - Converts light energy into electrical energy
  - Converts electrical energy into mechanical energy
  - Converts mechanical energy into electrical energy
- 6) True or False: A moving magnet creates an electric field.
- True
  - False
- 7) True or False: Electromagnets are preferred over permanent magnets in many devices.
- True
  - False

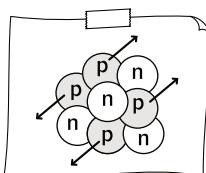
## PRACTICE PROBLEMS – ELECTROMAGNETISM

- (8) What happens when the electric current in an electromagnet is reversed?
- A. The poles of the magnet are inverted (flip to have opposite orientations)
  - B. The magnetic field stops and the core is no longer magnetic
  - C. The magnetic field gets stronger
  - D. The magnetic field gets weaker
- (9) What happens when the electric current in an electromagnet is turned off?
- A. The magnetic field becomes permanent
  - B. The magnetic field disappears
  - C. There is no change to the magnetic field
  - D. The magnetic field is inverted or changes direction
- (10) The magnet in a scrap yard can be used to pick up metal scraps and drop them in other locations. Which statement about this magnet is true?
- A. It must be an electromagnet
  - B. It must be a permanent magnet
  - C. There is not enough information to know what type of magnet it is
- (11) Assuming that the amount of current remains constant, what happens to the strength of an electromagnet when the number of coils around its core is increased?
- A. It decreases
  - B. It remains the same
  - C. It increases
  - D. It becomes zero
- (12) In an electromagnet, what type of material is used in the core to enhance the magnetic field?
- A. A highly conductive material such as copper
  - B. A ferromagnetic material such as iron
  - C. A gaseous material such as neon
  - D. A non-metallic material such as carbon
- (13) The process where a current is produced due to a changing magnetic field is called:
- A. Electrostatic discharge
  - B. Resonance
  - C. Electromagnetic induction
  - D. Triboluminescence
- (14) What role did the electromagnet play in the telegraph?
- A. It stored electric charge for sending messages
  - B. It converted electrical signals into mechanical movements
  - C. It provided a path for electrical currents to travel from the sender to the receiver
  - D. It translated words into a series of dots and dashes
- (15) True or False: Electric guitars use permanent magnets to convert string vibrations into electrical signals.
- A. True
  - B. False

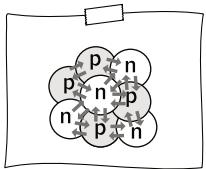
# NUCLEAR FISSION

# NUCLEAR FUSION

VS

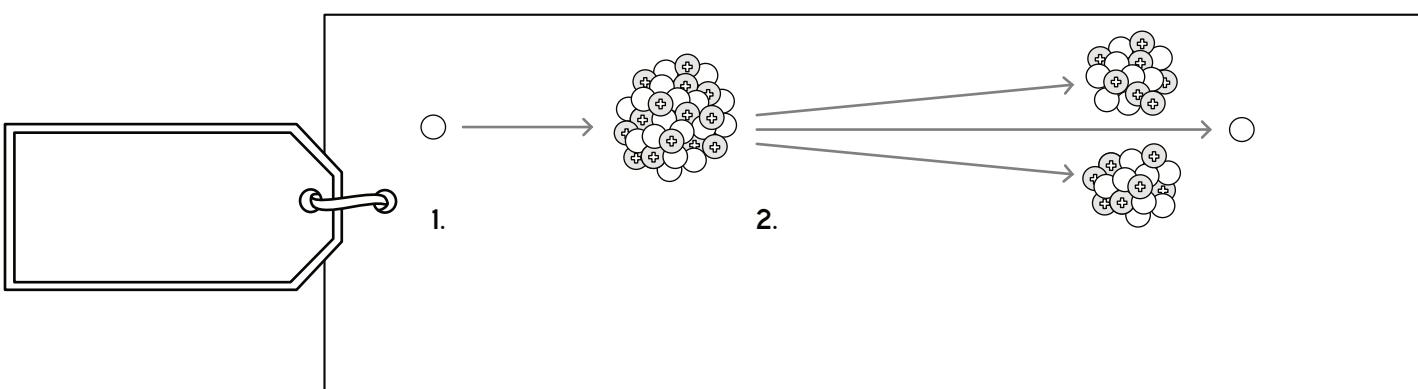
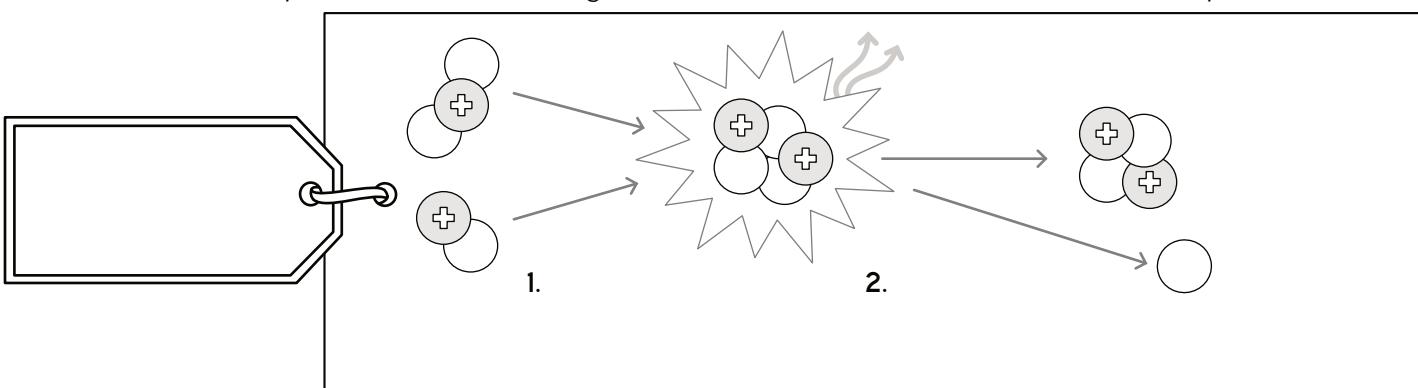


Electrostatic force:



Strong nuclear force:

Label each reaction pictured below as being either fission or fusion, and describe the steps:



Draw a line to match each description with fission, fusion, or both.

Releases the most energy

Principle behind atomic bombs

Requires high heat and pressure

Primary source of power in stars

Principle behind nuclear reactors

Fission

Poses risks of radiation

Uses Uranium

Fusion

Requires light abundant elements

Hydrogen atoms combine to make helium.

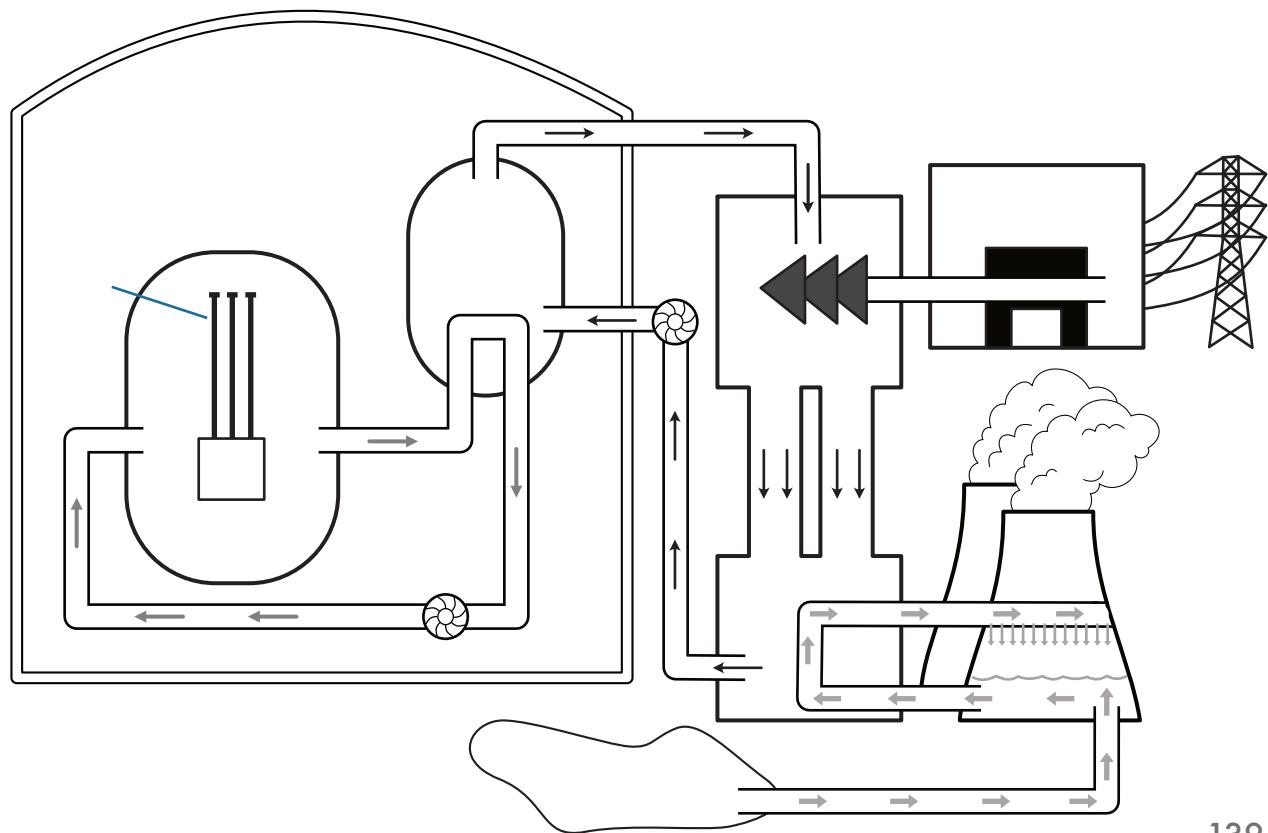
Requires very heavy elements like plutonium

### Nuclear Reactors

Nuclear reactors generate energy through controlled nuclear fission. Inside the reactor, uranium or plutonium fuel undergoes fission, releasing heat. This heat warms a coolant, which then produces steam. The steam drives turbines connected to generators, producing electricity. Reactors are designed with safety systems to control the fission process and contain radiation.

LABEL THE PARTS OF THE NUCLEAR REACTOR

Steam Generator	Turbine	Steam line	Control rods
Electric Generator	Cooling towers	Reactor	Containment structure



## PRACTICE PROBLEMS – GOING NUCLEAR

① What is nuclear fission?

- A. Two nuclei combining to form a larger nucleus
- B. A nucleus splitting into two smaller nuclei
- C. The process of losing an electron
- D. The orbit of electrons changing in an atom

② What process powers the sun and stars?

- A. Nuclear fission
- B. Chemical reactions
- C. Nuclear fusion
- D. Solar flares

③ What particle is often used to initiate nuclear fission?

- A. Electron
- B. Neutron
- C. Proton
- D. Photon

④ What is radioactivity?

- A. A process that strengthens materials
- B. The absorption of radiation by atoms
- C. The emission of energy as atomic nuclei decay
- D. The production of light by atoms

⑤ Why is nuclear fusion not yet widely used to generate electricity on Earth?

- A. It does not produce enough energy.
- B. It requires conditions that are difficult to achieve and maintain.
- C. It produces too much radioactive waste.
- D. It only works in space.

⑥ Decide whether each statement is true or false.

T F Nuclear fusion releases more energy than nuclear fission.

T F Nuclear fission is the process used by the Sun to produce energy.

T F Nuclear fusion requires very high temperatures to occur.

T F Nuclear reactors use fusion reactions to generate electricity.

T F Fission is the combining of two lighter atoms into a heavier atom.

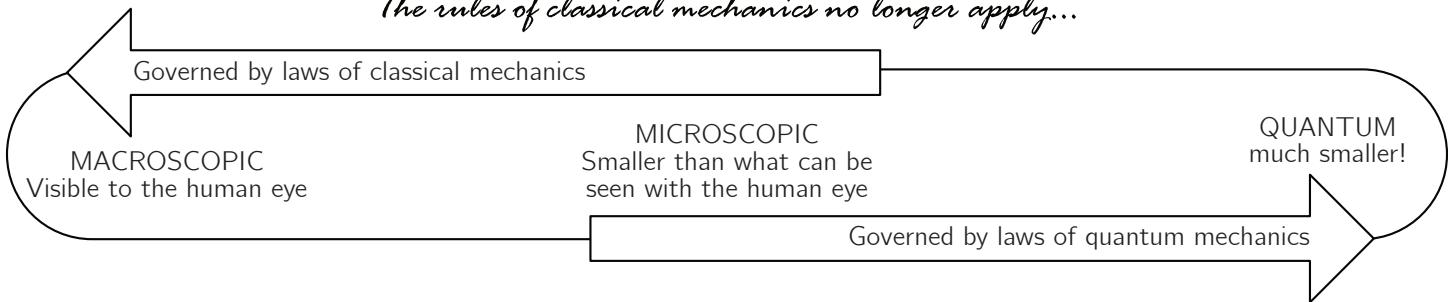
T F Fusion reactions are easy to control and widely used on Earth for energy production.

T F The waste from nuclear fission is more radioactive than the waste from nuclear fusion.

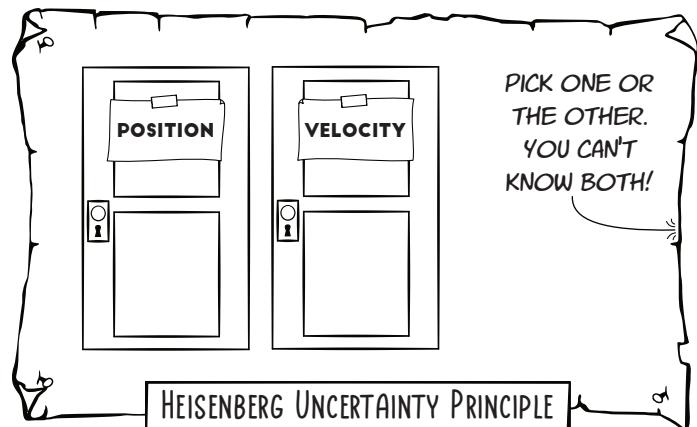
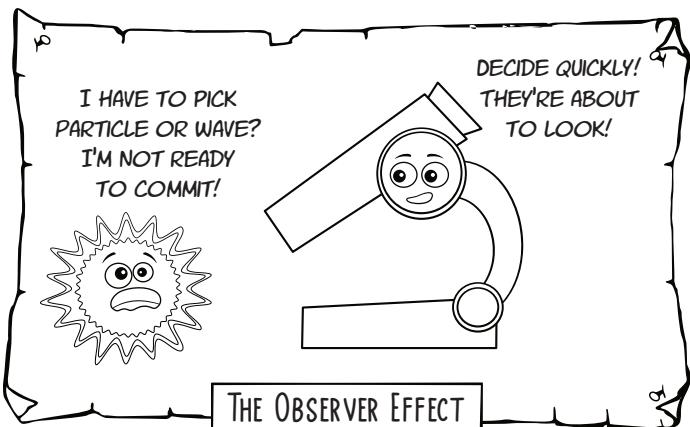
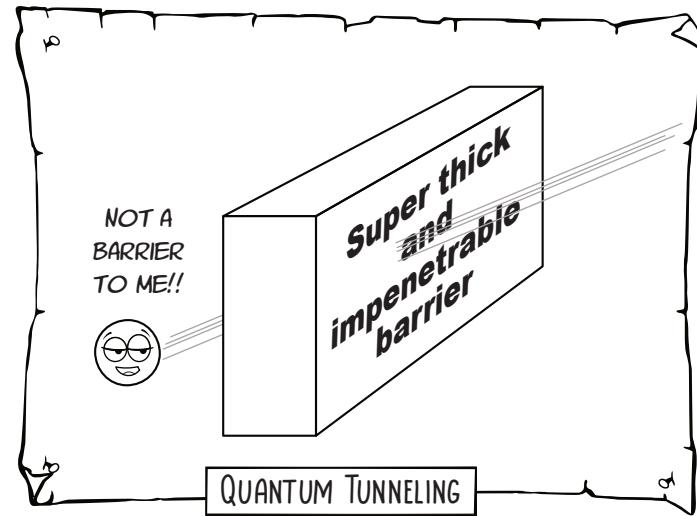
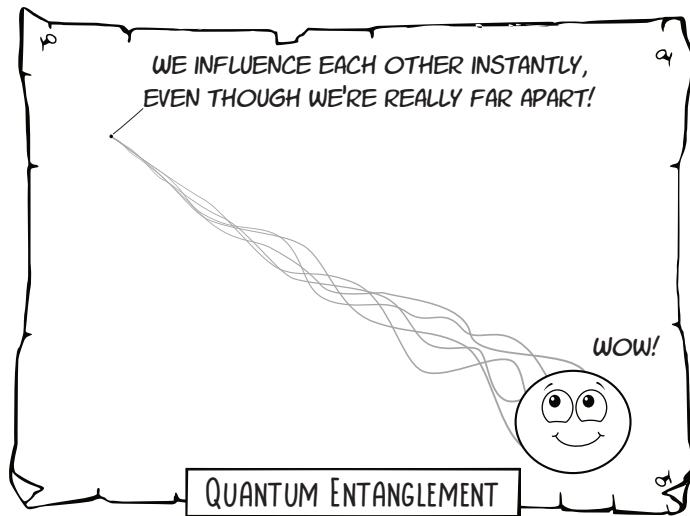
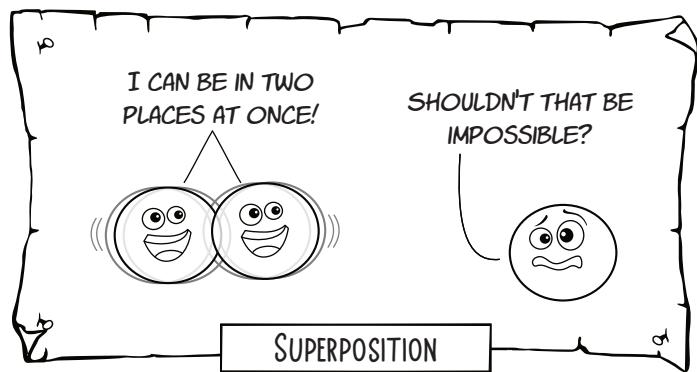
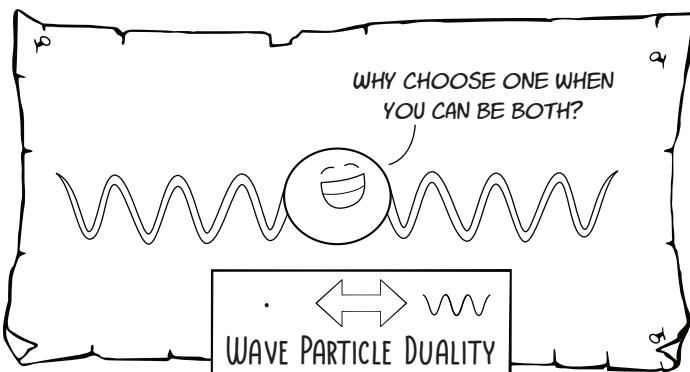
T F Fusion reactions produce heavy radioactive elements as byproducts.

# QUANTUM PHYSICS!

The rules of classical mechanics no longer apply...



Particles and physical matter exists in a spectrum of different sizes. The smaller things become, the more strongly the rules of quantum physics apply. The world of quantum physics is VERY different than classical mechanics! Below are 6 of the more common properties or effects seen at the quantum level.



## PRACTICE PROBLEMS – QUANTUM

- ① What phenomenon allows a particle to pass through a potential energy barrier that it classically cannot overcome?
  - A. Quantum entanglement
  - B. Quantum tunneling
  - C. Observer effect
  - D. Superposition
- ② According to the Heisenberg Uncertainty Principle, which pair of properties of a particle cannot be simultaneously precisely determined?
  - A. Position and velocity
  - B. Mass and charge
  - C. Momentum and energy
  - D. Spin and angular momentum
- ③ Which phenomenon describes the ability of particles to exist in multiple states simultaneously until observed?
  - A. Quantum tunneling
  - B. Superposition
  - C. Observer effect
  - D. Wave-particle duality
- ④ What term describes the concept that the act of measurement can alter the behavior of the system being observed?
  - A. Quantum tunneling
  - B. Superposition
  - C. Observer effect
  - D. Wave-particle duality
- ⑤ The double slit experiment was foundational in demonstrating which property?
  - A. Quantum tunneling
  - B. Superposition
  - C. Wave-particle duality
  - D. Observer effect
- ⑥ What is your favorite fact or question related to quantum mechanics?

## FINAL ASSESSMENT

- 1 Which of the following best describes the First Law of Thermodynamics?
- Energy cannot be created nor destroyed, only transferred or transformed.
  - Entropy of a closed system always increases.
  - Heat flows from cold objects to hot objects naturally.
  - The efficiency of a heat engine can never be 100%.
- 2 What type of heat transfer can occur in the vacuum of outer space?
- No heat transfer can occur in a vacuum.
  - Radiation only.
  - Convection and conduction.
  - Conduction, convection, and radiation.
- 3 What is the latent heat of vaporization?
- The heat required to melt a solid.
  - The heat required to freeze a liquid.
  - The heat required to change a liquid into a gas.
  - Heat released when gas condenses.
- 4 What is the typical speed of sound in air at room temperature?
- 25 m/s
  - 343 m/s
  - 562 m/s
- 5 The buoyant force on an object submerged in a fluid is equal to the:
- Volume of the fluid displaced.
  - Density of the fluid.
  - Weight of the fluid displaced by the object.
  - Weight of the object.
- 6 The phenomenon of light bending as it passes from one medium to another is called:
- Diffraction
  - Interference
  - Reflection
  - Refraction
- 7 The frequency of a wave is 500 Hz and its speed is 340 m/s. What is the wavelength?
- 0.68 m
  - 1.52 m
  - 0.85 m
  - 2.00 m
- 8 If the distance between two charges is DOUBLED, the force attracting them to each other will:
- Double
  - Stay the same
  - Be  $\frac{1}{2}$  as strong
  - Be  $\frac{1}{4}$  as strong
- 9 Which of the following statements about magnetic fields is true?
- Magnetic fields require a medium to travel through space.
  - Magnetic fields are only produced by permanent magnets.
  - Most of the elements in the periodic table are ferromagnetic.
  - Magnetic fields are created by moving electric charges.
- 10 If the volume of a gas is decreased from 4 liters to 2 liters while the temperature remains constant, what happens to the pressure of the gas assuming the initial pressure was 1 atm?
- The pressure decreases to 0.5 atm.
  - The pressure increases to 2 atm.
  - The pressure remains the same.
  - The pressure decreases to 0.25 atm.
- 11 Increasing the amplitude of a sound wave will:
- Increase the pitch
  - Decrease the pitch
  - Increase the volume
  - Decrease the volume
  - Increase the frequency
  - Decrease the frequency

- (12)** Bernoulli's principle states that, in a fluid, an increase in velocity occurs simultaneously with what other change?
- Increase in pressure
  - Decrease in pressure
  - Increase in temperature
  - Decrease in temperature
- (13)** Of the colors listed below, which color of light has the shortest wavelength?
- Red
  - Green
  - Blue
  - Yellow
- (14)** The phenomenon of light bouncing off an object at the same relative angle it arrived is called:
- Reflection
  - Refraction
  - Diffraction
  - Dispersion
- (15)** If the wave speed doubles while the frequency stays the same, what happens to the wavelength?
- It doubles
  - It is halved
  - It remains the same
  - It quadruples
- (16)** If the current in a wire increases, the magnetic field around the wire will:
- Increase
  - Decrease
  - Remain unchanged
  - Temporarily disappear
- (17)** A 20 lb weight falls into a pool and displaces a volume of water that weighs 4 lb. How much upward force will be needed to lift the weight while it is underwater?
- 5 lb
  - 16 lb
  - 24 lb
  - 80 lb
- (18)** What happens to the liquid pressure experienced by a submarine when it doubles its depth in the ocean?
- Liquid pressure is cut in half.
  - Liquid pressure remains the same.
  - Liquid pressure doubles.
  - Liquid pressure quadruples.
- (19)** What is the human audible range of sound frequency?
- 20 Hz to 2 kHz
  - 20 Hz to 20 kHz
  - 2 Hz to 20 kHz
  - 20 kHz to 2 MHz
- (20)** If a 400 N weight is placed on a cube that measures  $4\text{ cm} \times 4\text{ cm} \times 4\text{ cm}$ , how much pressure is applied to the cube face?
- 100 kPa
  - 250 kPa
  - 400 kPa
  - 1600 kPa
- (21)** What quantity measures the average kinetic energy of particles in a substance?
- Temperature
  - Heat
  - Entropy
  - Enthalpy
- (22)** Write out the seven types of electromagnetic radiation from lowest frequency to highest frequency.
- 1.
  - 2.
  - 3.
  - 4.
  - 5.
  - 6.
  - 7.

# Electromagnetic Spectrum Song

adapted from Ghost Riders in the Sky

Stan Jones / Serge Ballif

♩ = 240



7

Ra-di-o and mi-cro-waves fol-lowed by in-fra red The vi - si - ble light  
Ra-di-o and vi - si - ble light a - ble to get through. The at - mos-sphere blocks  
Mag-ne-tic and el - ectrlic fields to - ge - ther-in-ter - twined. A con-stant speed they



7

spe-ctrum is a rain - bow pri-sm spread. Ul - tra vi - olet light the en - er - gy be-gins to  
most the rest pro - tec - ting me and you. Three hun-dred mil-lion me-ters ev - ery sec-ond that goes  
tra - vel ma - ny wave-lengths are com-bined. These pho-ton full of en - er - gy their co-lors are so

F



13

rise. X - rays and ga - ma rays a ti - ny wave-length size.  
by. Does - n't need a me - dium through va - cuum it will fly.  
bright. We only see a ti - ny range and that's what we call light.



20

E - lec - tro-mag - ne - tic

Ra - di - a - tion

F



30

2

Tra - veling at the speed

of light

## USEFUL FORMULAS

### Temperature

$C$  = temp in  $^{\circ}\text{C}$ ,  $F$  = temp in  $^{\circ}\text{F}$

$$F = \frac{9}{5}C + 32$$

### Density

$\rho$  = density,  $m$  = mass,  $V$  = volume

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

### Pressure

$P$  = pressure,  $F$  = force,  $A$  = area

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

### Weight

$w$  = weight,  $m$  = mass,  $g = 9.8 \text{ m/s}^2$

$$w = mg$$

### Liquid Pressure

$P_{\text{fluid}}$  = pressure,  $\rho$  = density,  
 $g = 9.8 \text{ m/s}^2$ ,  $h$  = depth

$$P_{\text{fluid}} = \rho gh$$

### Boyle's Law

$P_1$  = first pressure,  $V_1$  = first volume,  
 $P_2$  = second pressure,  $V_2$  = second volume

$$P_1 V_1 = P_2 V_2$$

### Ideal Gas Law

$P$  = pressure,  $V$  = volume,  $n$  = number of mols,  
 $R \approx 8.314 \frac{\text{J}}{\text{K} \cdot \text{mol}}$ ,  $T$  = temperature in K

$$PV = nRT$$

### Wave Speed

$v$  = wave speed,  $f$  = frequency,  
 $\lambda$  = wavelength

$$v = f\lambda$$

### Power = Voltage $\times$ Current

$P$  = power,  $V$  = voltage,  $I$  = current

$$P = VI$$

### Ohm's Law

$V$  = voltage,  $I$  = current,  $R$  = resistance

$$V = IR$$