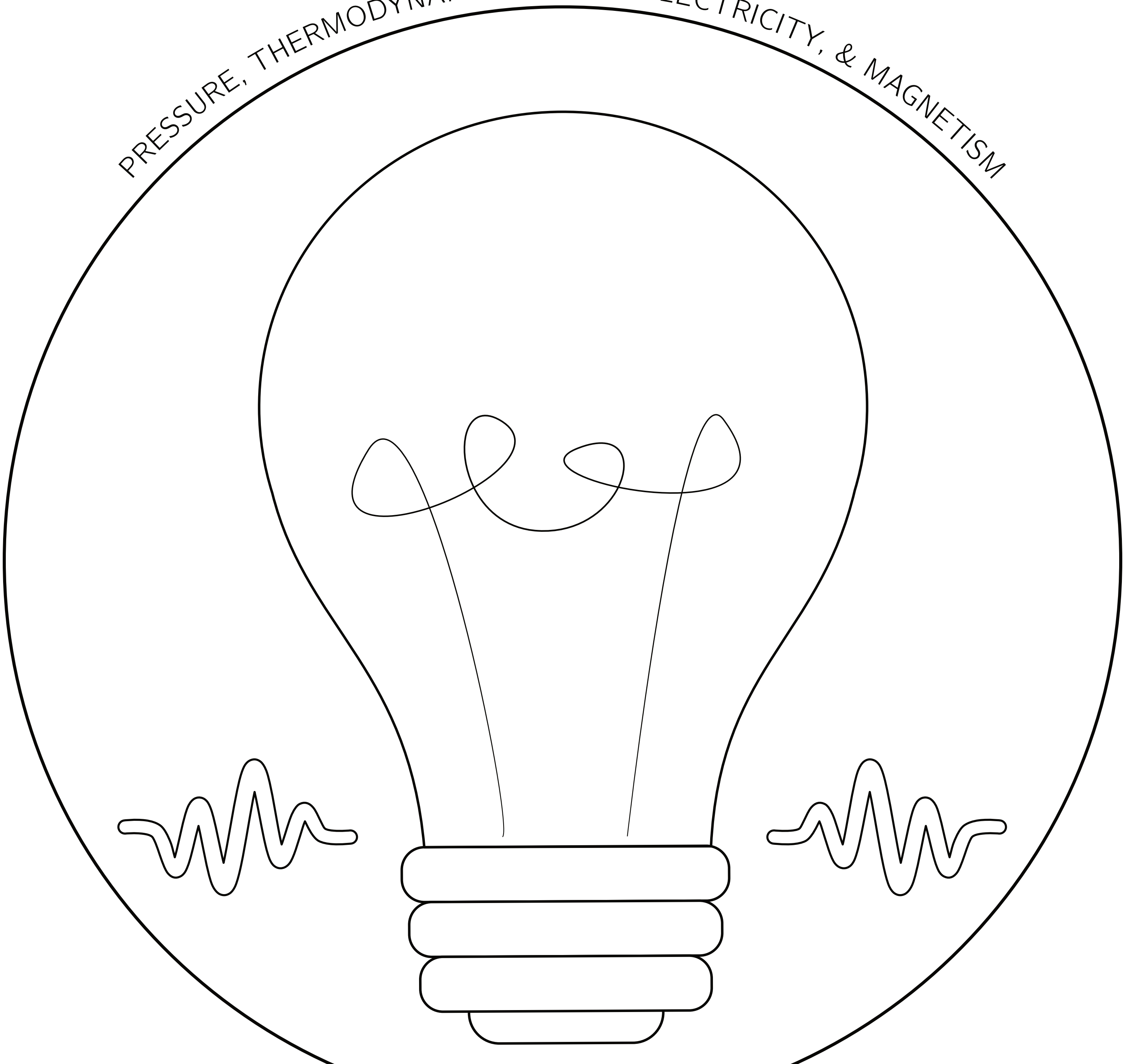
Physics 2

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
12	Wednesday, Feb 14	Pressure & fluids	
13	Self-paced	Egg in a Bottle	
14	Monday, Feb 19	Going for a Swim	
15	Wednesday, Feb 21	Density & Buoyancy	
16	Self-paced	Boat Float OR Density Column	
17	Monday, Feb 26	Ocean of Air	
18	Wednesday, Feb 28	Fluids in Motion	
19	Self-paced	Tricks of air	
20	Monday, Mar 4	Push and shove	
21	Wednesday, Mar 6	PRESSURE QUIZ SHOW	
22	Self-paced	Assessment	
Mar 11-15 · SPRING BREAK 1			
23	Monday, Mar 18	What's a wave?	
24	Wednesday, Mar 20	Sound	
25	Self-paced	DIY Chladni plate	
26	Monday, Mar 25	Earthquakes	
27	Wednesday, Mar 27	Light 1	
28	Self-paced	Water Xylophone	
29	Monday, Apr 1	Light 2	
30	Wednesday April 3	Waves Quiz Show	
31	Self-paced	Assessment	

Lesson	Date	Topic	Pages
		Apr 8-12 · SPRING BREAK 2	
32	Monday, Apr 15	Electromagnetism 1	
33	Wednesday, Apr 17	Electromagnetism 2	
34	Self-paced	Make a magnet with a battery	
35	Monday, Apr 22	Electromagnetism 3	
36	Wednesday, Apr 24	Electromagnetism 4	
37	Self-paced	Paper flashlight	
38	Monday, Apr 29	Electromagnetism 5	
39	Wednesday, May 1	Nuclear	
40	Self-paced	Review or homopolar motor	
41	Monday, May 6	The weird world of quantum	
42	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

Make Your Own Handwarmers OR 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 Icecream

- 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

Egg in a Bottle

- 2 or 3 **medium-size** hard boiled eggs, peeled
- Bottle with an opening slightly smaller than the egg
- Small birthday candles or matches
- Matches or lighter

Boat Float OR Density Column

Boat Float:

- Aluminum foil
- Water
- Coins

Density Column

- 2 tall clear cups or cylindrical containers
- Sugar and water OR rubbing alcohol, vegetable oil, water, dishwashing soap, and corn syrup
- Measuring cup
- Food coloring

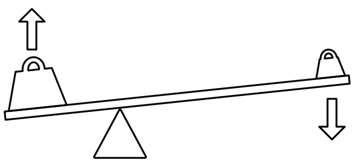
Remaining supply list and science standards to come here in later versions of the notes.

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!

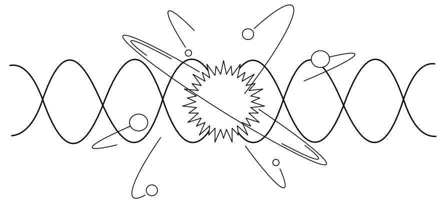
In our Physics 1 class we studied classical mechanics and had one bonus lesson on relativity (which is a pretty important concept in astrophysics). In Physics 2 we'll be covering a wide variety of topics!

CLASSICAL MECHANICS



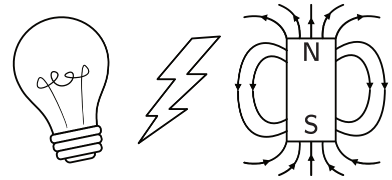
- [x] The study of how everyday objects move and behave

QUANTUM MECHANICS



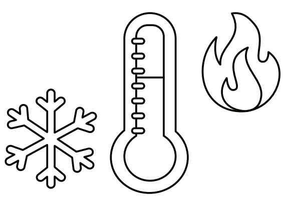
- [ ] The study of how very small particles behave

ELECTROMAGNETISM



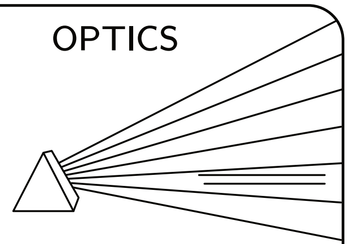
- [ ] The study of electric and magnetic fields

THERMODYNAMICS



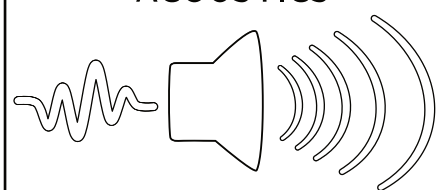
- [ ] The study of heat, energy, and entropy

OPTICS



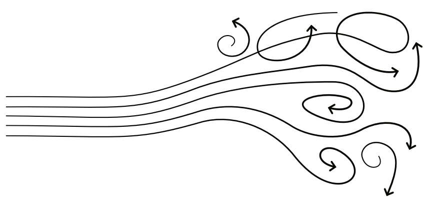
- [ ] The study of the behavior and properties of light

ACOUSTICS



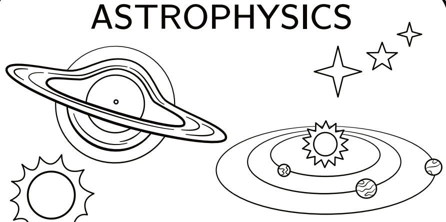
- [ ] The study of mechanical waves such as sound

FLUID DYNAMICS



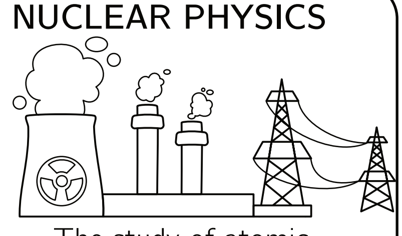
- [ ] The study of the flow of liquids and gases

ASTROPHYSICS



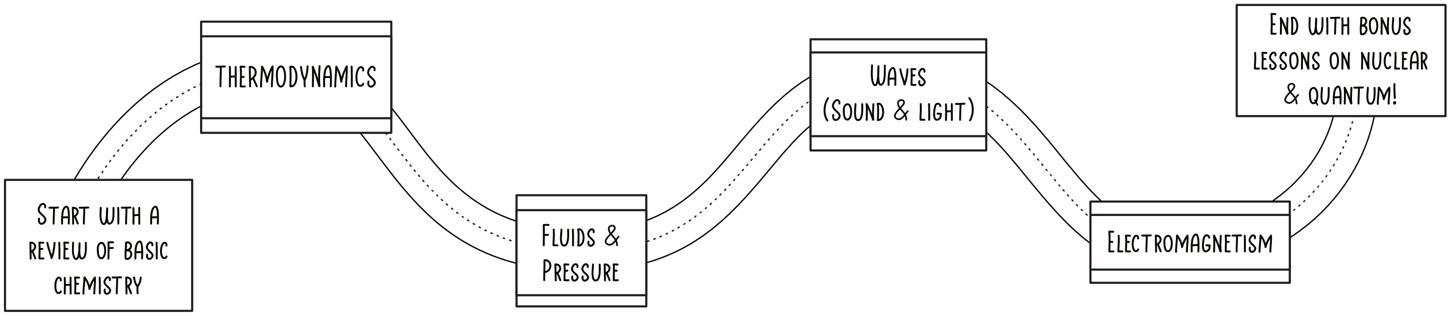
- [x] Physics in outer space! How stars, black holes, and solar systems work

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?

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.

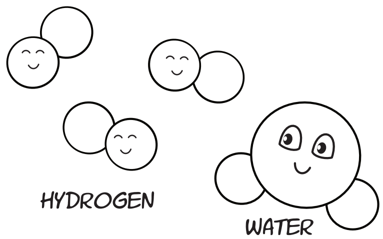
My plan for watching the lessons and using the notes:

My plan for doing the practice problems:

My plan for completing the labs or hands-on activities:

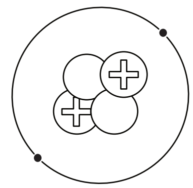
Unit 1: the chemistry you need for physics!

MOLECULE



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

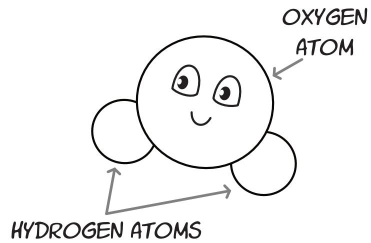
ATOM



One atom of helium

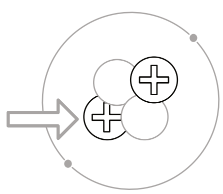
The smallest unit of an element

COMPOUND



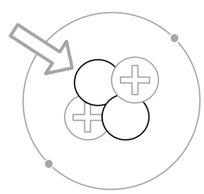
A molecule or substance made of two or more elements bonded together

PROTON



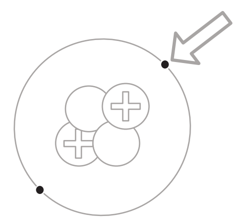
Positively charged particle in the nucleus of an atom

NEUTRON



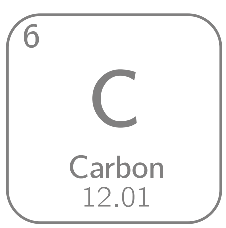
A particle with no charge in the nucleus of an atom

ELECTRON



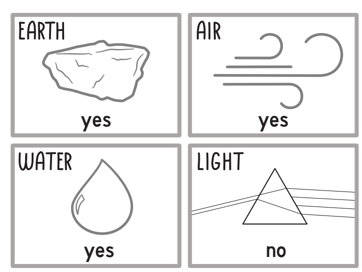
A negatively charged particle that orbits the nucleus of an atom

ELEMENT



A substance that cannot be broken down by chemical reactions

MATTER



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

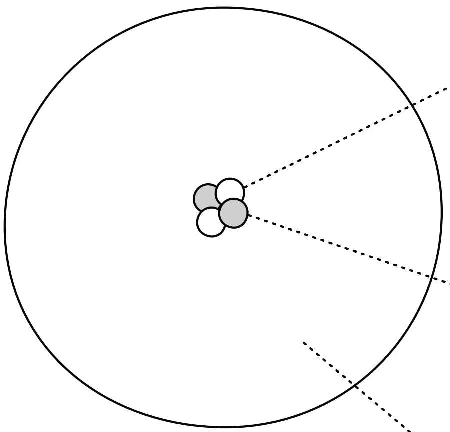
WHAT'S THE MATTER?

FILL IN THE BLANKS:

nucleus	*neutrons*	*properties*	*sharing*	*atoms*	*bond*	*protons*

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

THE PARTS OF AN ATOM:



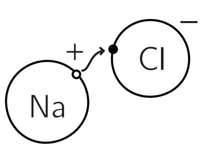
+ charge
PROTONS – positive charge and a mass of about 1 atomic mass unit. Located in the nucleus.

no charge
NEUTRONS – no charge and a mass of about 1 atomic mass unit. Located in the nucleus.

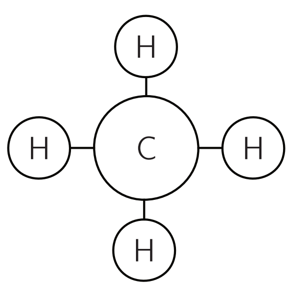
– charge
ELECTRONS – negative charge and almost no mass. Super tiny! Located in a cloud around the nucleus.

TYPES OF CHEMICAL BONDS

Electrons transferred from one atom to another

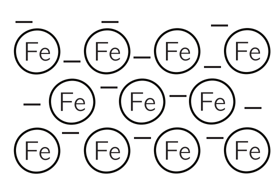


Makes + and – ions!

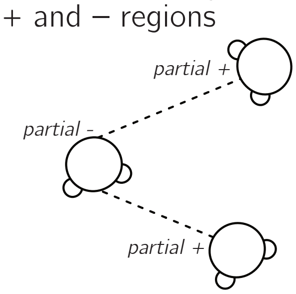


Share electrons between atoms

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



Weak attraction between partially + and – regions



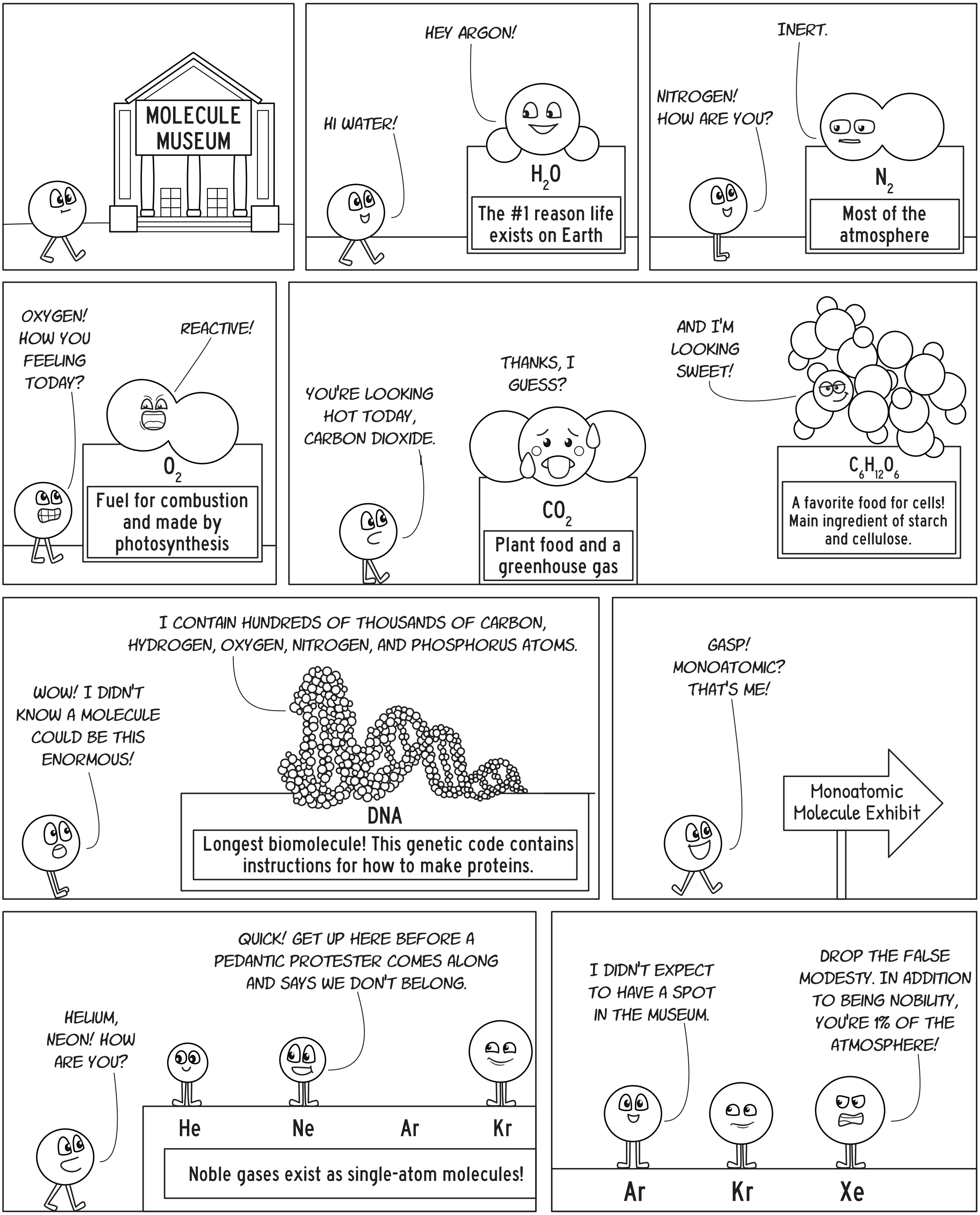
IONIC

COVALENT

METALLIC

HYDROGEN

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

(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

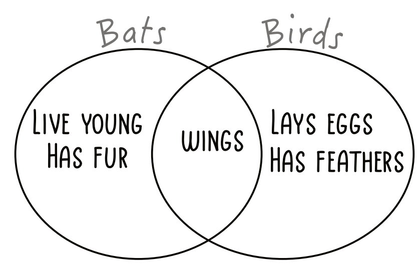
(10) Which of the following is not composed of atoms?
A. Water
B. Rock
C. Sunlight
D. Plastic

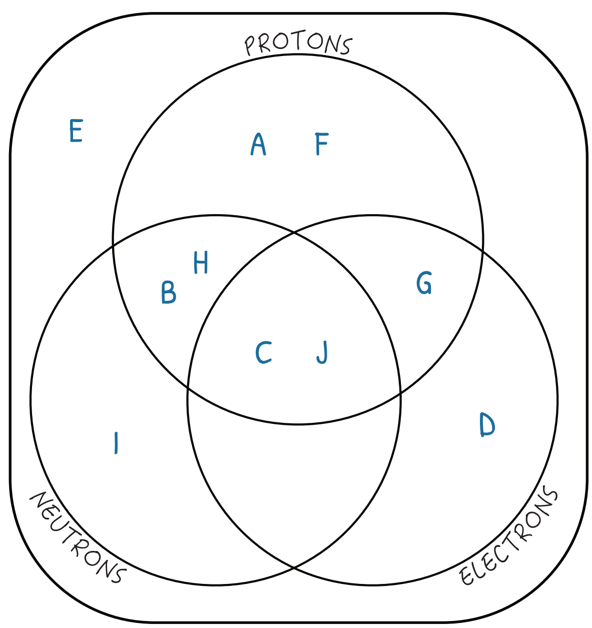
(11) Bonds between atoms primarily involve:
A. Sharing or transferring protons
B. Sharing or transferring neutrons.
C. Sharing or transferring electrons.
D. Sharing or transferring photons.

(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:

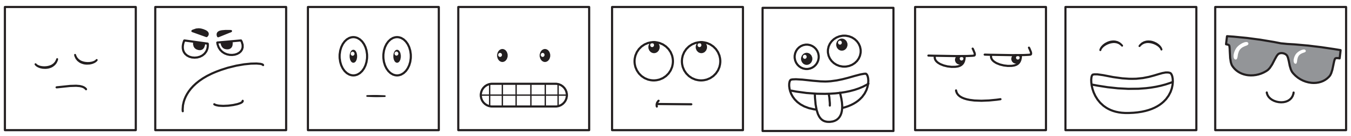




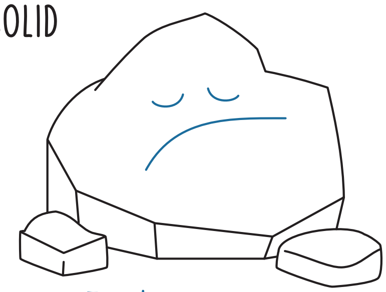
Elemental

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

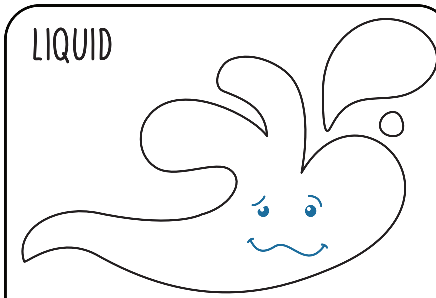


SHAPE: Fixed

VOLUME: Fixed

ENERGY LEVEL:

LIQUID

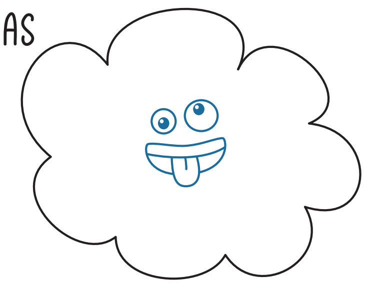


SHAPE: Flexible

VOLUME: Fixed

ENERGY LEVEL:

GAS



SHAPE: Flexible

VOLUME: Flexible

ENERGY LEVEL:

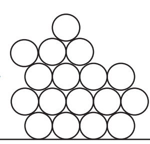
THE ENERGY OF MOVING PARTICLES IS CALLED KINETIC ENERGY.

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.

Solid

Ex. Iron, wood, rubber, granite

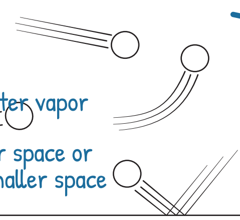
Can be in crystal structure (regular pattern) or not (amorphous)



Gas

Ex. Air, helium, steam or water vapor

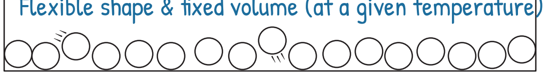
Can expand to occupy larger space or be compressed to occupy smaller space



Liquid

Ex. Water, rubbing alcohol, oil, lava

Flexible shape & fixed volume (at a given temperature)



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 H Hydrogen																	2 He Helium
3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium											13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
55 Cs Caesium	56 Ba Barium		72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium		104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

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

MATCH EACH ELEMENT SYMBOL WITH THE CORRESPONDING NAME AND FACT:

7 N	**Carbon** - Forms strong covalent bonds with many other elements and with itself. The primary element in biomolecules and living organisms.
17 Cl	**Hydrogen** - The lightest and most abundant element in the universe. The Sun, Jupiter, and Saturn are all mostly made of hydrogen.
6 C	**Nitrogen** - 78% of the atmosphere is nitrogen gas (N_2). This element is also an essential ingredient of proteins and DNA.
1 H	**Chlorine** - Widely used to purify water and as a cleaning agent. In pure form, it is toxic and highly reactive.
8 O	**Oxygen** - Approximately 21% of the atmosphere is made from this element. It is reactive and forms many compounds with other elements.
94 Pu	**Iron** - This magnetic element is abundant in the Earth's crust and essential for many animals because of it's role in transporting oxygen in the blood.
26 Fe	**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

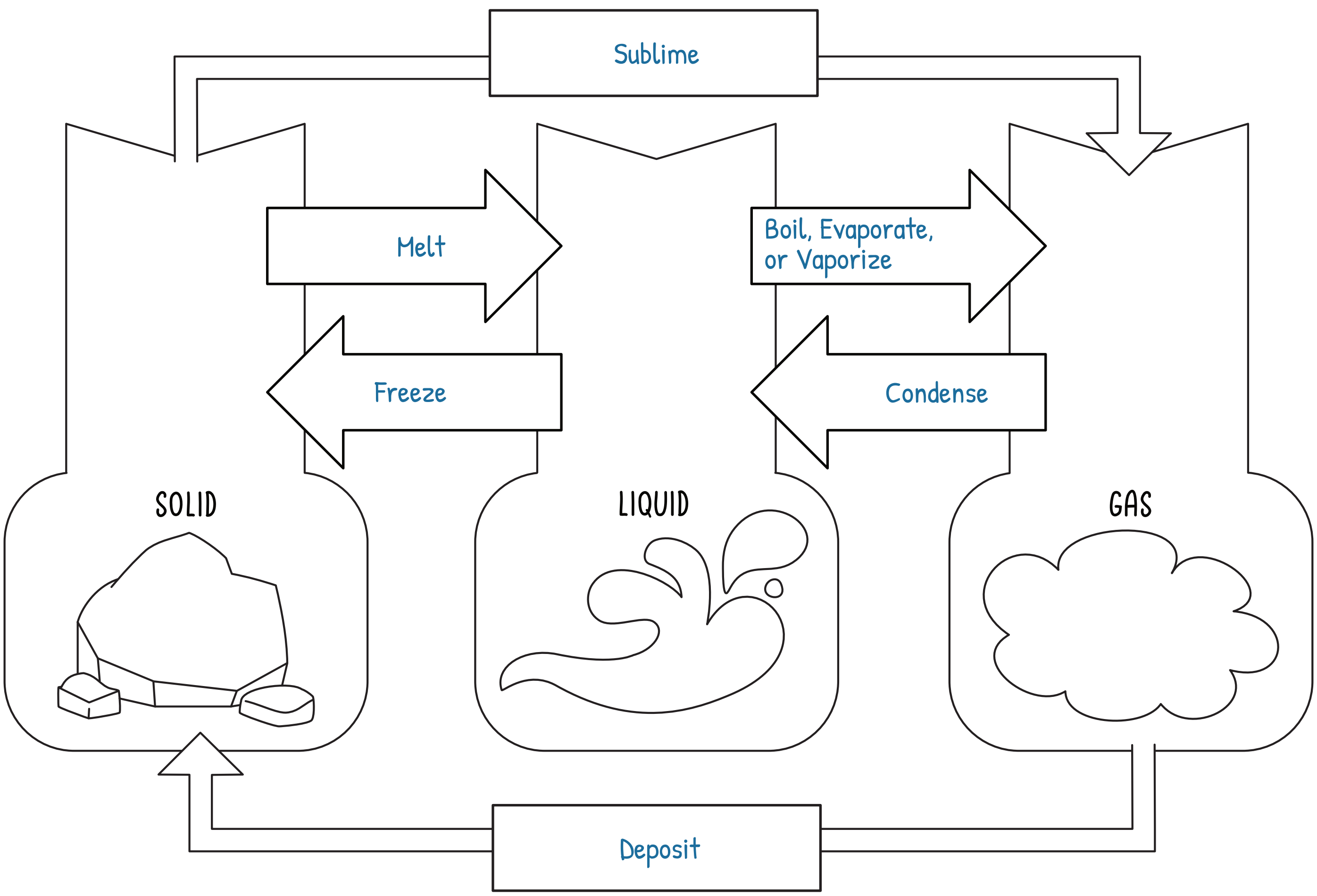
8. What happens to particles when a substance changes from solid to liquid?
   A. They move closer together and more slowly
   B. They spread out and move slower
   C. They move closer together and faster
   D. They spread out and move faster

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.*

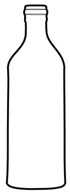
    Note: one of the arrows will have three words.

Melt	*Freeze*	*Evaporate*	*Condense*	*Sublime*	*Deposit*	*Boil*	*Vaporize*

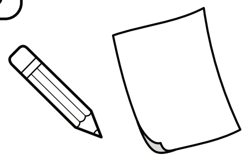


FUN PHYSICS TRICKS

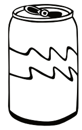
MATERIALS



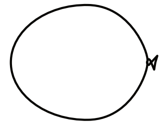
1 bottle with a narrow neck



Drawing supplies and paper

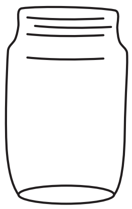


An empty aluminum can

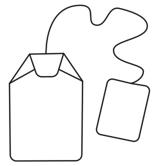


1 balloon or a short length of plastic pipe

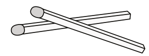
A coin



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?

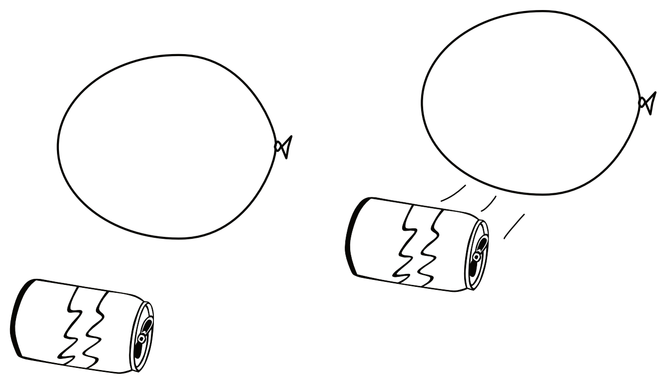
1. Place an empty soda can on a horizontal surface so that it is laying on its side.

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.

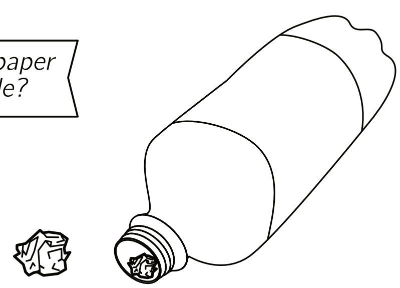
4. Hold the balloon close to the can (but don't touch it!) and then move it away from the can. The can will roll towards the balloon.

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



2 Paper Wad Challenge

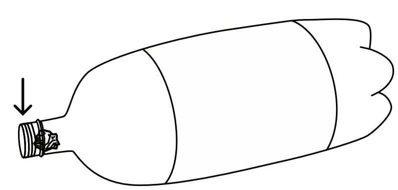
Can you blow the wad of paper into the empty water bottle?



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.

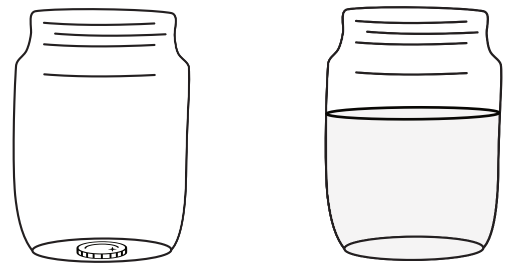
2. Challenge a friend to get the paper into the bottle by blowing on it.

3. After they fail, demonstrate the correct way to blow in the paper by blowing gently from directly above the mouth of the bottle.



3 Disappearing Coin

Watch a coin disappear!



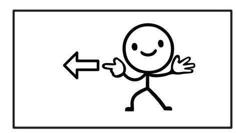
1. Place the coin on a table or counter.

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?

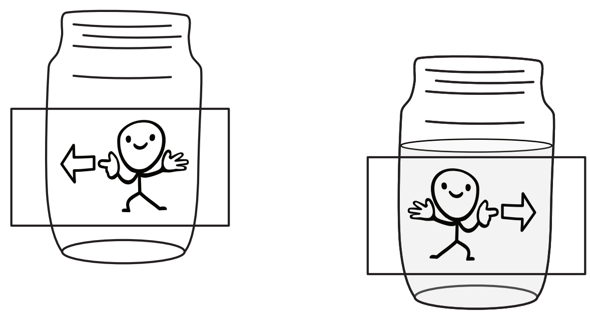
4 Image Reverser

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.



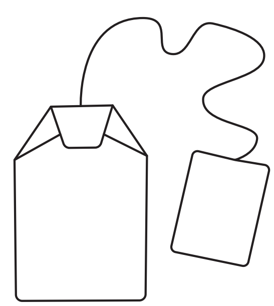
3. Place the image about 10 cm behind the glass. It should look about the same.

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

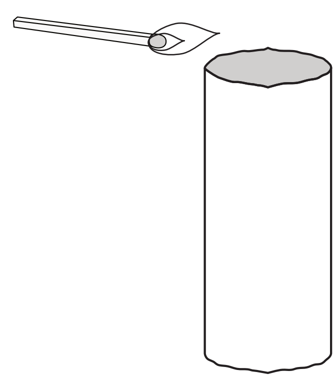
Can you make a tea bag launch into the sky by lighting it on fire?



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!

Tale 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!

Your rating
from one star (not satisfying) to 5 stars (very satisfying!)

1 Aluminum Can Mover

☆☆☆☆☆

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! ____________________

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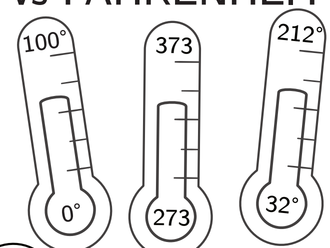
Unit 2: Thermodynamics

All about heat and the transfer of energy!

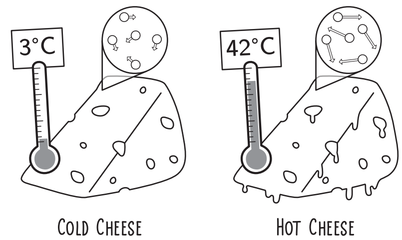
CELSIUS vs KELVIN vs FAHRENHEIT



K °C °F

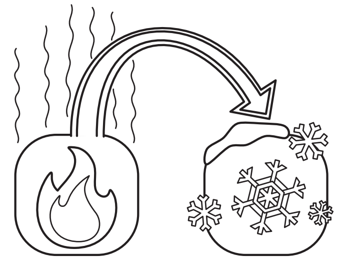
Three different systems for measuring temperature

TEMPERATURE



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

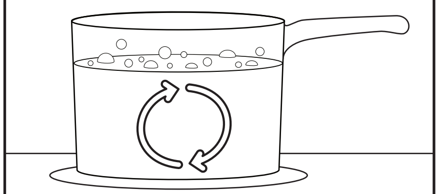
HEAT



cal or J

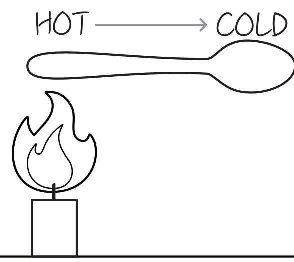
Energy moving from one object to another because of a difference in temperature.

CONVECTION



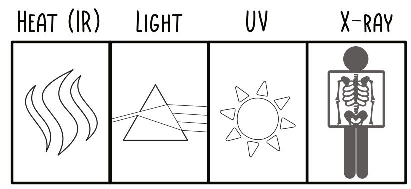
Heat transfer by the movement of fluids (gas or liquid)

CONDUCTION



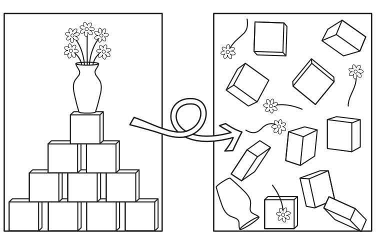
The movement of heat or electricity through a material.

RADIATION



Energy transmitted by electromagnetic waves

ENTROPY



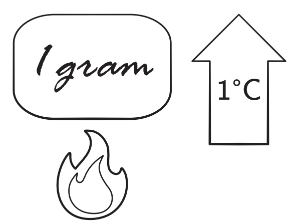
S

A measure of the disorder or randomness in a system

INTERNAL ENERGY

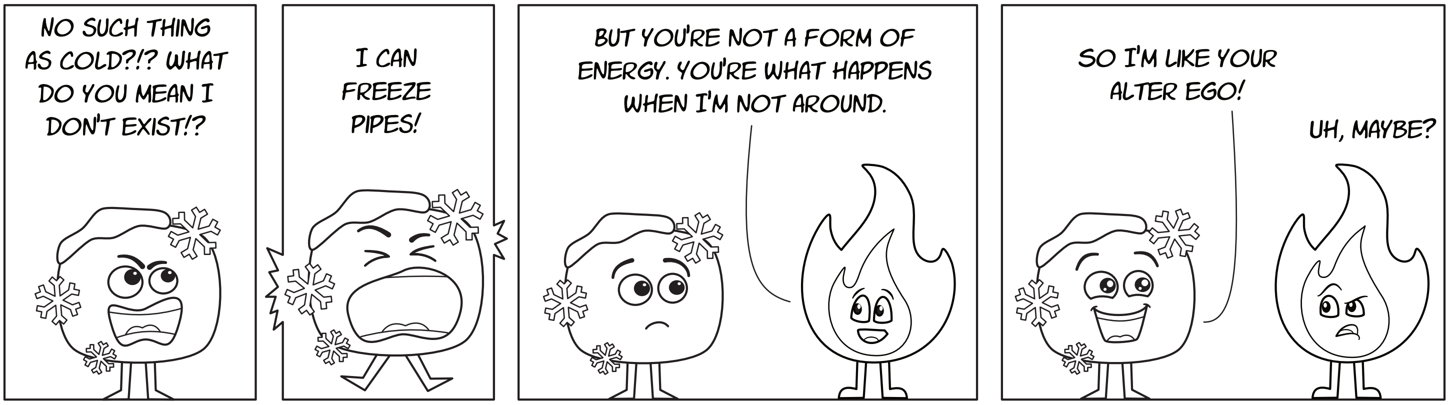
The total kinetic and potential energy of the particles in a system.

SPECIFIC HEAT CAPACITY



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

No Such Thing as COLD

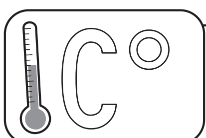


FILL IN THE BLANKS:

molecules	*temperature*	*energy*	*cold*	*absence*	*higher*	*kinetic*

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

Record some facts about each temperature measurement system:

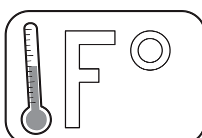


Celsius (also called centigrade)

0 is freezing point of water, 100 is boiling point.

Most widely-used temp scale in the world.

Invented by Anders Celsius in 1742.

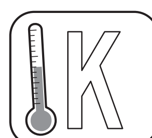


Fahrenheit

Has 180 degrees between freezing (32˚) and boiling point (212˚) of water.

Oldest temp scale (invented in 1724)

Used primarily in United States.

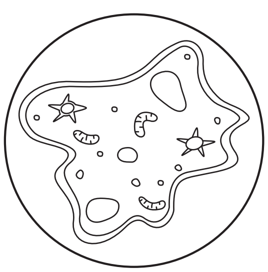


Kelvin

Used in scientific fields, the SI unit for temperature.

No negative numbers in this scale. Zero Kelvin is known as "absolute zero." Nothing can be colder.

K =C + 273.15

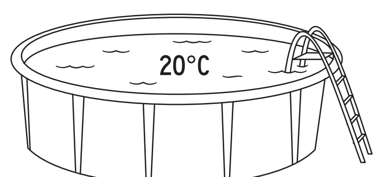


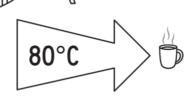
Consider an amoeba that can survive in water as long as the temperature stays ABOVE 15° C (59° F).

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)



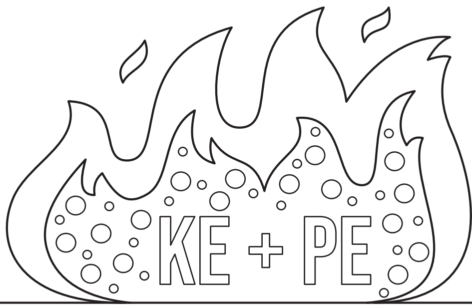


WHICH CONTAINER WOULD KEEP THE AMOEBA WARM THE LONGEST AND WHY? The swimming pool would stay warmer longer because it takes longer to change the temperature of a large body of water than a smaller one. The internal energy of an object is the energy from the movement and interactions of the molecules. This is why a large iceberg has more internal energy than a cup of hot coffee, and a 2,000 liter pool has more than a ½ liter of hot water.

INTERNAL ENERGY VS HEAT

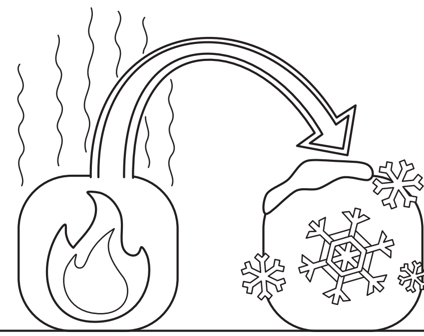
LABEL EACH CARD WITH THE CORRECT TERM AND DEFINITION, THEN DESCRIBE THEIR SIMILARITIES AND DIFFERENCES.

INTERNAL ENERGY



The total kinetic energy (temperature) and potential energy (ex. chemical bonds) of the particles in a system.

HEAT



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

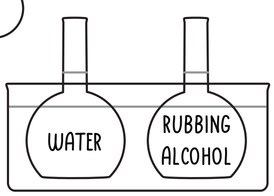
SOMETHING SIMILAR: Both measured in Joules.

SOMETHING DIFFERENT: Heat is a process. Internal energy is the total energy of a system or object.

THERMAL EXPANSION

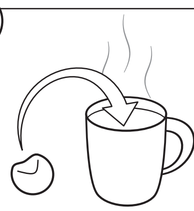
Record what happens in each case below. Is it what you expected?

1



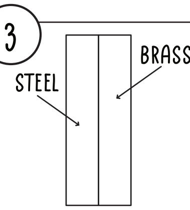
COLD FLASKS OF FLUID ARE PLACED IN A HOT WATER BATH.

2



A DENTED PING PONG BALL IS PUT IN ALMOST BOILING WATER.

3



A BIMETALLIC STRIP OF METAL IS HEATED

The rubbing alcohol rises higher than the water

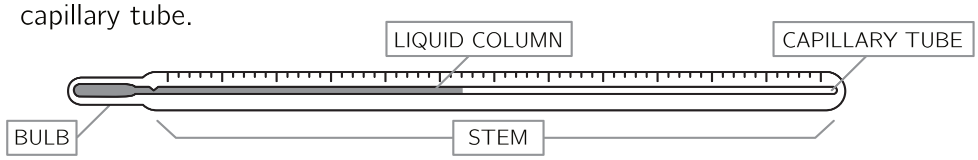
Ping pong ball inflates

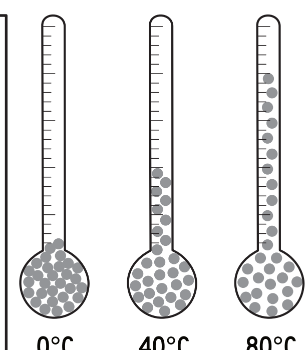
Strip of metal bends because brass expands more than steel

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

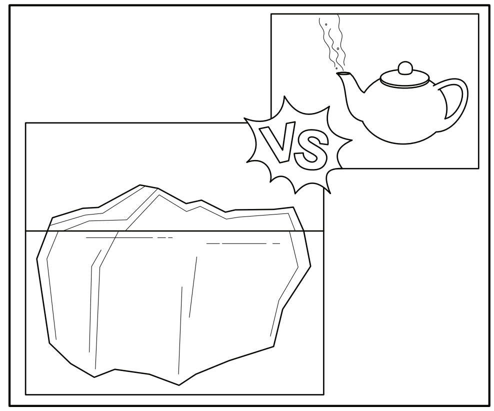
① List 3 examples of thermal expansion that occur in every day life?

Examples could include joints or gaps in sidewalks and bridges, which prevent the structures from cracking due to temperature changes. The shape of overhead power lines (on cold days there is less sag, more on warmer days), railway tracks have gaps between sections as well so they don't heat and warp. Sea level rises as the ocean warms etc.

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

The tea kettle of boiling water is hotter than the ice. The obvious answer here is correct!

Boiling water has a higher temperature than ice. Another way to say this is that the average kinetic energy of the molecules in the teakettle is higher than in the iceberg.



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. Although the average kinetic energy of the molecules in an iceberg is lower, the enormous number of molecules in the iceberg means their TOTAL kinetic and potential energy (internal energy) is higher than the tea kettle. To use an over-simplistic analogy: 5 molecules with a rating of 10 each (high energy) have less total energy ($5 \cdot 10 = 50$ units) than 1 million molecules with a rating of 1 for lower energy ($1 \cdot 1$ million = 1 million units)

Note: This is a hypothetical question or thought experiment. In real life applications, internal energy is challenging to quantify and is often measured indirectly (such as by changes to volume or temperature).

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

In theory, absolute zero is the temperature at which molecular motion would cease entirely. However, according to quantum mechanics, molecules still retain movement and energy (called zero-point energy) even at absolute zero. This motion is not thermal (i.e., not related to heat), but rather arises from the inherent principles of quantum mechanics.

Experiments have managed to cool substances to temperatures a fraction of a degree above absolute zero. According to our current scientific understanding, it's impossible to reach absolute zero.

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

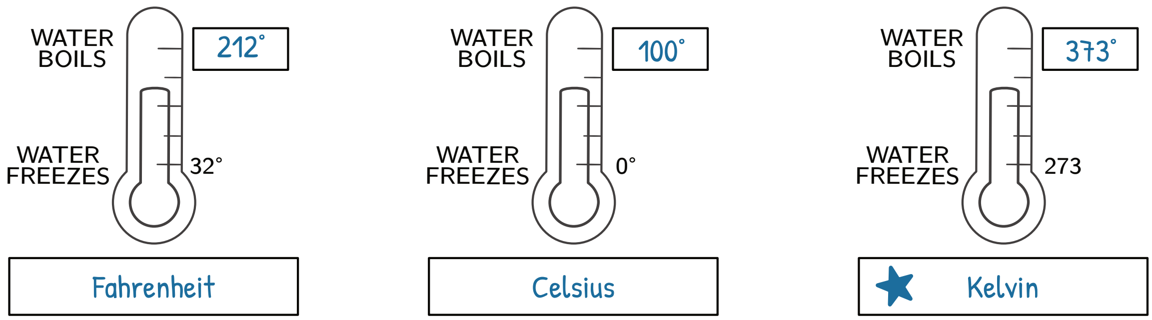
B. The transfer of thermal energy between two systems

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 (°C, °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?

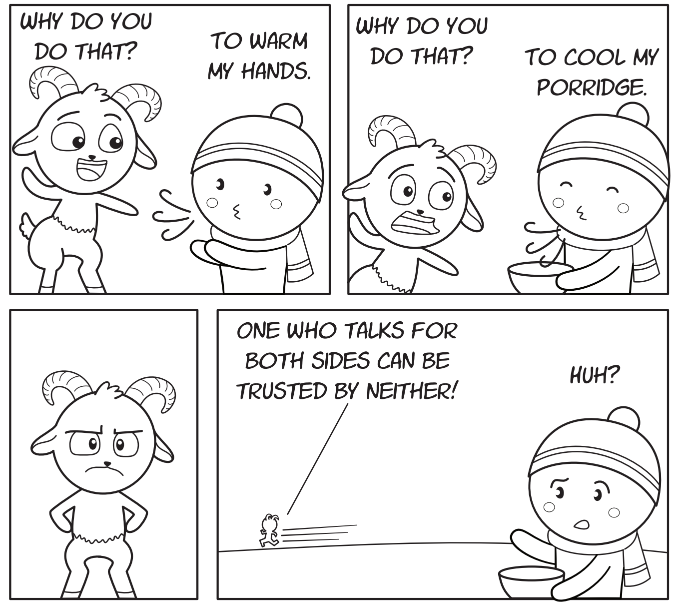
A. The temperature increases
B. The temperature decreases
C. The molecules move more quickly and are further apart from each other
D. The molecules move more slowly and are closer together to each other
E. Both B and D
F. Both A and C

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!

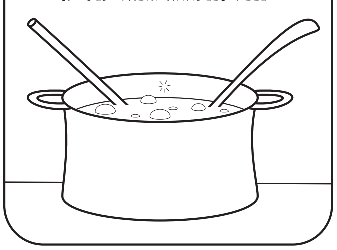
In actuality, the temperature of the man's breath was always the same. How can you explain the fact that the same breath can be used both to cool and warm something?



Because heat always flows from the warmer object to the cooler object. If the object is cooler than the breath, the breath will warm the object. If the object is hotter than the breath, then the breath will be warmed as it blow across (and the object will be cooled because it warmed the breath).

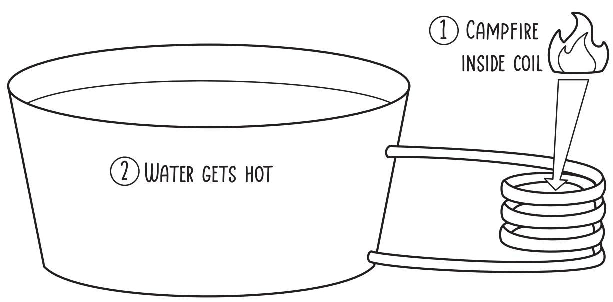
*What is your prediction for each situation below? Check the box you agree with, then describe how the heat is being **transferred**.*

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



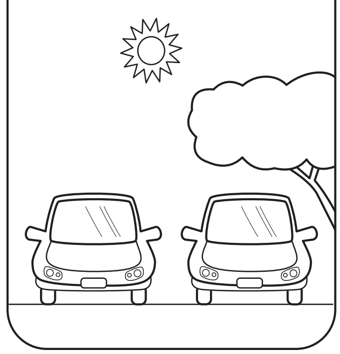
- [ ] *Both spoons are hot*
- [x] *Metal spoon is hot, wooden spoon is cool*
- [ ] *Wooden spoon is hot, metal spoon is cool*
- [ ] *Both spoons are cool*

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.



- [x] *This would work*
- [ ] *This would not work*

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



- [x] *Car in the sun*
- [ ] *Car in the shade*

What is TRANSFERRING the heat?

Rapidly moving molecules that bump into each other. (water to metal spoon, atoms of metal to other atoms of metal). The free electrons in the metal also convey heat through the metal.	Rapidly moving molecules that bump into each other. As the campfire heats the water in the coiled pipe, the hot water molecules move more rapidly. This hotter water rises, moving out to the top of the tub. This creates a current that draws cooler water into the coils from the bottom of the tub.	Light and infrared radiation (heat) pass through the window and into the car. The air molecules in the car are heated by this radiation.

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. FASTEST 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!

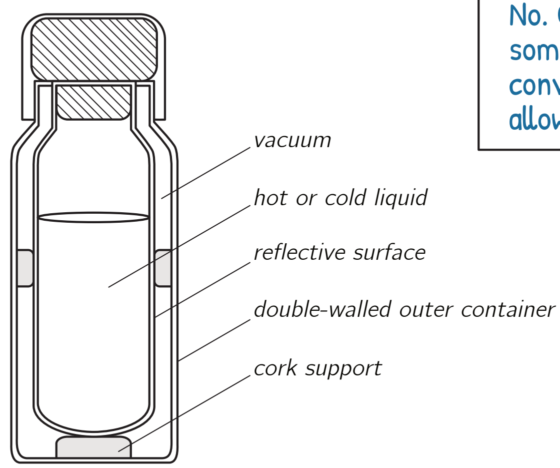
FIND 3 EXAMPLES OF THERMAL CONDUCTORS IN YOUR HOME:

Examples could include: metal cooking pots and pans, copper pipes, oven racks, toaster (the metal filaments inside), hair dryer, an iron for ironing clothes, metal doorknobs and handles (which feel cool to the touch because they are conducting heat away from your hand)

FIND 3 EXAMPLES OF THERMAL INSULATORS IN YOUR HOME:

Examples could include: double paned windows (the air in between the glass insulates the window), fiberglass insulation in walls, the cloth, foam, or rubber in an oven mitt, a styrofoam cup, a thermos with a layer of air in between the layers, etc.

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?

No. Convection and conduction both need to happen through some kind of matter. The vacuum has no matter, so there is no convection or conduction heat transfer through it. Air would allow some heat transfer (although not a great deal)

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

Radiation or radiative heat transfer.

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.

   The lid would cause the hot chocolate to cool down more slowly or stay warmer longer. The lid would stop steam from rising up into the air. The layer of warm air under the lid would also act a bit like an insulating layer.

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.

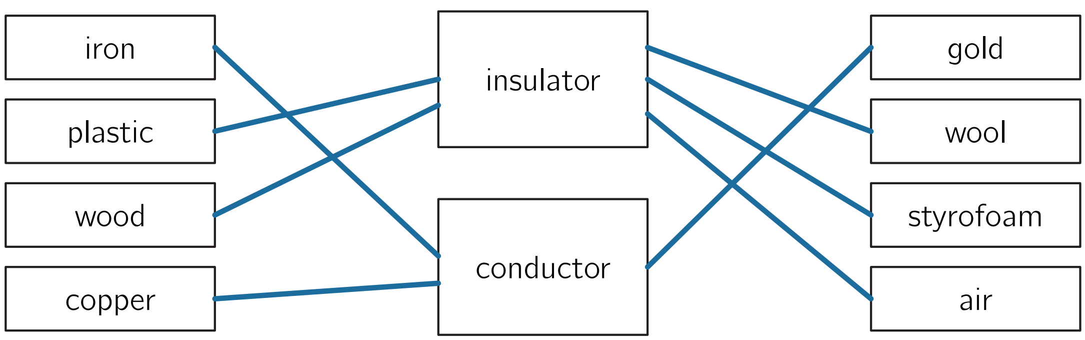
   Metal feel colder than wood at the same temperature because metals are better conductors of heat. When Emily touches the metal railing, it conducts heat away from her skin more efficiently than the wooden post. The higher heat transfer means the metal feel colder, even though both are at the same temperature.

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.



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

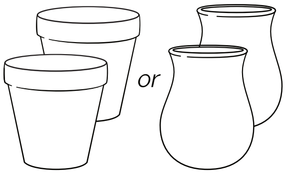
A substance is a good thermal conductor if it allows heat to flow easily through it. This is often due to its atomic or molecular structure, which allows energetic particles to quickly transfer their energy to neighboring particles.

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

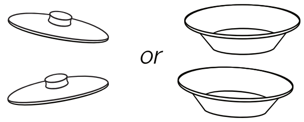
Insulators have a structure that restricts the flow of heat. Their atoms or molecules do not transfer energy as effectively as conductors, so they slow down or prevent the transfer of heat.

MAKE A FRIDGE FROM CLAY AND SAND

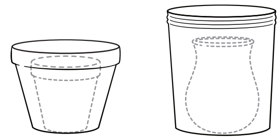
MATERIALS



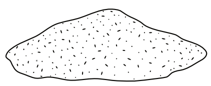
2 small clay pots or vases



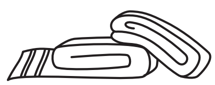
2 metal lids or aluminum pie tins that can cover the top of the clay pots



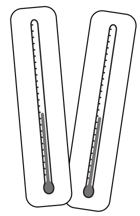
2 buckets or clay pots that are larger than the small clay pots



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.

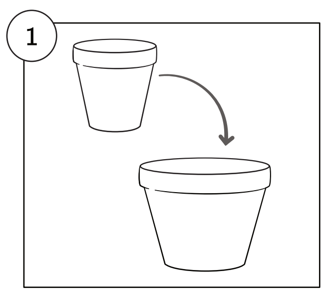
2. Fill the space between the small pots and the larger containers with sand. Label one setup "wet" and the other one "dry."

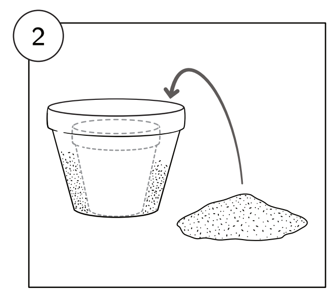
3. Pour water into the sand of the pot labeled as "wet" until the sand is completely moist. Be careful not to pour water into the inner pot. Leave the sand in the "dry" pot as is.

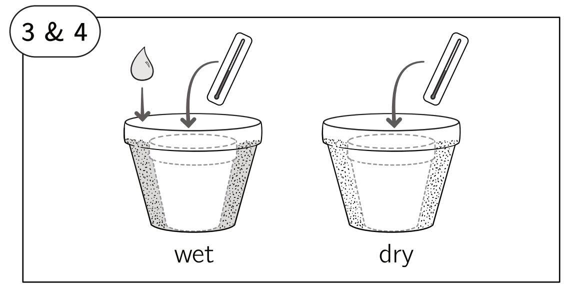
4. Place a thermometer inside each clay pot and take a temperature reading. Then cover both of the clay pots with metal lids.

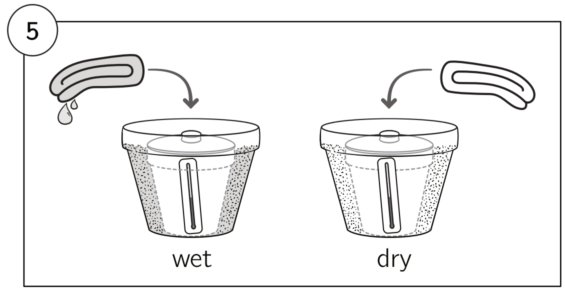
5. Get one of the towels completely wet and ring out excess water. Place it over the clay pot that has wet sand. Place the other towel over the dry clay pot.

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.





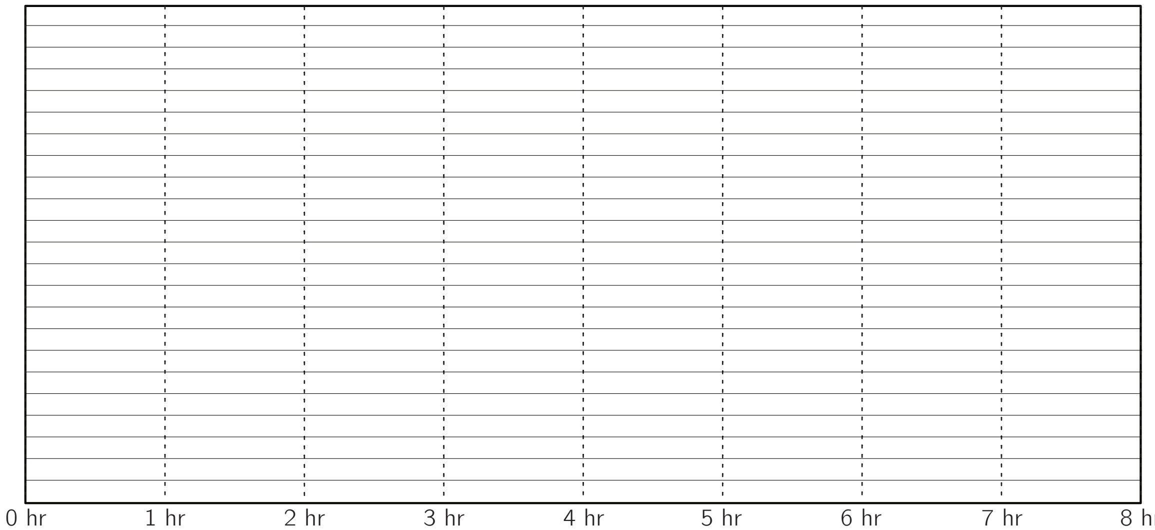




When water evaporates, it absorbs heat from its surroundings. This principle is used in many cooling methods such as sweating, swamp coolers, misters, cooling towers in industrial plants, and "pot in pot" refrigerators or Zeer pots.

A Cool Experiment

Label temperature on the Y axis



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

- ☐ Wet
- ☐ Dry

Which clay pot fridge had lower temperatures inside?

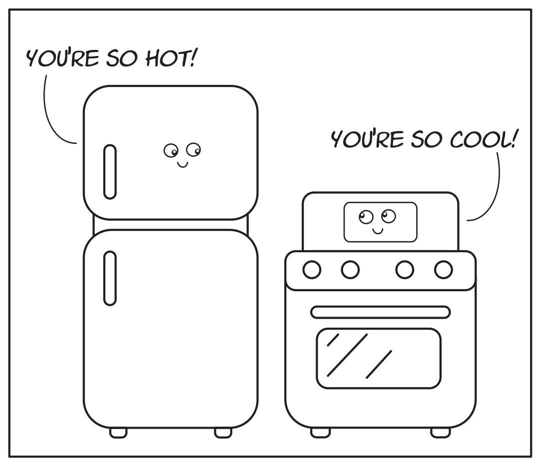
____

What caused the differences in temperature between the 2 pots?

____

____

____



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.

____

____

____

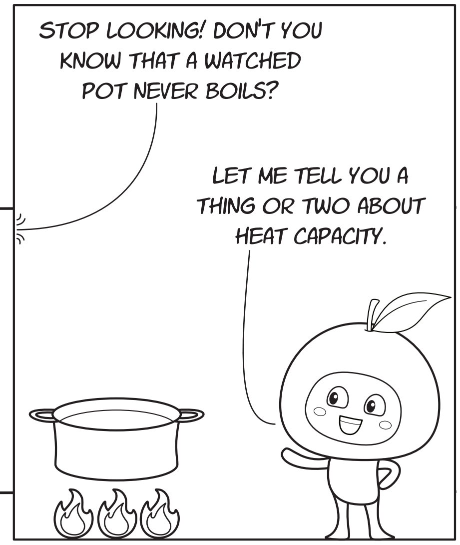
What could be changed to improve the clay pot fridge? Could it preserve food and keep the internal temperature near 3 to 5 °C or 40° F? Why or why not?

____

____

____

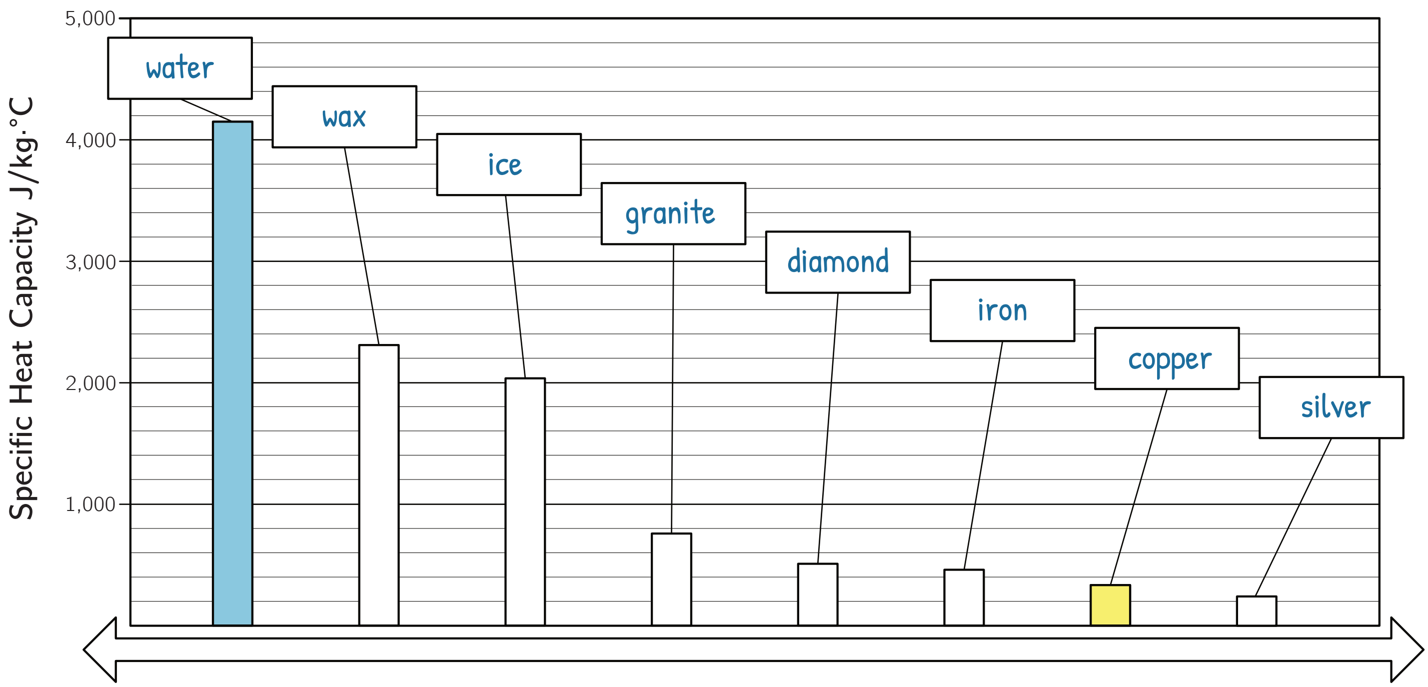
Specific Heat Capacity



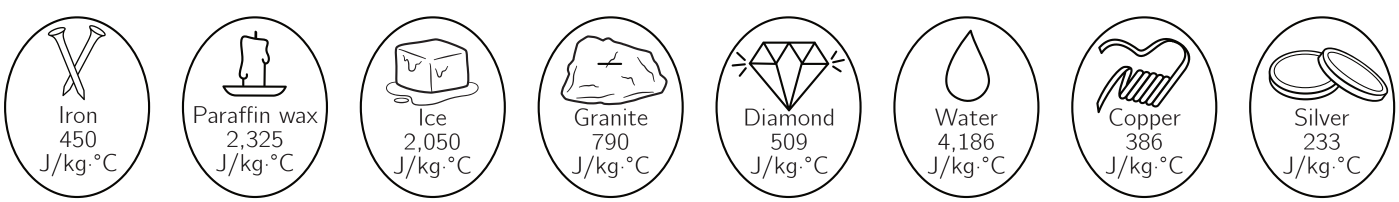
Fill in the blanks:

heated	*energy*	*degree*	*gram*

Specific Heat is the amount of heat ___energy___ required to raise the temperature of one ___gram___ of a substance by one ___degree___ Celsius. It is a measure of how easily a substance can be ___heated___ or cooled.



Use the information in the circles below to label the chart above. Color the bar for water blue and copper yellow.



List 2 or 3 examples where objects respond differently when exposed to the same amount of heat:

Examples could include:

*A metal seat buckle in a hot car vs cloth seat belt.

*Water vs sand at a lake or beach

*Metal vs plastic playground slide

*Copper bottom pot vs stainless steel pot

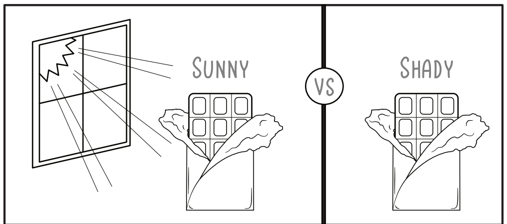
DID YOU KNOW?

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

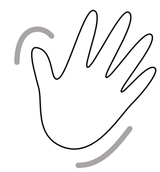
Do melting & vaporization ABSORB or RELEASE energy? *Consider these questions before answering:*



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?

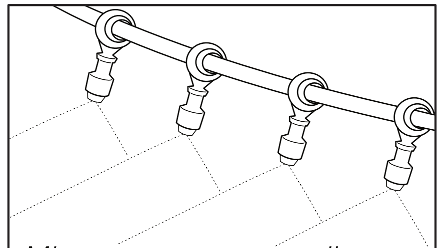
The chocolate in the sunny location will melt because it is receiving heat energy (in the form of radiation) from the Sun.



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?

The hand feels cool because of evaporative cooling. The alcohol absorbs energy/heat from the hand as it evaporates.

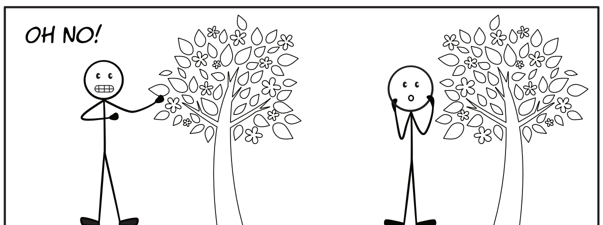


Misters spray super small water droplets into the air, which then evaporate.

Why do the misters cool the area underneath?

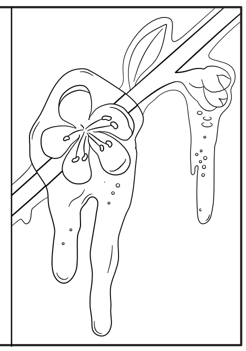
Evaporative cooling! As the water evaporates it absorbs heat from the surroundings.

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.

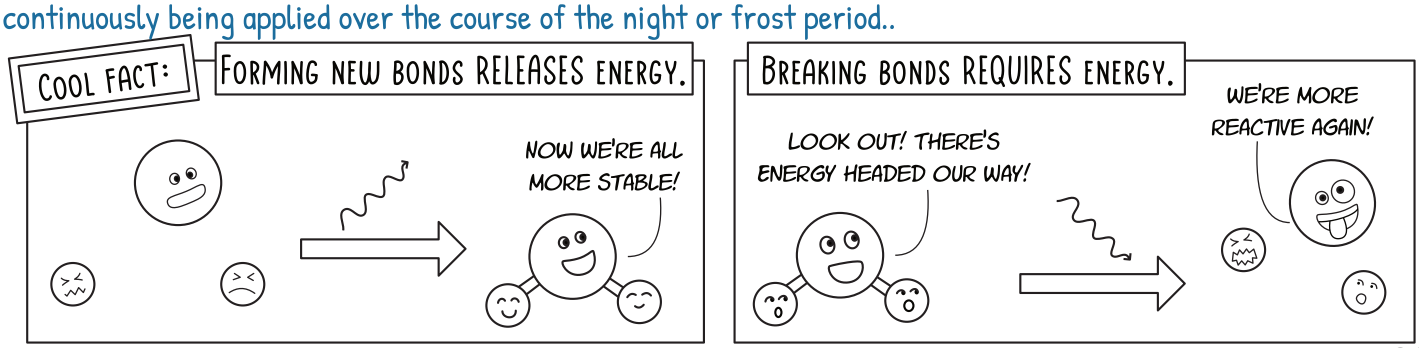
Deja turns on sprinklers all night, covering the trees in a layer of ice. Bob doesn't turn on sprinklers.



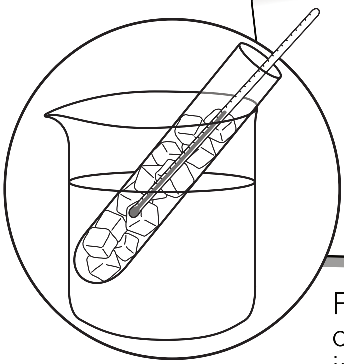
Deja's trees have flowers after the frost. Bob's trees lose all of their blossoms.

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?

When water changes from liquid to solid (freezes), it releases heat. This released heat is absorbed by the surrounding environment. Even though the water on the plants is turning into ice, the process of freezing actually releases enough heat to keep the plants at a temperature just above freezing. This only works in certain conditions. If it is too cold, frost irrigation won't keep the plants from freezing. It also only works if the water is continuously being applied over the course of the night or frost period..



Change of Phase



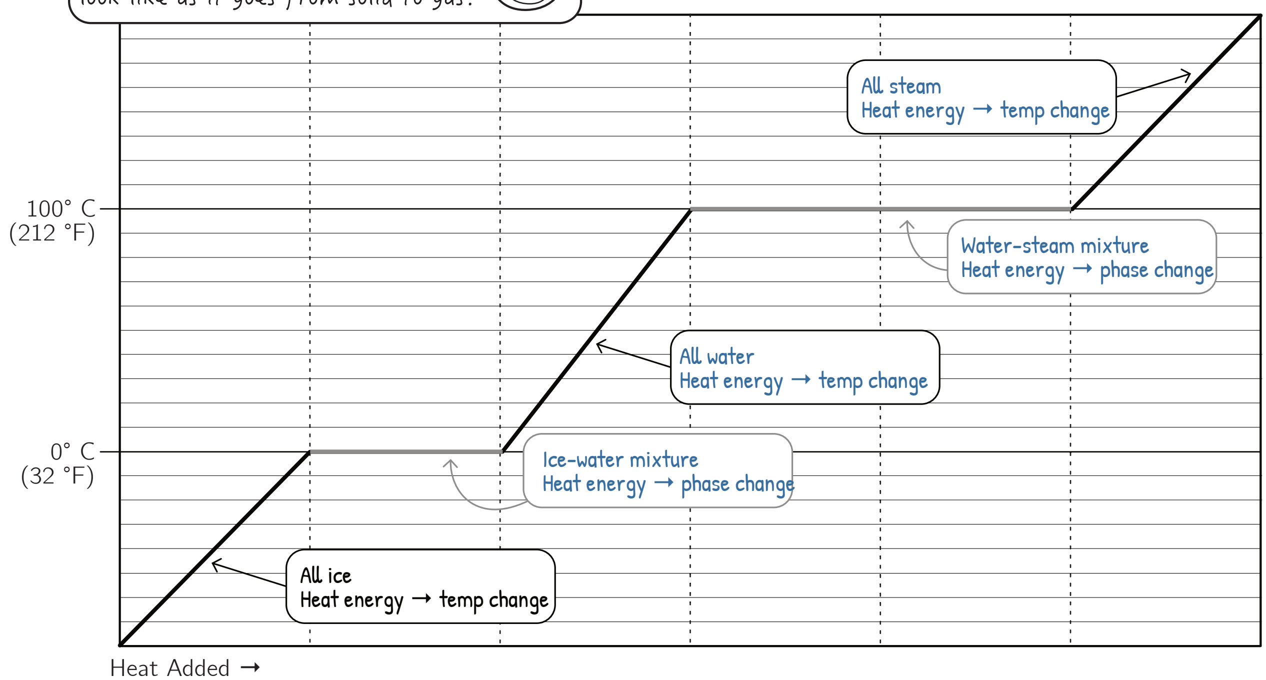
Frozen water is placed in a glass tube along with a thermometer then heated until it melts and then boils into gas.

Below is a graph of the temperature change as heat is added. This is called a heating curve.

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.

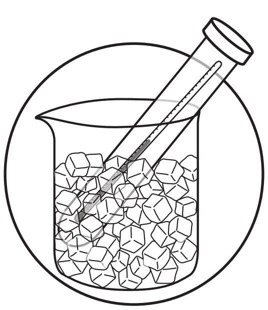
HEATING CURVE

What will the temperature change look like as it goes from solid to gas?

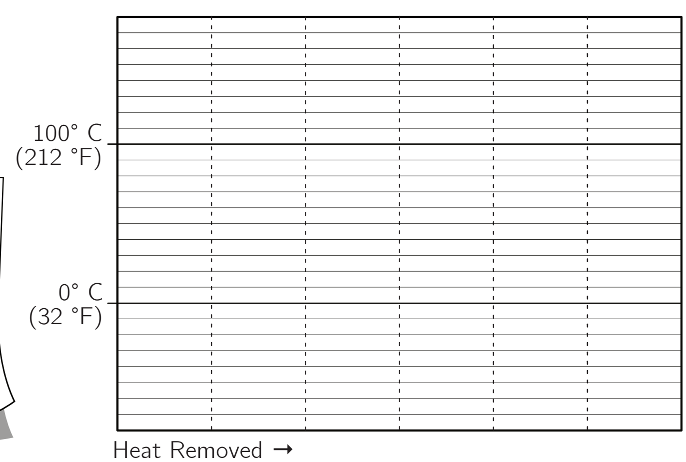


COOLING CURVE

What about from gas to solid?



Gaseous water is placed in a container along with a thermometer then cooled until it condenses and then freezes. Draw the cooling curve!



PRACTICE PROBLEMS – HEAT CAPACITY & CHANGE OF PHASE

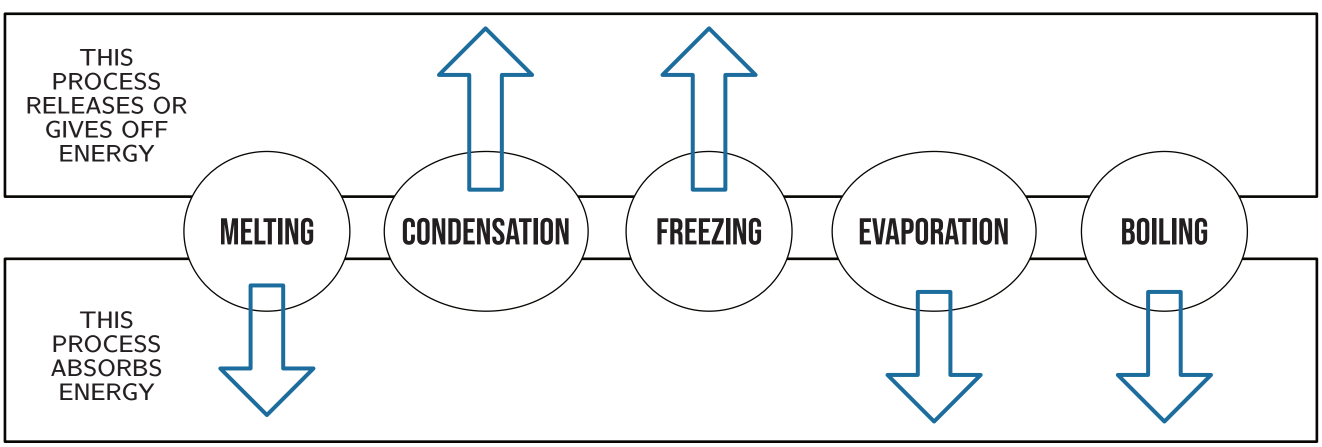
1. When water is boiling, it is undergoing which phase change?
   A. Melting
   B. Freezing
   C. Vaporization
   D. Condensation

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.

Melting occurs when a substance changes from a solid to a liquid state and requires heat to be added (endothermic). Freezing is when a substance changes from a liquid to a solid state and involves heat being released (exothermic).

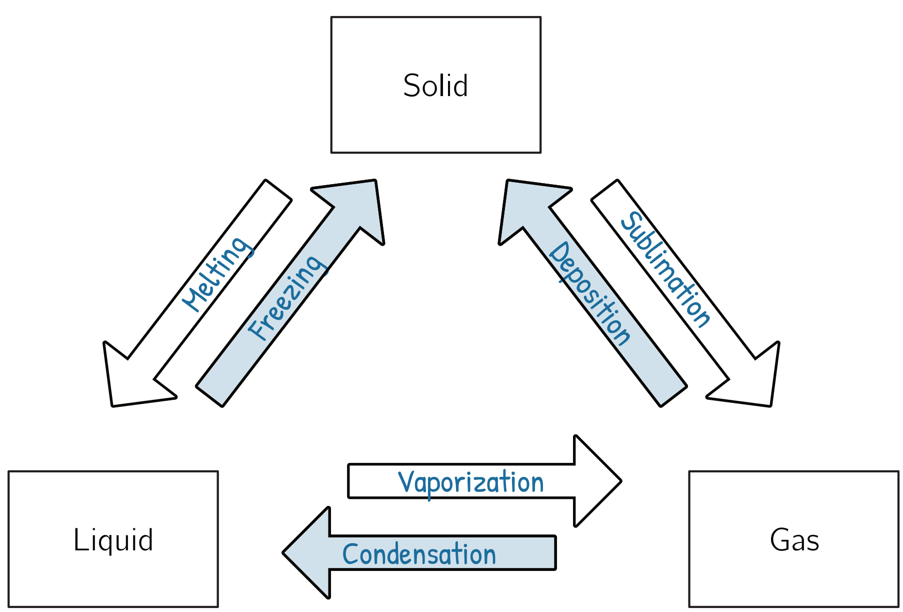
7. What is the difference between vaporization and condensation when considering heat transfer?

Vaporization is when a substance changes from a liquid to a gas and requires heat to be added (endothermic). Condensation is when a substance changes from a gas to a liquid state and involves heat being released (exothermic).

8. Why might some substances have a higher heat capacity than others?

Different substances have different atomic or molecular structures, which can affect how they store and transfer energy. A substance with a higher heat capacity can absorb more heat without a significant rise in temperature compared to another substance with a lower heat capacity.

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.

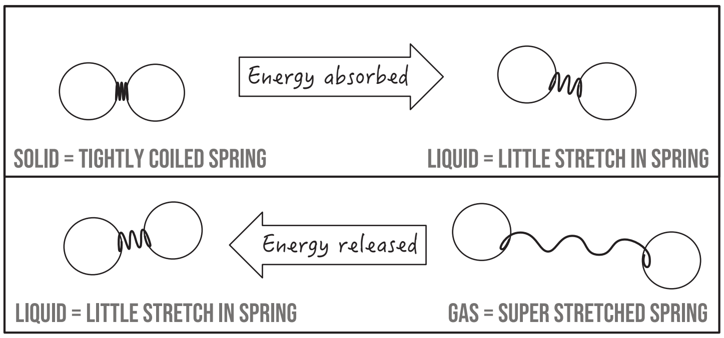


Thermodynamics

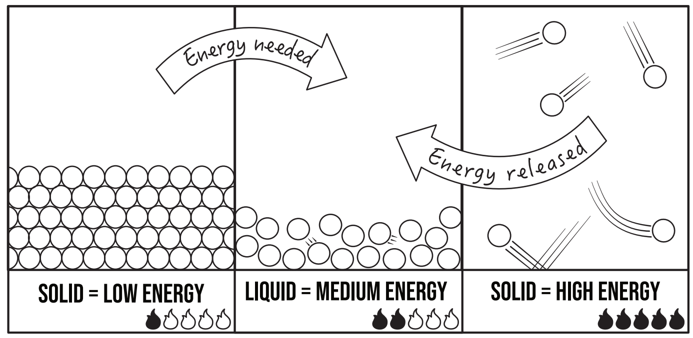
Review: Bob has water condensing on the outside of his fish tank and wants to know if the condensation is warming up or cooling down the tank. In other words, does condensation absorb or release heat? How would you explain the answer to Bob?

Answers will vary, but hopefully include the fact that condensation involves moving from a higher energy state (gas) to a lower energy state (liquid) so heat will be released. The condensation is releasing heat. Although this process is warming the tank, it may or may not be a significant amount of warming depending on the size of the tank.

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?

Answers will vary.

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 it's correct description. Then draw diagrams or pictures to represent each concept.

HEAT

Diagrams or pictures will vary. Something with an arrow or other visual to show the transfer of energy would be great!

TEMPERATURE

Diagrams or pictures will vary. Something with particles and something to show their motion/movement would be great!

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

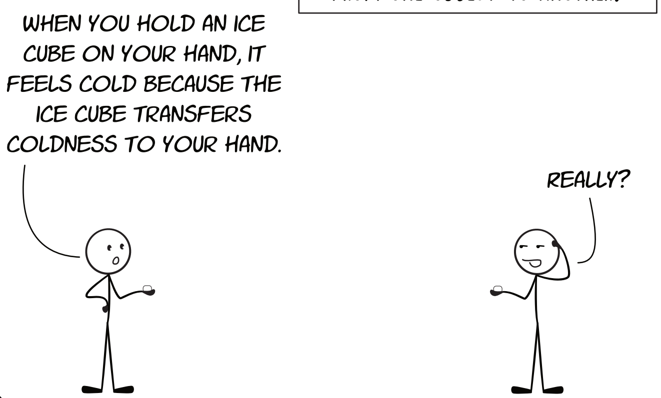
Thermal energy that is transferred from a warmer object to a cooler one.

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.



Correct the misconception:

Cold is not a transferable entity! Cold is the absence of heat.

When there is an ice cube on a person's hand, the hand feels colder because heat is flowing from the hand to the ice.

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.

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

Correct the misconception:

While higher heat correlates with higher temperatures, objects with different heat capacities will experience different changes in temperature when exposed to the same amount of heat.

For example, a copper and steel cup will both get very hot when filled with boiling water. A styrofoam cup, on the other hand, will not have nearly as much of a temperature increase when filled with boiling water even though it was exposed to the same amount of thermal energy.

PUTTING IT ALL TOGETHER

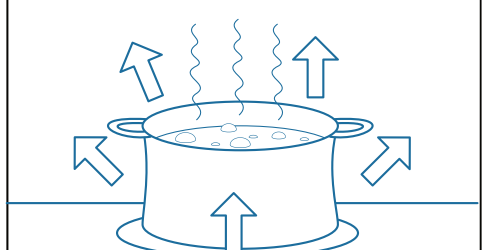
Much of what we've learned in this unit can be summarized in the three laws of thermodynamics.

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.

Answers will vary. Possibilities include a cup of tea getting cold when it is left out. A refrigerator transferring heat from inside to the back, anything involving cooking or heating a home in winter time or cooling it in summer etc.

HEAT TRANSFER EXAMPLE

Heat from boiling pot of soup is transferred to air and kitchen.

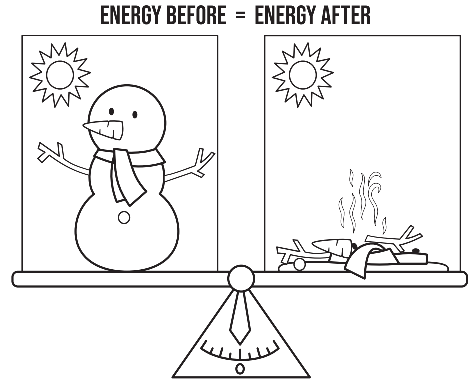


1st law: Electric energy is transformed into heat in the stovetop.

2nd law: the transfer of energy is not 100% efficient.

First Law of Thermodynamics

Also known as the Law of Energy Conservation!



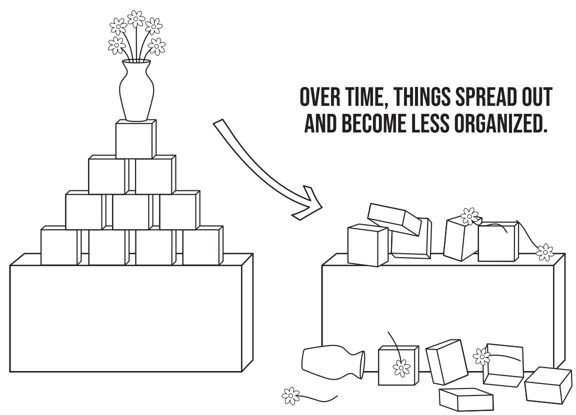
In a closed or isolated system, energy cannot be created or destroyed. It can only be transferred from one form to another.

$\Delta U = Q - W$

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 disorder or messiness of things tends to increase. The transfer of energy cannot be 100% efficient!

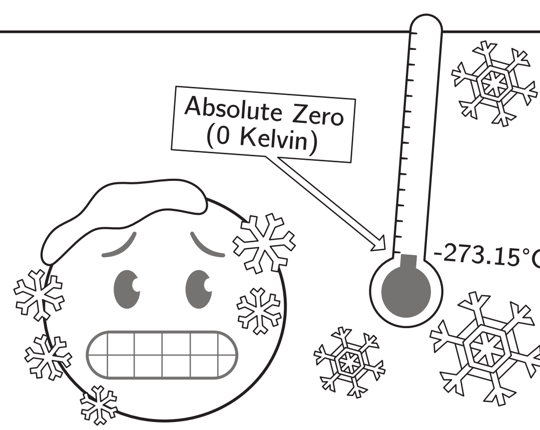
In other words, entropy is always increasing.

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 motion would stop.

As the temperature approaches absolute zero,

the entropy of the system decreases.

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

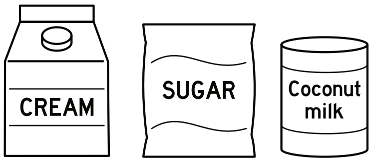
5. If you leave a hot cup of coffee in a cold room, what will happen according to the second law of thermodynamics?
   A. The coffee will get hotter.
   B. The temperature of the coffee and the room will equalize.
   C. The room will become hotter than the coffee.
   D. Nothing; the temperature will 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.

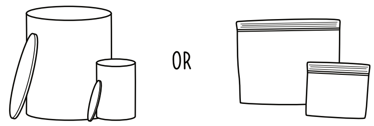
MAKE YOUR OWN ICE CREAM

MATERIALS



Ingredients for ice cream

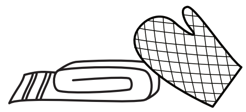
(For a dairy-based dessert, use sugar, cream, and desired flavorings. For a dairy-free dessert, use coconut milk, dates, and cocoa powder.)



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

Ice

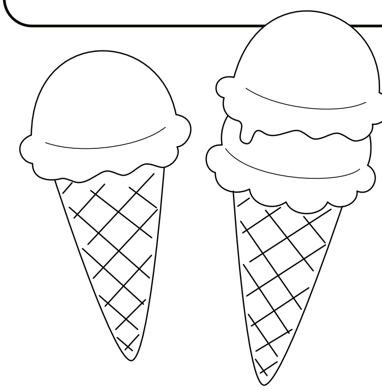
Rock salt



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!



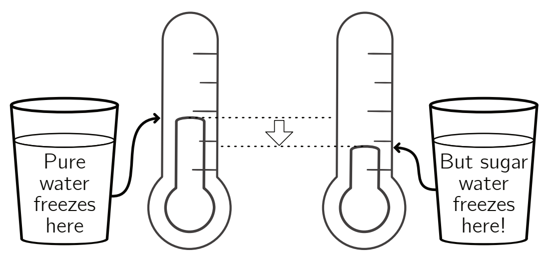
Pre-lab Questions:

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

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

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!

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:

1. **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.
2. **Refrigerate for 1 hour:** This step is optional but it will help the ice cream making go much quicker!
3. **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.
4. **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.
5. **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.
6. **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?

____

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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____

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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.

Answers will vary.

CONDUCTION: The transfer of heat through a substance, particle to particle.

CONVECTION: The transfer of heat by moving the heated substance itself.

ENTROPY: The measure of the disorder of a system.

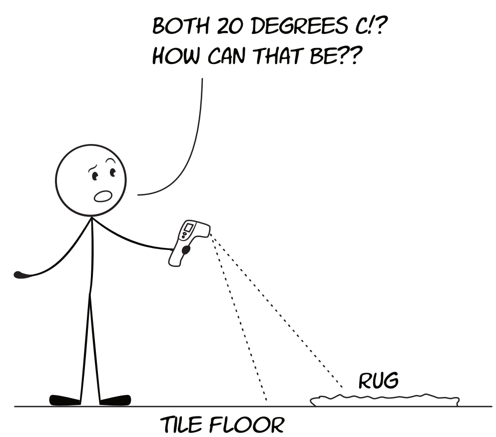
HEAT: The energy that flows from one object to another due to a difference in their temperatures. Heat is measured in calories or joules.

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?

Bob's understanding of thermodynamics is the thing that needs to be fixed here, not the thermometer!

The bathroom tile feels cooler to the touch because it is more efficient at transferring heat to Bob. The rug is a poorer conductor of heat, so there is less heat transfer. If the rug and tile were both very hot (say 90 °C) then the floor would feel hotter than the rug.



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: The quantity of heat required to raise the temperature of one grame of a substance by 1˚C.

RADIATION: Energy that is transmitted by electromagnetic waves.

TEMPERATURE: A measure of the average translational kinetic energy per molecule of a substance.

INTERNAL ENERGY: The total energy in the atoms and molecules within a substance

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:
   A. Particles lose energy when heated
   B. Particles attract each other when heated
   C. Heated particles move less and take up less space
   D. Heated particles move more and take up more space

5. What is an example of conduction?
   A. Sunlight warming the earth
   B. Hot water rising from a hydrothermal vent at the sea floor
   C. A metal spoon becoming warmer after being in a pot of hot soup

6. What is thermal energy or internal energy?
   A. The total kinetic and potential energy of the particles in an object.
   B. Only the kinetic energy of the particles in an object
   C. Energy that is transferred to the object's surroundings

7. What is temperature?
   A. The transfer of thermal energy
   B. The amount of coldness
   C. The average kinetic energy of particles in a substance
   D. 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?
   A. Convection occurs in fluids (gas and liquids) but not solids.
   B. Heat transfer by radiation must involve direct contact between objects.
   C. Conduction is the fastest form of heat transfer
   D. A and C are both true
   E. None of the above statements are true

10. When a substance freezes, heat is:
    A. released
    B. absorbed
    C. There is no change in heat

11. When a liquid vaporizes, heat is:
    A. released
    B. absorbed
    C. There is no change in heat

12. The first law of thermodynamics states that:
    A. Entropy is always increasing
    B. In an isolated system, energy will always be conserved
    C. Heat flows from cold to hot objects

13. Which phase change below releases heat?
    A. Evaporation
    B. Sublimation
    C. Melting
    D. Freezing

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