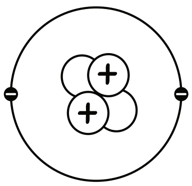
ELECTROSTATICS

The study of stationary charges

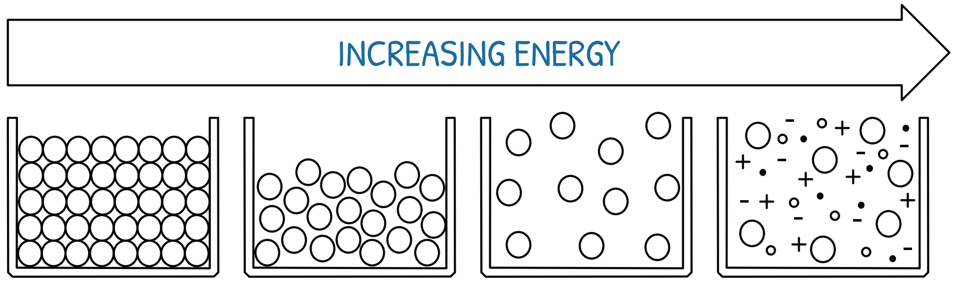
Quick Review:



Proton: In nucleus, positive charge

Neutron: In nucleus, no charge

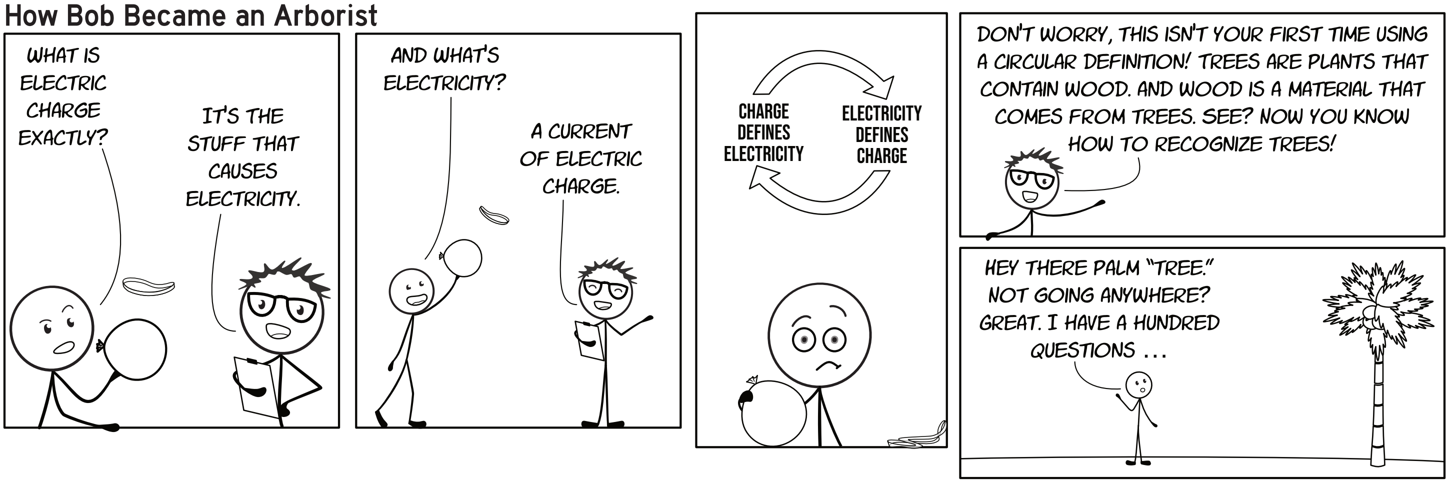
Electron: Orbits the nucleus, negative charge



SOLID | LIQUID | GAS | PLASMA

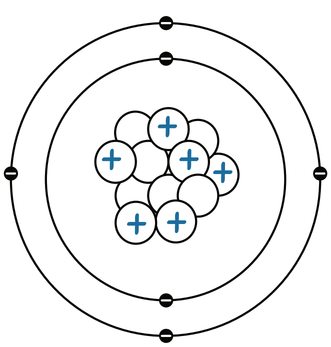
PLASMA: most abundant state of matter in universe

How Bob Became an Arborist



3 Important Facts About Charges:

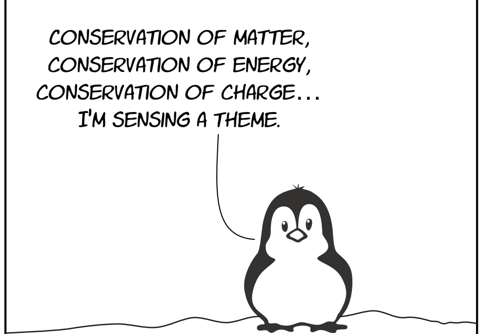
CHARGE IS A PROPERTY OF SUBATOMIC PARTICLES.



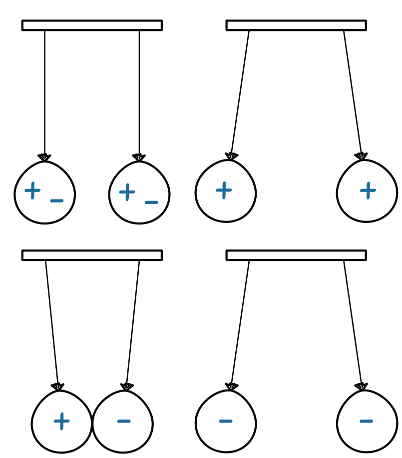
PROTONS HAVE positive CHARGE.

ELECTRONS HAVE negative CHARGE.

IN AN ISOLATED SYSTEM, CHARGE IS conserved. IT CAN BE TRANSFERRED BUT CANNOT BE CREATED OR DESTROYED.



Like CHARGES REPEL EACH OTHER AND opposite CHARGES ATTRACT EACH OTHER.



FILL IN THE BLANKS:

negative *positive* *neutral* *charge* *fundamental*

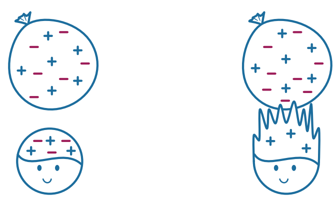
Charge is a fundamental property of matter. There are two types of charge which we call positive and negative. When an object has a negative charge, it possesses an excess of electrons compared to protons. When an object that has a net positive charge it has fewer electrons than protons. When an object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

Separating charges!

1. Peeling Scotch Tape

When scotch tape is pulled off it can develop either positive or negative charge depending on what surface/material it was pulled from and the order it was peeled. If the charges are the same, the pieces of tape bend away from each other. If the charges are opposite, the tapes bend toward each other. There is a force (electrostatic force!) at work here!

2. Rubbing a Balloon on hair



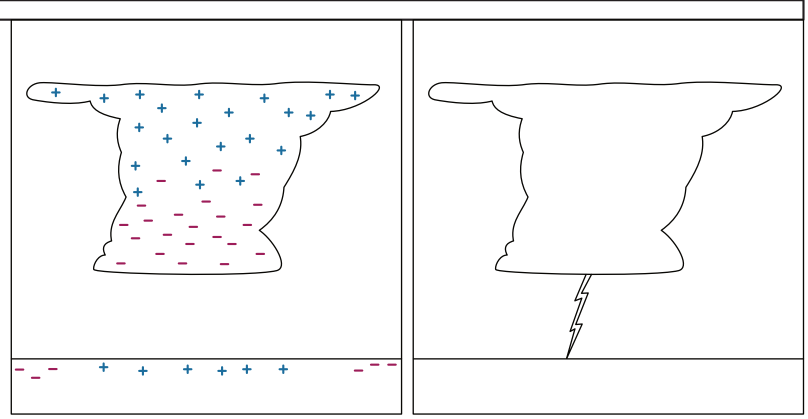
Before friction/rubbing, there are balanced charges on hair and balloon. Rubbing transfers electrons to the balloon, giving the balloon an overall negative charge and the hair an overall positive charge. This is why the hair rises up toward the balloon.

3. Rubbing a Balloon on a sweater

Before friction/rubbing, there are balanced charges on hair and sweater. Rubbing transfers electrons to the balloon, giving the balloon an overall negative charge and the sweater an overall positive charge.

Lightning!

The movement of air and other particles in large clouds causes the bottom of the cloud to develop a negative charge. This charge induces a positive charge in the ground below it. Lightning is an electrical discharge.



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?

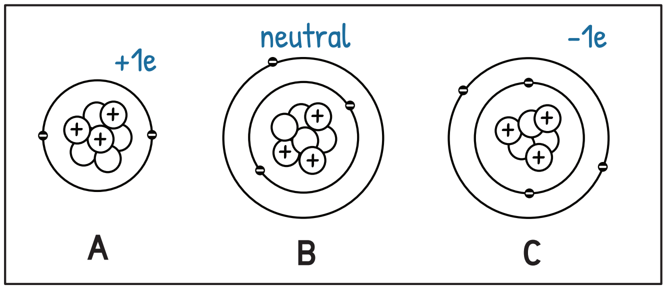
   Electrons are transferred from one source to another at the point of contact. Objects that receive electrons become negatively charged, objects that lose electrons become positively charged.

(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.

Atom A has 3 protons and 2 electrons. Since it has 1 more proton than electrons, it will have a positive charge.

Atom B has an equal number of protons and electrons, so it is neutral and has no net charge.

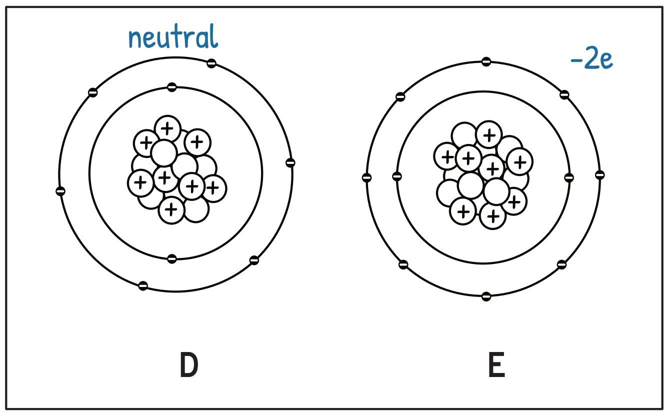
Atom C has 3 protons and 4 electrons, so it has a negative charge. Note: the number of neutrons does not impact the charge.



(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.

Atom D has 8 protons and 8 electrons. Since the number of protons and electrons is balanced, it will have no charge.

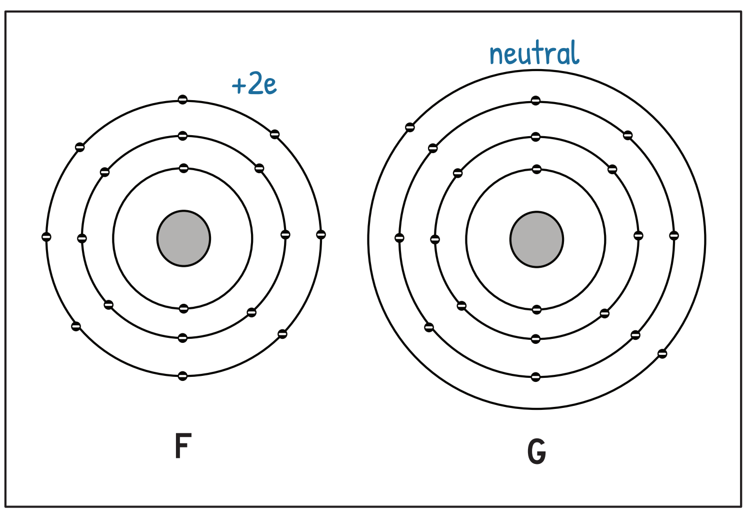
Atom E has 8 protons and 10 electrons so it has a negative charge.



(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.

Atom F has 20 protons and 18 electrons, so it has a positive charge (+2e).

Atom G has 20 protons and 20 electrons, so it has no charge.



The Current Event

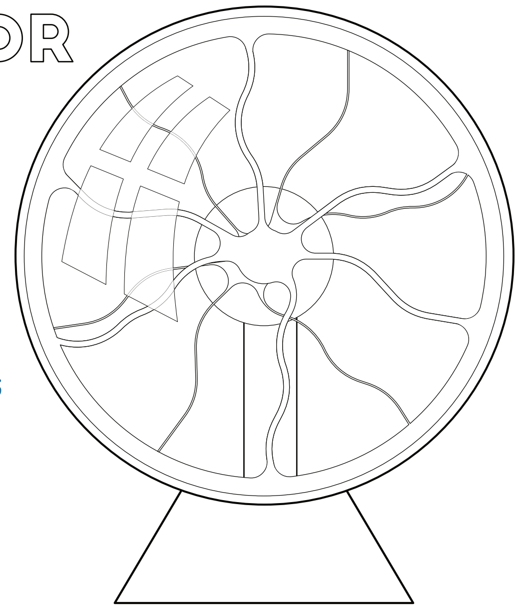
CONDUCTOR vs INSULATOR

CONDUCTORS have outer shell electrons that move freely

Examples: copper, aluminum, gold, silver. Most electric conductors are good thermal conductors too.

INSULATORS have electrons that are stuck with their atoms and don't move around freely. As a result, insulators are able to accept/store extra electrons.

Examples: air, plastic, glass, hair, cloth, diamond. Most electric insulators are also thermal insulators.

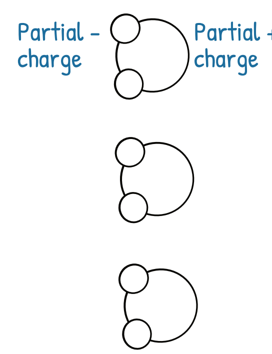


Is water an insulator or a conductor?

Pure water is an insulator because all of the electrons are bound and occupied with being a part of water.

But in reality, water isn't pure! Water that is exposed to air or just about any other substance contains ions. As a result, this type of water we encounter in every day life behaves as a conductor of electric charge.

A water molecule has a partially negative side and a partially positive side, so a narrow stream of water bends toward a charged surface.



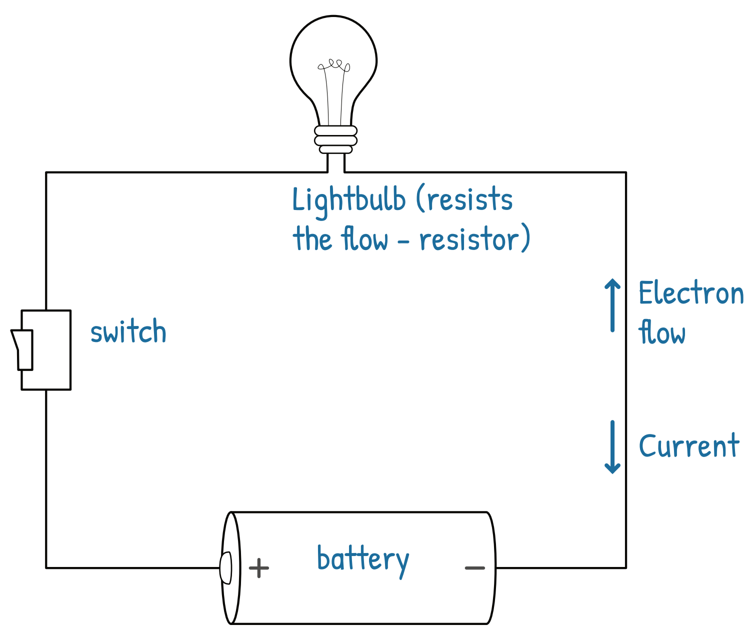
Will water be attracted to charged things?

Circuits

When electrons flow through an insulator (air) we get a discharge (lightning). When electrons flow through a conductor we get a current!

A circuit requires a closed loop.

Electrons flow from – to +



VOLTAGE (VOLT): • The work done to separate 1 C of charge
• The difference between 2 electric potentials

$\frac{J}{Coulomb}$ = Potential difference

CURRENT (AMPERE OR AMP): Charge is quantized because it always comes in multiples of an electron's charge!

$\frac{Coulomb}{second}$

RESISTANCE: A measure of the opposition to electric current. Measured in ohms, which are equal to 1 volt/1 amp. Insulators have higher resistance than conductors.

Ω OHM'S LAW: VOLTAGE = CURRENT · RESISTANCE

V=IR Voltage (V) = Current (I) · Resistance (R)

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?

Use Ohm's law: V = IR.

$V = 0.9\ A \cdot 1.8\ \Omega$

(Remember, ohms are equal to volts/amps, so amps multiplied by ohms = volts.)

$V = 1.62V$

It is safe for Sasha to use the charging cable. 1.62V is well under the 5V limit.

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 and developed Coulomb's 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.
   A. Plastic
   B. Copper
   C. Glass
   D. Wood

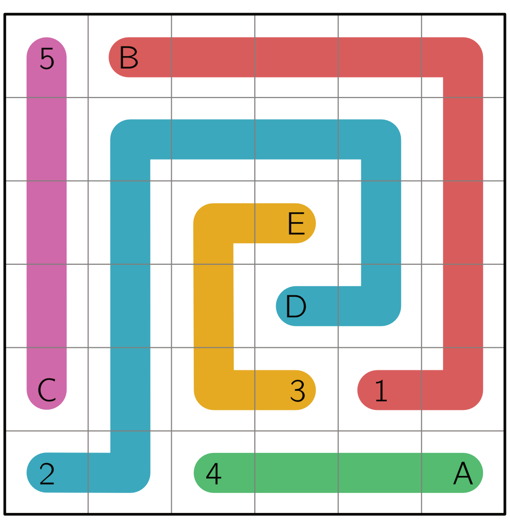
2. A material is made of atoms that loosely hold onto their electrons, leaving the ones in the outer shell free to wander around. This material will be a
   A. Conductor
   B. Insulator

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)
   A. The paper becomes charged as well by induction
   B. The paper is repelled and moves away from the balloon
   C. There is no change; the paper remains uncharged
   D. The paper is attracted to the ballon because all insulators have the same charge

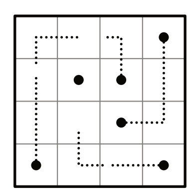
4. **Electrical potential** is called:
   A. Voltage
   B. Current
   C. Resistance
   D. Amp

5. The **flow** of electrons in an electrical current is called:
   A. Voltage
   B. Current
   C. Resistance
   D. Amp

Pipe Flow Matching

6. 

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.

1. Electrostatics	A. A charged atom
2. Conductor	B. Electricity at rest
3. Insulator	C. SI unit of electric charge
4. Ion	D. Allows charged particles to flow
5. Coulomb	E. 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 Ω stand for in physics?
   A. Ohms
   B. Amps
   C. Volts/Amps
   D. Coulombs

Resistance is measured in ohms (Ω).

1 ohm is equal to 1 volt/1 amp.

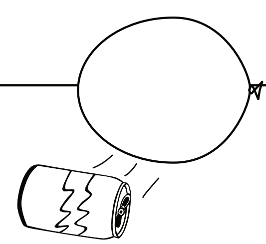
9. What is required for current to flow in a circuit?
   A. A resistor
   B. An insulator
   C. A light bulb
   D. A closed loop

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

Voltage (V) = Current (I) · Resistance (R)

Explain the rolling can:



When the balloon is rubbed on another material it accumulates excess electrons and develops a charge. Since the aluminum can is a conductor it cannot develop a charge unless it is well insulated from its surroundings. So it has both + and – charges.

When the balloon is brought close to the can, the negative charge in the can gathers on the opposite side of the can. This gives the part of the can closest to the balloon a net positive charge.

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 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.

WHAT'S A WATT?

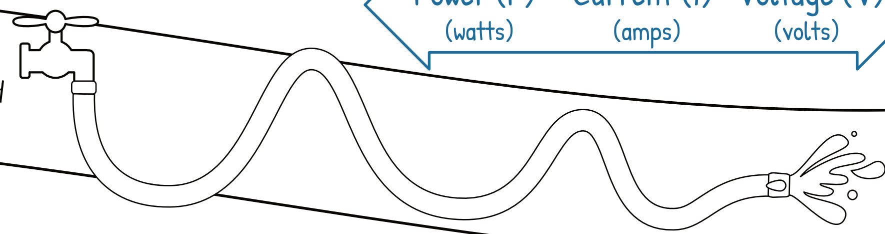
THE UNIT OF ELECTRICAL POWER: Watts measure power. They are the rate of electrical work (1 watt = 1 ampere of current flowing across an electric potential difference of 1 volt)

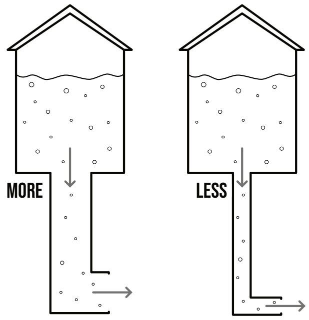
1 watt = 1 Joule/second

Power (P) = Current (I) · Voltage (V)
(watts) (amps) (volts)

THE WATER PIPE ANALOGY*

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



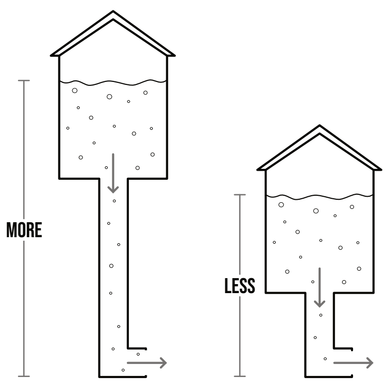


FLOW RATE IS LIKE:

Electric current (amps)

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.

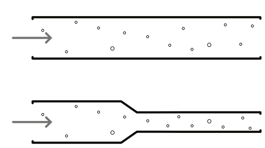


WATER PRESSURE IS LIKE:

Voltage (volts)

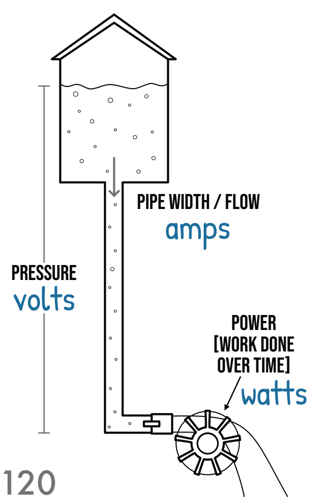
A RESTRICTION IN THE FLOW IS LIKE A CHANGE IN:

Resistance (ohms)



THE AMOUNT OF POWER A WATER SYSTEM HAS IS LIKE:

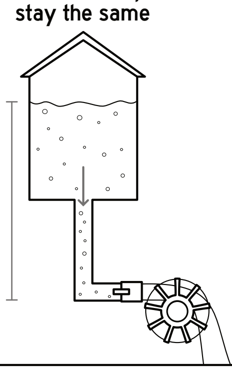
Wattage (watts)



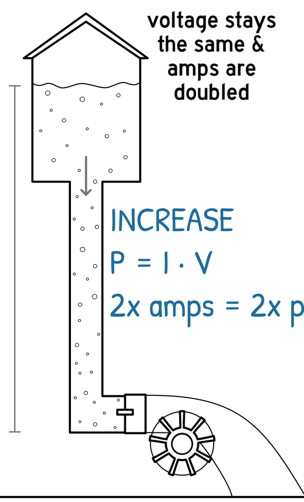
WHAT WILL HAPPEN TO POWER (WATTS) IN EACH OF THESE CASES? COMPARED TO THE FIRST TOWER WITH A WATER WHEEL, WILL THE POWER/WATTAGE INCREASE, DECREASE, OR STAY THE SAME?

DECREASE
Power = Current · Voltage
½ voltage = ½ power

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



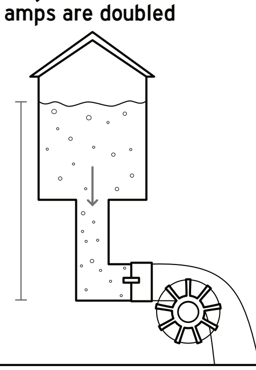
voltage stays the same & amps are doubled



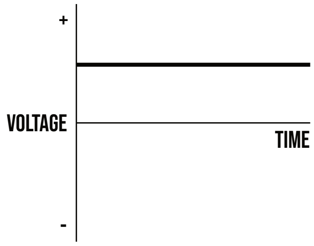
INCREASE
P = I · V
2x amps = 2x power

STAY THE SAME
P = I · V
2x amps · ½ voltage = same power as before

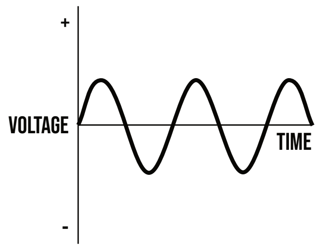
voltage is cut in half & amps are doubled



ALTERNATING CURRENT VS DIRECT CURRENT

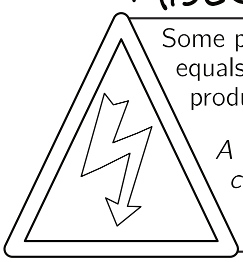


Direct current: Has constant voltage. Used in electronic devices like computers and phones. All batteries use DC. Solar panels too.



Alternating current: Flow of electric charge reverses or alternates. Voltage also alternates. AC is more efficient for being transmitted over long distances. Homes are wired for AC and AC is most common in the electric grid as a whole.

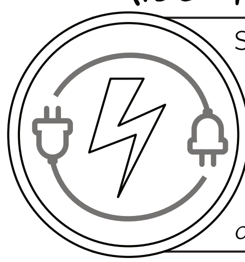
MISCONCEPTION ALERT #1



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

Typical LED lightbulb that produces 750 lumens of light requires 120 volts but only uses 9 watts.

An incandescent bulb that required 120 volts would use around 60 watts to produce the same amount of light.

LAPTOP CHARGER VS HAIR DRYER

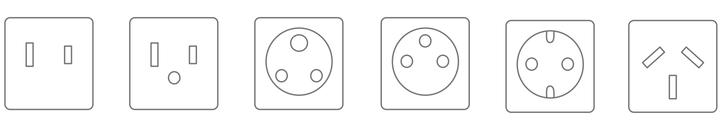
The laptop charger and hair dryer both plug into the same outlet with the same voltage. But the dryer will use a LOT more power than the charging cord!

CAR BATTERY

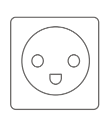
Relatively low voltage but still dangerous! If short-circuited it can cause dangerous burns and/or painful shocks.

WELDING EQUIPMENT

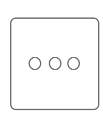
Relatively low voltage (10 to 30 volts) but very high current (up to 500 amps) and thus VERY high heat!



TYPE A TYPE B TYPE D TYPE E TYPE F TYPE I



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!

TESLA COIL

Incredibly high voltage - large ones can make over 1 million volts and small desktop ones can produce over 50,000 volts! While the voltage of a tesla coil is high, the CURRENT is low (milliamp range), which makes them relatively safe.

VAN DE GRAAFF GENERATOR

Can create incredibly high voltage (small models can generate over 100,000 volts) but because their current is low (around 0.0000001 amps) they are quite safe. People will often touch them in science demonstrations, making their hair stand on end.

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

   The first step in dealing with an electrical fire is to turn off the electricity. Otherwise, there could be a continual supply of new heat and sparks from the current that would overcome whatever suppression efforts were being used. Adding water would be VERY dangerous.

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

   Remember that Power (W) = Current (measured in amps) · Voltage (V)
   2 amps · 120 volts = 240 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

   Batteries use direct current.

Practice Problems – Whats a watt?

9. What does it mean if a light bulb is rated at 60 watts?
   A. It uses 60 volts of electricity
   B. It draws a current of 60 amperes
   C. It uses 60 joules of energy per second
   D. None of the above

Remember a watt is defined as 1 joule/second.

10. Amil uses an 800 watt microwave at work and a 1200 watt microwave at home. Which one will cook food faster?
    A. The 800 watt microwave
    B. The 1200 watt microwave
    C. There will be no difference in cook time between the two microwaves

A 1200W microwave will heat food significantly faster than an 800W microwave. Although it uses the same voltage (is plugged into the same type of outlet) it uses much more power.

11. What would happen if you plug a device rated for 220 volts into a 120 volt socket?
    A. The device will operate more efficiently
    B. The device will operate faster
    C. The device will overheat because it is receive too much current
    D. 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?
    A) By using a high amount of current
    B) By using a low amount of current
    C) By having incredible resistance
    D) There is no such thing as a high wattage but low voltage device

Remember power (watts) = current · voltage
Low voltage · high current would equal high wattage.

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?
    A. The LED uses higher voltage
    B. The incandescent bulb is more efficient
    C. They use the same amount of electrical current
    D. 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.
    A. True
    B. False

Voltage is not the only factor determining electrical safety or risk! The CURRENT determines what degree of shock could occur and that depends on both the voltage and the power.

If the devices were electric heaters that were both going to produce 2400 watts, then the 240V device would use 10 amps of current while the 120V device would use 20 amps of current. The higher current used in the 120V device would be more likely to trip breakers or blow fuses.

15. Which of these appliances would use the most electric current (amperes) when operating?
    A. A 10-watt LED bulb running on a 120 volt supply
    B. A 1,500-watt hair dryer running on a 120-volt supply
    C. A 1,000-watt electric stove burner running on a 240-volt supply
    D. A 5-watt phone charger on a 120-volt supply

Remember watts = current· voltage
Divide both sides of the equation by voltage to get current = watts/voltage.
Hair dryer uses 12.5 amps. Stove uses 4.6. The phone and lighbulb use less than 1.

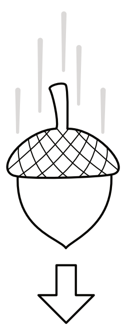
Marvelous Magnets

Fill in the blanks:

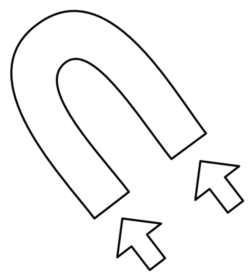
gravity | electrostatics | repel | force

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

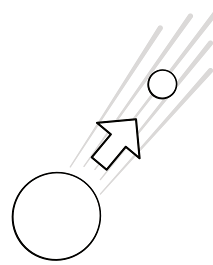
The 4 fundamental forces:



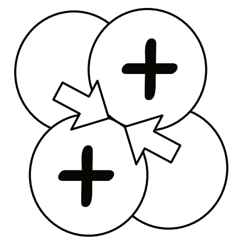
Gravitational force



Electromagnetic force



Weak force



Strong force

Infinite range but strength very strongly linked with distance (Gravitational force, Electromagnetic force)

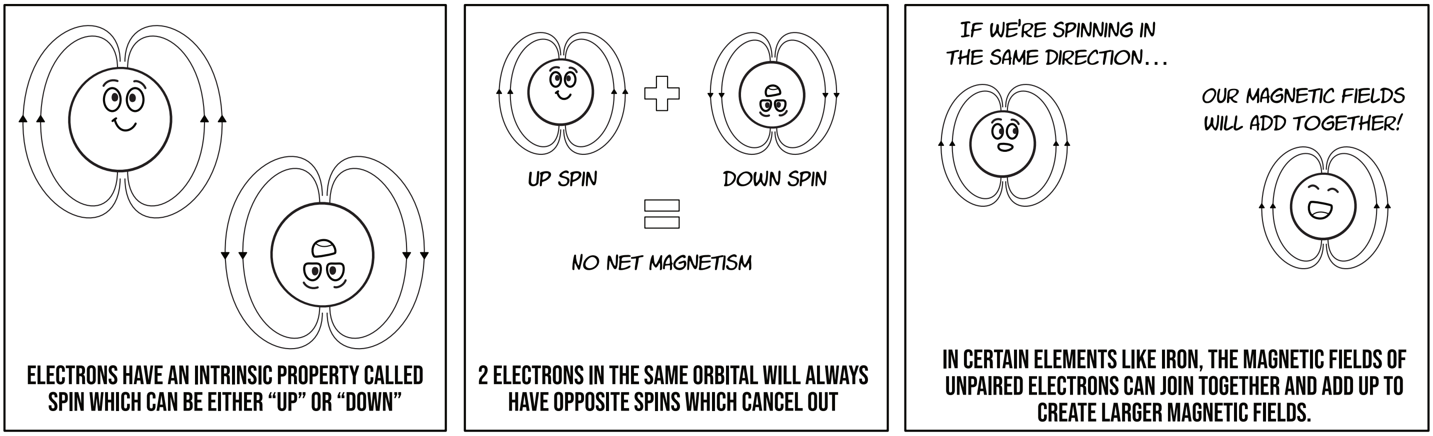
Only effective at short range, the dominant forces at subatomic level (Weak force, Strong force)

Which demonstration from class was your favorite? How did it work?

Answers will vary!

Science Mom's favorite was the "flipping magnets" demonstration. When similar poles of a magnet get close together, the repelling force is strong enough to flip one of the magnets over. Then the attractions between the N and S poles will pull them together.

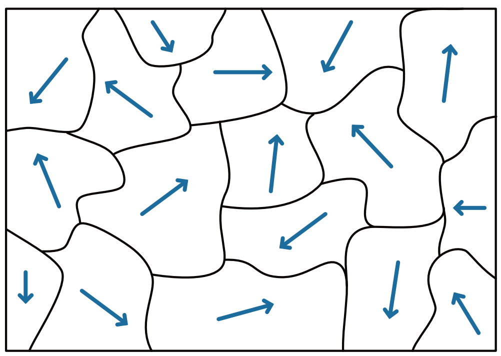
But what is magnetism? It's a force produced by the movement of charges! Since electrons are charged particles that move... they create small magnetic fields.



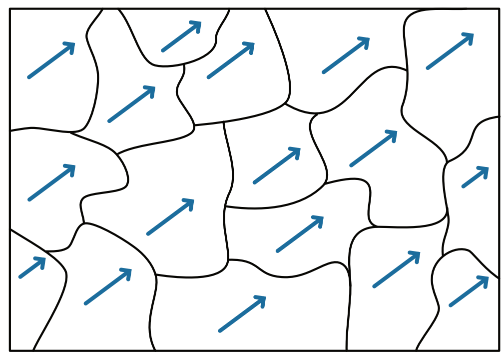
Most atoms have electrons which are paired in a way that cancels out their magnetic fields. Certain elements (like iron) have atoms with magnetic fields that can join together and add up instead of canceling out.

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.

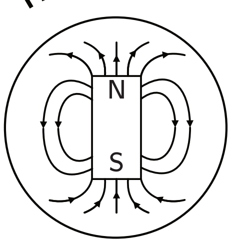


weak magnet / not magnetic



strong magnet

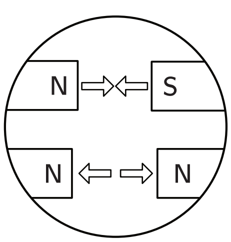
PROPERTIES OF PERMANENT MAGNETS:



Have magnetic poles (North / South) with magnetic field lines (go from north to south)

26 IRON 27 COBALT 28 NICKEL

Ferromagnetic materials are attracted to magnets and can become magnetized. Iron, cobalt and nickel are strongly ferromagnetic but they aren't the only materials that respond to magnetic fields. Others are paramagnetic (weakly attracted) or diamagnetic (weakly repelled).



Opposites poles attract each other, like poles repel each other

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

With the early compasses, the north-seeking pole of a magnet was defined to be "north" because it pointed in the direction we called "north." But remember, opposite poles attract!

This means the magnetic pole near Earth's geographic north pole is actually the south magnetic pole. If you stood at this location with a compass that could move in 3D, the needle would point straight down.

If you hold a compass by a bar magnet, it will always point at the S end of the magnet.

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 an 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

(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

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

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

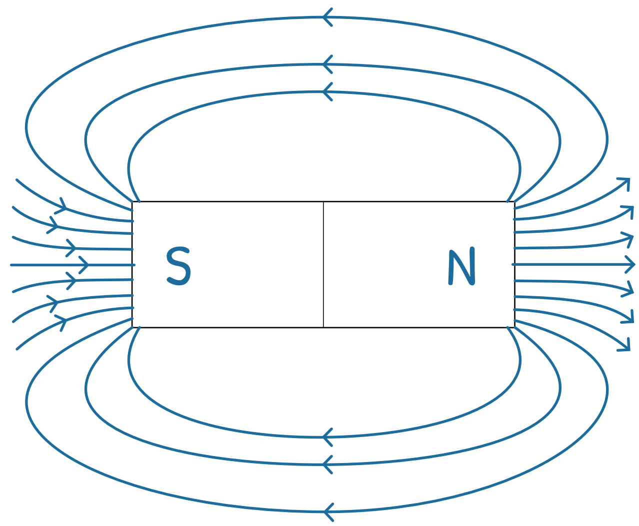
D. The force between magnets is dependent on gravity

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

ferromagnetic

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

Drawings may vary – important aspect is that lines go from N to S and are strongest / most concentrated at the poles of the magnet.



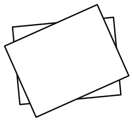
(14) List 3 examples of devices that use magnets:

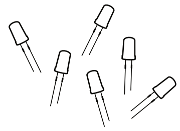
There are a lot of options! Here are a few:

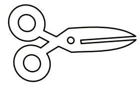
- Hard drive in a computer
- MRI machine
- Electric motors and generators
- Compass
- Credit card or debit cards – have a magnetic strip that encodes information to connect to financial institution
- Speakers and headphones – most speakers use a permanent magnet to convert the signal (electric energy) into sound (mechanical energy)
- Wireless charging pads
- Wind turbines
- Generators in a dam
- Maglev train
- Some computer cords have a magnet so it can snap off without damaging the cord or computer if it's tripped over

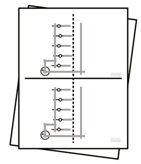
LED HOLIDAY CARD

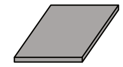
MATERIALS (TO MAKE 2 CARDS)

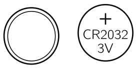

1 piece of cardstock


Between 3 to 20 LED lights (3 mm)

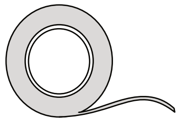

Scissors


Printed templates OR pencil and pen to create your own design

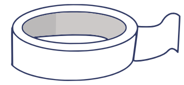

A small piece of cardboard (optional)

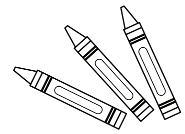


2 Button batteries (CR2032 3-volt batteries work well)


0.5 meters of conductive maker tape


Push pin OR sewing needle


Glue stick and tape


Coloring supplies

GOALS

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

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!

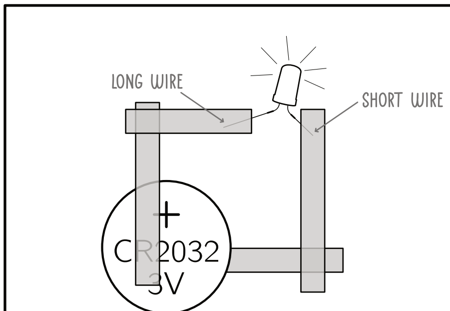


Figure A

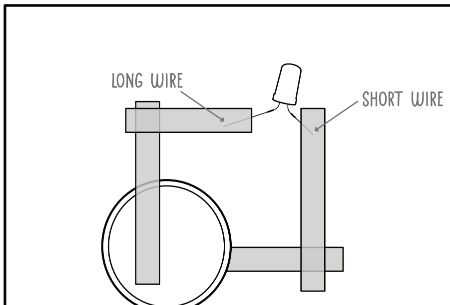
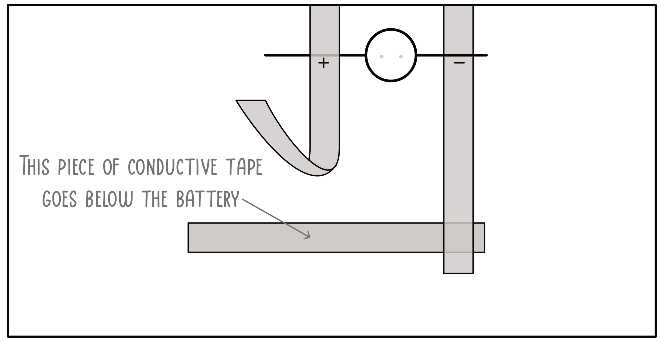


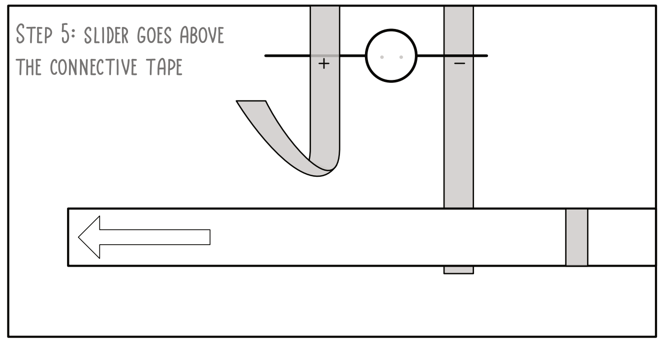
Figure B

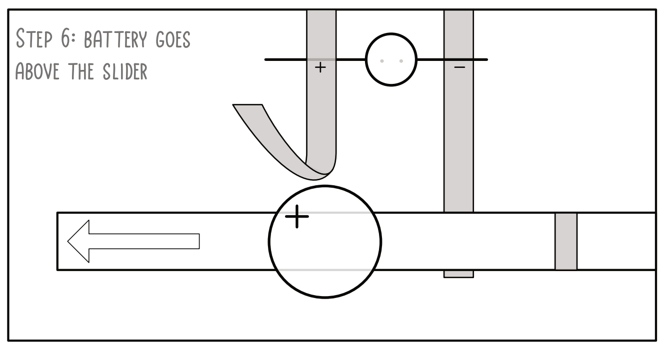
INSTRUCTIONS FOR A “SLIDER” CARD:

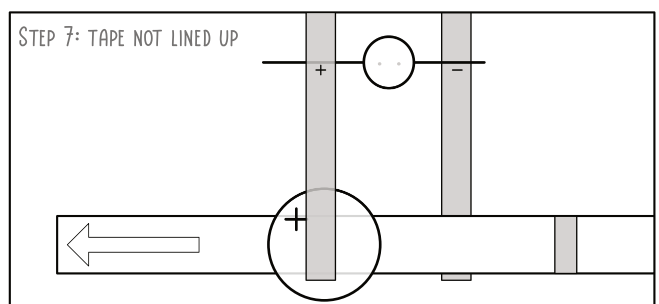
Matches the paper slider card template.

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.

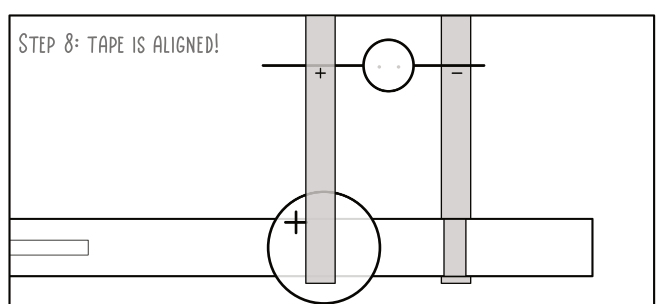








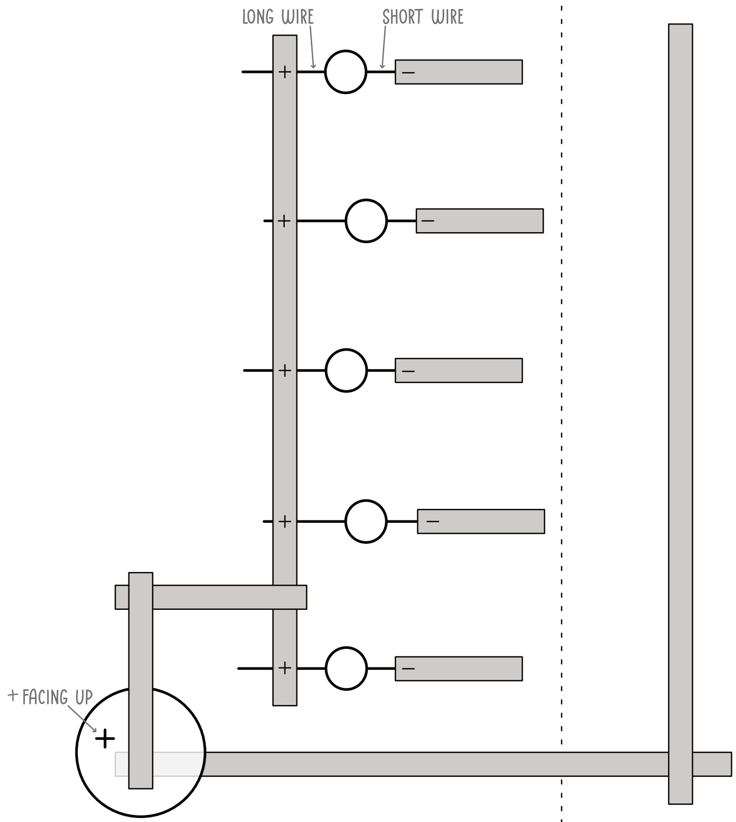
Circuit incomplete = lights off



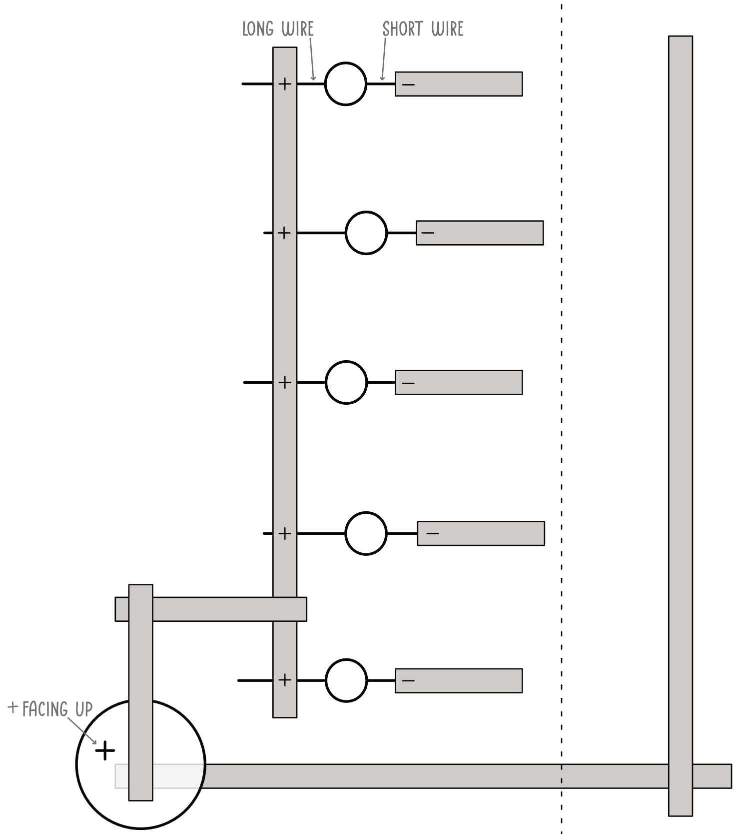
Circuit complete = lights on

TO MAKE YOUR OWN CARD:

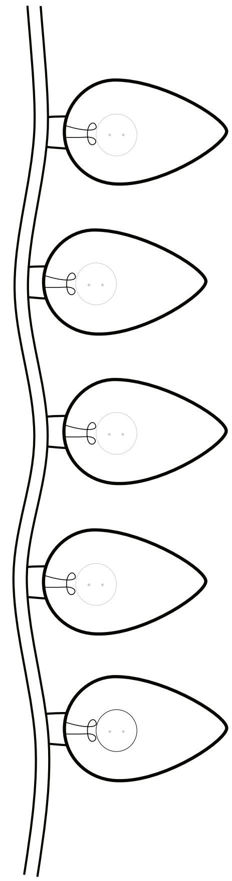
1. Design a circuit so that the circuit will be complete either when the card is closed or when a slider is moved into place.
2. Arrange the LED lights so that the long wires and short wires are all on the same sides.
3. Connect a button battery to the conductive tape so that the positive side connects 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.

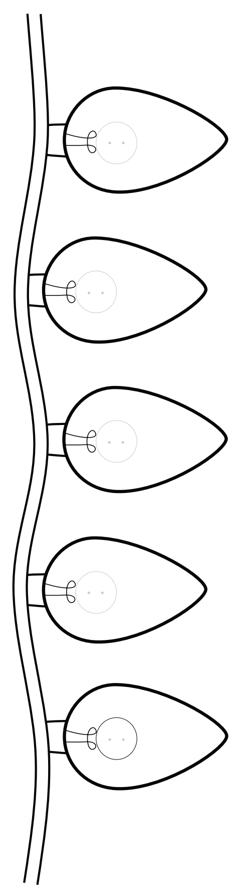


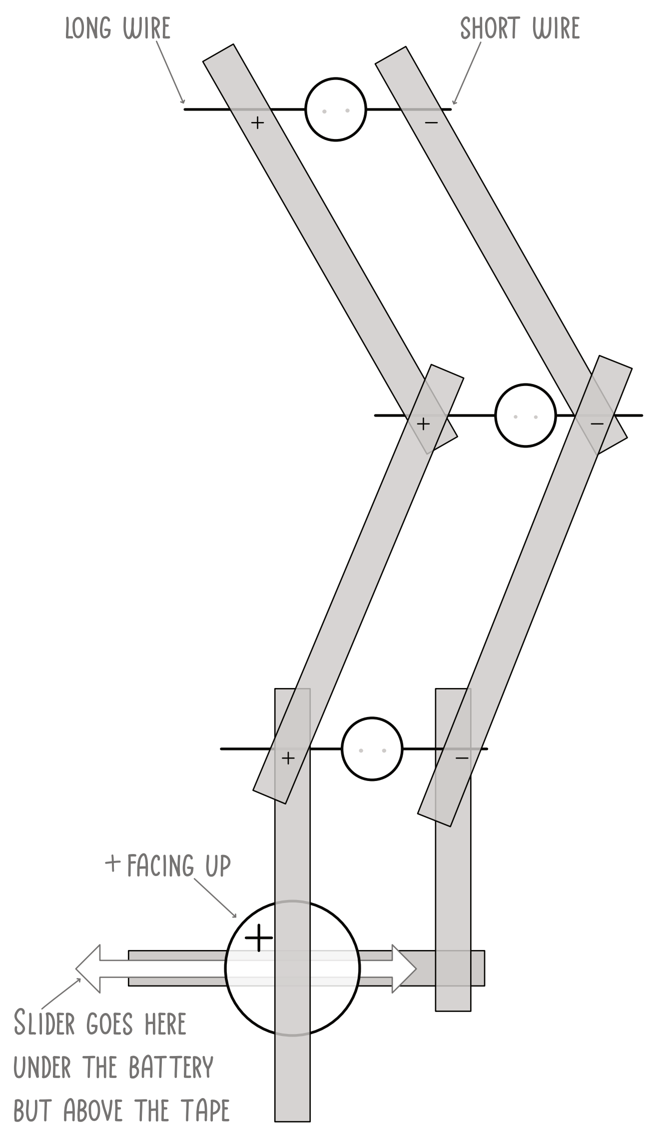
String of Lights LED
Circuit Card Template
SCIENCE MOM

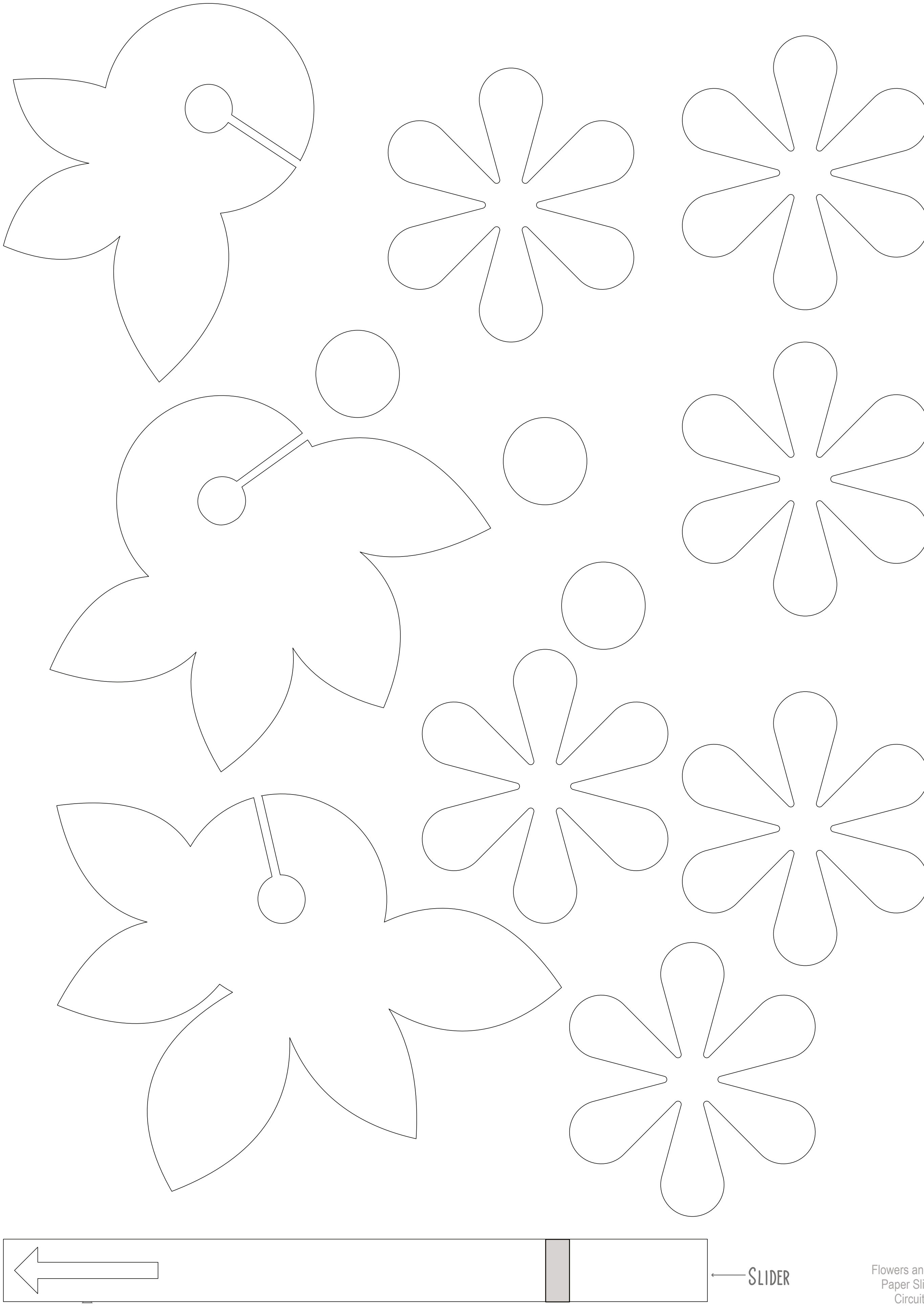


String of Lights LED
Circuit Card Template
SCIENCE MOM






LONG WIRE
SHORT WIRE
+
−
+
−
+
−
+ FACING UP
+
SLIDER GOES HERE
UNDER THE BATTERY
BUT ABOVE THE TAPE

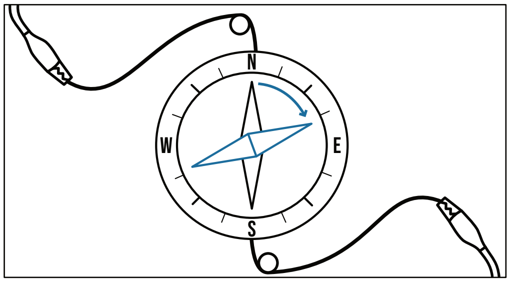


Flowers and slider for
Paper Slider LED
Circuit Card

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?

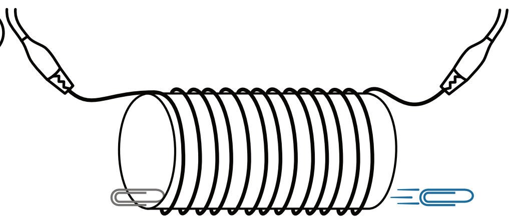
PREDICTION:

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

RESULT:

The compass points a different direction! It behaves similar to how a compass behaves when placed by a magnet. The change in direction depends on the strength and direction of the electric current.

2.



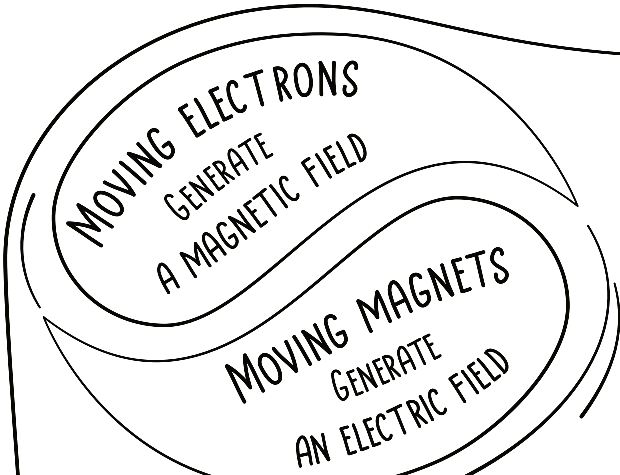
CURRENT FLOWS THROUGH A COIL OF WIRE. A PAPERCLIP IS PLACED AT THE INNER EDGE OF THE COIL. WHAT WILL HAPPEN?

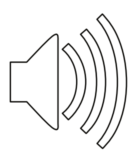
PREDICTION:

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

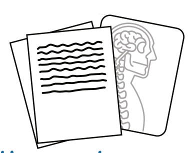
RESULT:

The paperclip shoots through the coil! (The coil is called a solenoid and has a stronger magnetic field than a straight wire with current.)

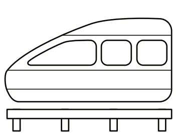




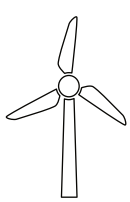
Speakers use an electromagnet to create sound waves. They use the magnetic field to convert the electric signal into movement.



An MRI machine has strong magnets which force protons in the body to align with their field. Short bursts of radio waves then knock the protons out of the alignment. As they go back, they emit radio signals which are used to make the images.

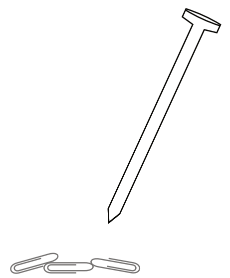


Superconducting magnets with strength 10x stronger than ordinary magnets repel each other so the train hovers above the track. Electricity is used to propel the train forward.



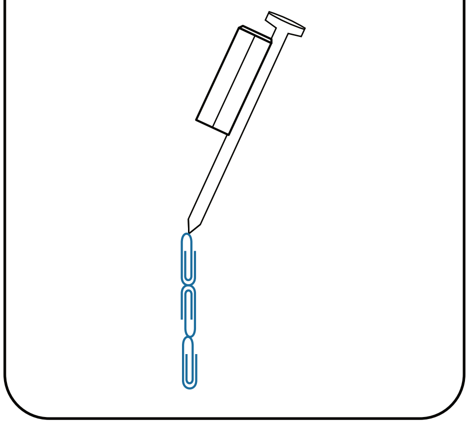
Generators in wind turbines, hydroelectric dams, and other devices operate by spinning a magnet to generate an electric current or by spinning a coil of wire around a magnet.

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

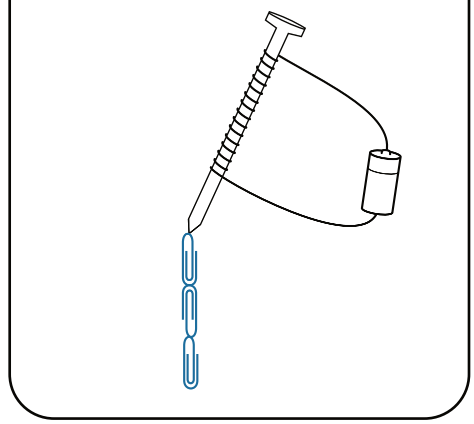


What would happen to the nail & paperclips in each of these scenarios and why?

SCENARIO 1: STRONG MAGNET ON TOP OF THE NAIL



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



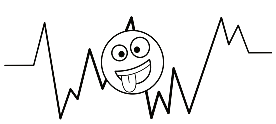
MAGNET ON NAIL:

Magnetic induction! The magnetic field of the magnet causes domains in the nail to align, strengthening their magnetic field. This alignment turns the nail into a temporary magnet by inducing a magnetic field throughout the nail.

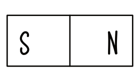
WIRE CONNECTED TO BATTERY:

Electromagnet! The electric current generates a magnetic field around the wire. This magnetic field causes the domains in the nail to align and point the same direction, making the nail a strong magnet (temporarily).

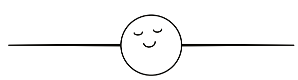
Draw lines to match each of these descriptions as belonging to a permanent magnet or electromagnet.



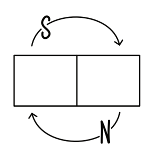
VARIABLE MAGNETIC FIELD
STRENGTH CAN BE EASILY ADJUSTED OR CHANGED



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

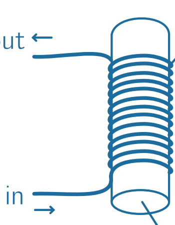
PERMANENT MAGNET

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.

An electromagnet uses electricity to produce a magnetic field. It has a core made of ferromagnetic material (usually iron) and is wrapped with a coil of insulated wire. When current flows through the coil, the core is magnetized.



Examples:

Electric motors, MRI machines, speakers, electric door locks, relays, maglev trains, telegraph

(2) A magnet that can be repeatedly turned on and off is called:

A. A bipolar magnet
B. An electromagnet
C. A permanent magnet
D. A temporary magnet

(3) What is always created when an electric current flows through a wire?

A. A vacuum
B. High temperature
C. A magnetic field
D. Sound waves

(4) What happens to the magnetic field of an electromagnet when more current is put through the coil?

A. The magnetic field increases
B. The magnetic field decreases
C. The direction of the magnetic field reverses
D. The magnetic field becomes unstable

(5) An electric generator does which of the following?

A. Converts mechanical energy into sound energy
B. Converts light energy into electrical energy
C. Converts electrical energy into mechanical energy
D. Converts mechanical energy into electrical energy

(6) True or False: A moving magnet creates an electric field.

A. True
B. False

(7) True or False: Electromagnets are preferred over permanent magnets in many devices.

A. True
B. False

Electromagnets are preferred because they can be turned on and off

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

Most electromagnets use cores of soft magnetic materials where the domains quickly return to a random state. They do not retain magnetization after the electric field is removed. But some core materials would have domains that went out of alignment more slowly. These would retain some residual magnetism after the electromagnet was turned off.

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

They use electromagnets (called pickups) to convert string vibrations into electrical signals.

NUCLEAR FISSION VS NUCLEAR FUSION

NUCLEAR FISSION

Fission occurs when one atomic nucleus SPLITS apart.

Releases energy ($E=mc^2$)

Can only yield net energy if atoms are larger than iron

Too many neutrons can cause an atom to become unstable and undergo fission (radioactive decay). In certain elements (like plutonium) one fission event can set off a chain reaction that causes all of the other atoms to split as well.

NUCLEAR FUSION

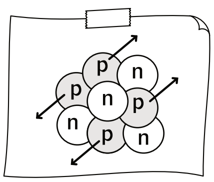
Fusion occurs when two atomic nuclei COMBINE to form a larger nucleus.

Releases energy ($E=mc^2$)

Can only yield net energy if atoms are smaller than iron

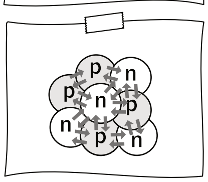
Powers our sun, where intense pressure and heat convert H to He

In theory, fusion could be a clean and incredibly powerful energy source but we haven't yet been able to create a sustainable system/method.



Electrostatic force:

Positively charged protons repel each other.

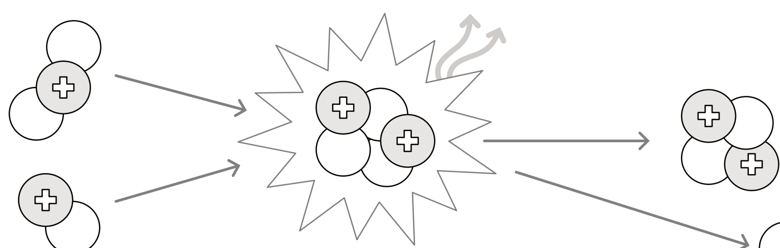


Strong nuclear force:

All nucleons (protons or neutrons) are attracted to each other by the strong nuclear force. Which force "wins" depends on the size of the atom and the ratio of protons to neutrons.

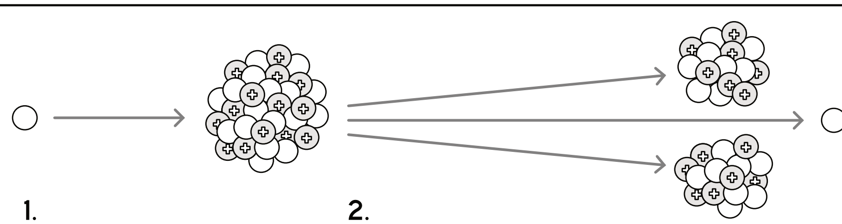
Label each reaction pictured below as being either fission or fusion, and describe the steps:

Nuclear Fusion



1. Two atoms collide and combine
2. Energy and a neutron are released

Nuclear Fission



1. A neutron collides with a nucleus, making it unstable
2. The atom splits into lighter elements, releasing energy and expelling a neutron

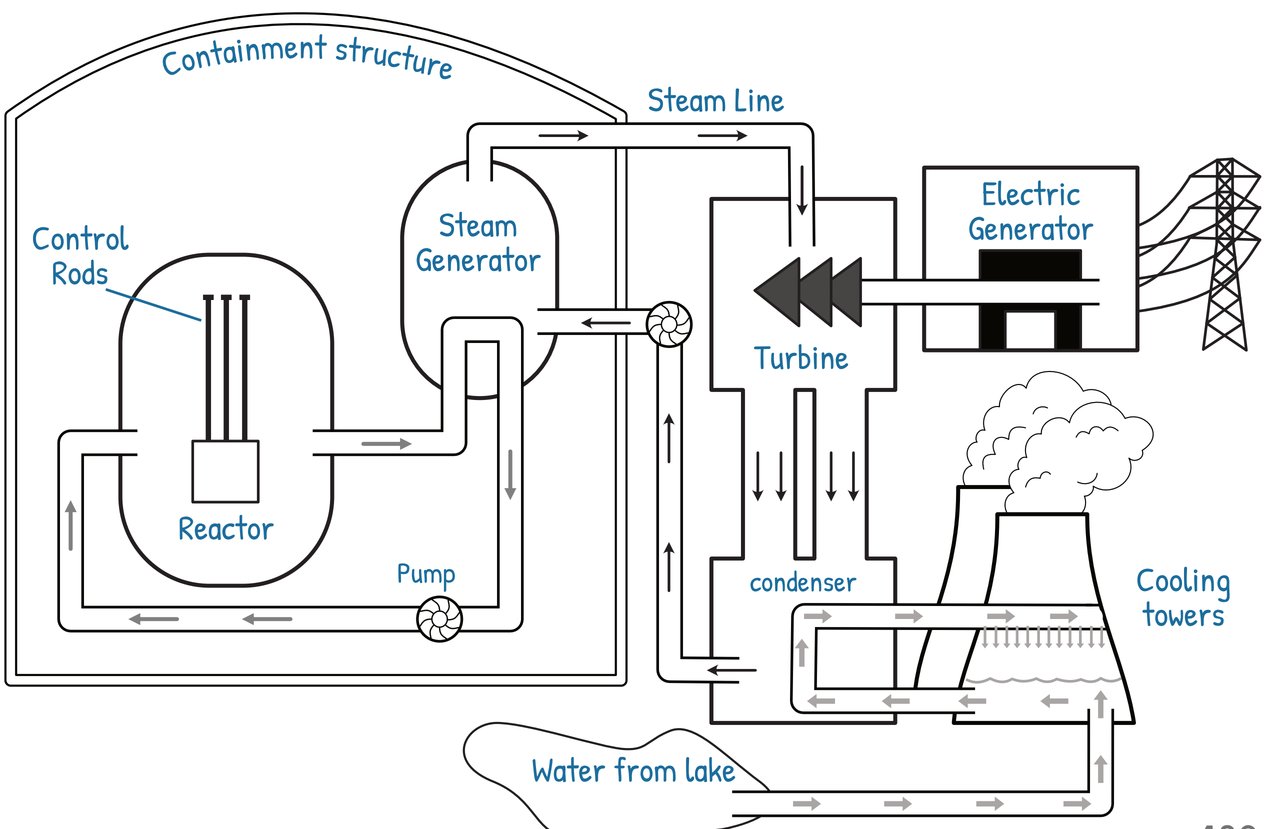
Draw a line to match each description with fission, fusion, or both.

Releases the most energy		Principle behind atomic bombs
Requires high heat and pressure	**Fission**	Primary source of power in stars
Principle behind nuclear reactors		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

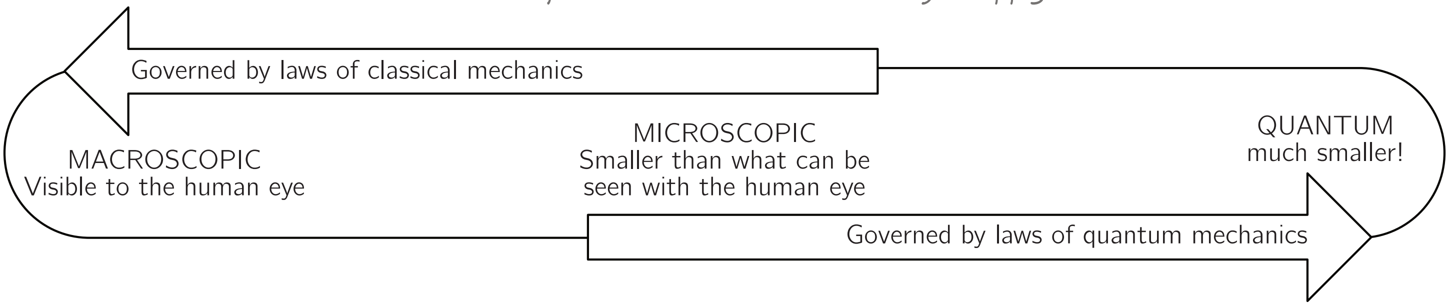
4. What is radioactivity?
   A. A process that strengthens materials
   B. The absorption of radiation by atoms
   C. The emission of energy as atomic nuclei decay
   D. The production of light by atoms

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.

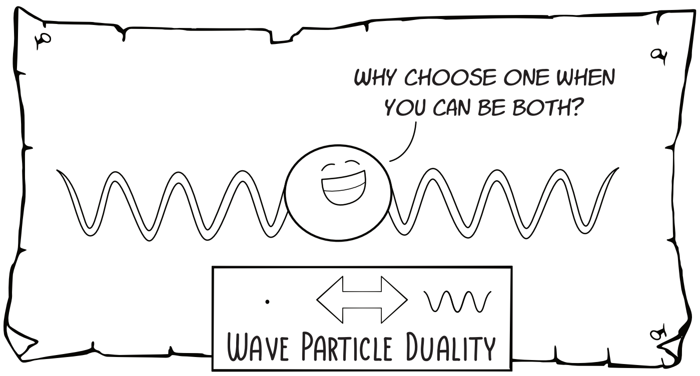
6. Decide whether each statement is true or false.
   T F Nuclear fusion releases more energy than nuclear fission.
   T F Nuclear fission is the process used by the Sun to produce energy.
   T F Nuclear fusion requires very high temperatures to occur.
   T F Nuclear reactors use fusion reactions to 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.

The Weird World of Quantum

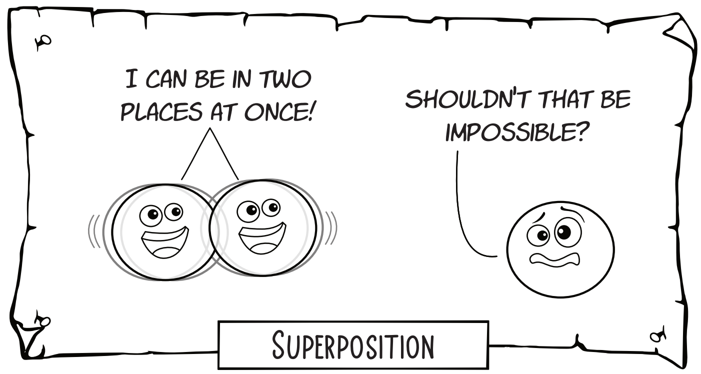
The rules of classical mechanics no longer apply!



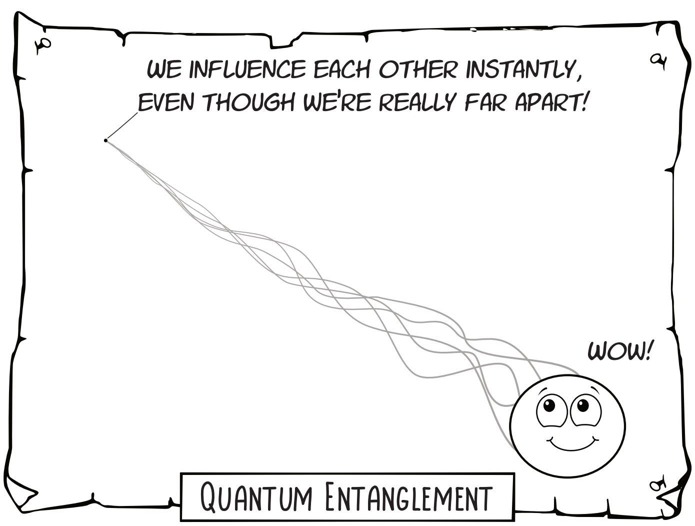
Particles and physical matter exist in a spectrum of different sizes. The smaller things become, the more strongly the rules of quantum physics apply. The world of quantum physics is VERY different than classical mechanics! Below are 6 of the more common properties or effects seen at the quantum level.



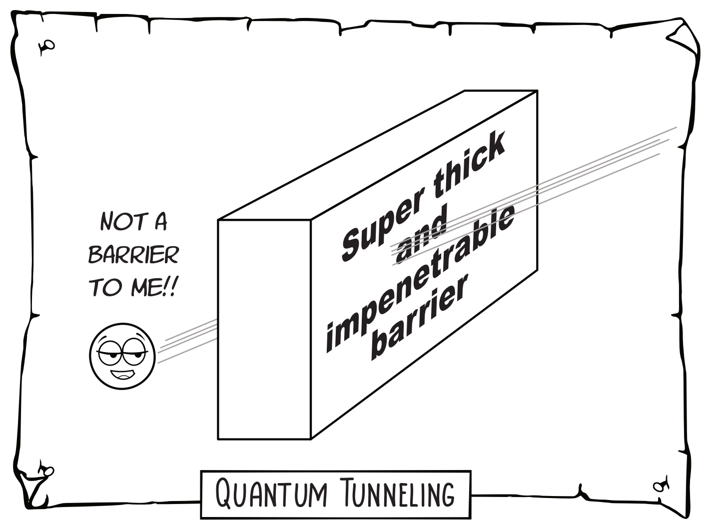
Wave Particle Duality



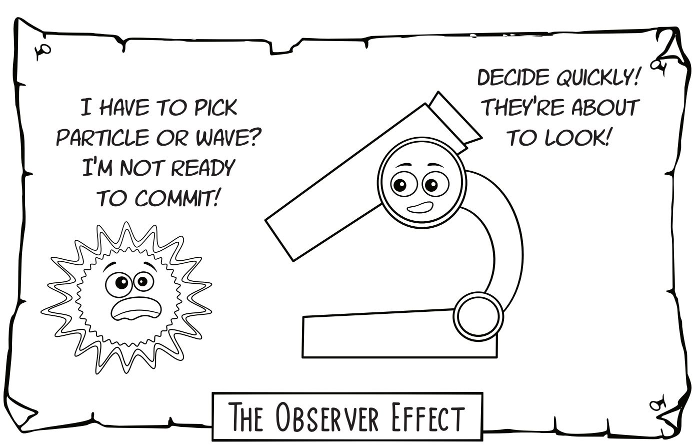
Superposition



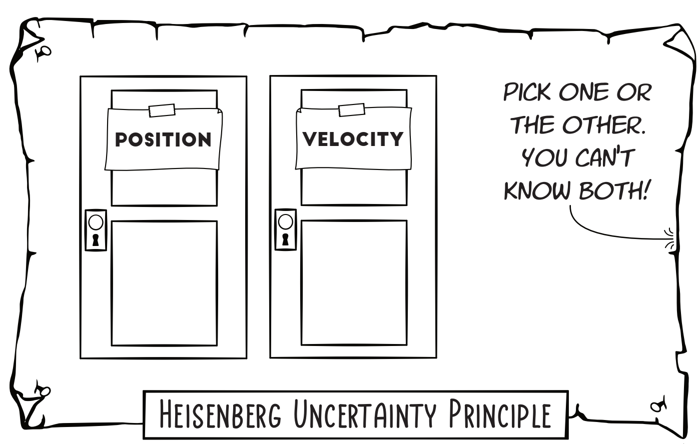
Quantum Entanglement



Quantum Tunneling



The Observer Effect



Heisenberg Uncertainty Principle

Practice Problems – The Weird World of 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?

Answers will vary.

Science Mom's favorite fact is the observer effect, which directly ties into her favorite question. How is it possible that something like an electron knows it is being observed?

Math Dad's favorite fact is wave-particle duality. It's fascinating that photons and other "particles" can be both! His favorite unanswered question related to quantum physics is "What is dark matter and why does it exist?" Maybe one of our students will find the answer someday. For now, we don't know!

Final Assessment

1. Which of the following best describes the First Law of Thermodynamics?
   A. Energy cannot be created nor destroyed, only transferred or transformed.
   B. Entropy of a closed system always increases.
   C. Heat flows from cold objects to hot objects naturally.
   D. The efficiency of a heat engine can never be 100%.

2. What type of heat transfer can occur in the vacuum of outer space?
   A. No heat transfer can occur in a vacuum.
   B. Radiation only.
   C. Convection and conduction.
   D. Conduction, convection, and radiation.

3. What is the latent heat of vaporization?
   A. The heat required to melt a solid.
   B. The heat required to freeze a liquid.
   C. The heat required to change a liquid into a gas.
   D. Heat released when gas condenses.

4. What is the typical speed of sound in air at room temperature?
   A. 25 m/s
   B. 343 m/s
   C. 562 m/s

5. The buoyant force on an object submerged in a fluid is equal to the:
   A. Volume of the fluid displaced.
   B. Density of the fluid.
   C. Weight of the fluid displaced by the object.
   D. Weight of the object.

6. The phenomenon of light bending as it passes from one medium to another is called:
   A. Diffraction
   B. Interference
   C. Reflection
   D. Refraction

7. The frequency of a wave is 500 Hz and its speed is 340 m/s. What is the wavelength?
   A. 0.68 m
   B. 1.52 m
   C. 0.85 m
   D. 2.00 m

8. If the distance between two charges is DOUBLED, the force attracting them to each other will:
   A. Double
   B. Stay the same
   C. Be ½ as strong
   D. Be ¼ as strong

9. Which of the following statements about magnetic fields is true?
   A. Magnetic fields require a medium to travel through space.
   B. Magnetic fields are only produced by permanent magnets.
   C. Most of the elements in the periodic table are ferromagnetic.
   D. 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?
    A. The pressure decreases to 0.5 atm.
    B. The pressure increases to 2 atm.
    C. The pressure remains the same.
    D. The pressure decreases to 0.25 atm.

11. Increasing the amplitude of a sound wave will:
    A. Increase the pitch
    B. Decrease the pitch
    C. Increase the volume
    D. Decrease the volume
    E. Increase the frequency
    F. Decrease the frequency

12. Bernoulli's principle states that, in a fluid, an increase in velocity occurs simultaneously with what other change?
   A. Increase in pressure
   B. Decrease in pressure
   C. Increase in temperature
   D. Decrease in temperature

13. Of the colors listed below, which color of light has the shortest wavelength?
   A. Red
   B. Green
   C. Blue
   D. Yellow

14. The phenomenon of light bouncing off an object at the same relative angle it arrived is called:
   A. Reflection
   B. Refraction
   C. Diffraction
   D. Dispersion

15. If the wave speed doubles while the frequency stays the same, what happens to the wavelength?
   A. It doubles
   B. It is halved
   C. It remains the same
   D. It quadruples

   Remember wave speed = frequency · wavelength

16. If the current in a wire increases, the magnetic field around the wire will:
   A. Increase
   B. Decrease
   C. Remain unchanged
   D. 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?
   A. 5 lb
   B. 16 lb
   C. 24 lb
   D. 80 lb

18. What happens to the liquid pressure experienced by a submarine when it doubles its depth in the ocean?
   A. Liquid pressure is cut in half.
   B. Liquid pressure remains the same.
   C. Liquid pressure doubles.
   D. Liquid pressure quadruples.

19. What is the human audible range of sound frequency?
   A. 20 Hz to 2 kHz
   B. 20 Hz to 20 kHz
   C. 2 Hz to 20 kHz
   D. 20 kHz to 2 MHz

20. If a 400 N weight is placed on a cube that measures 4 cm × 4 cm × 4 cm, how much pressure is applied to the cube face?
   A. 100 kPa
   B. 250 kPa
   C. 400 kPa
   D. 1600 kPa

   Remember pressure is force per unit area and pascals are N/m^2

   $400\ N / (0.04\ m \times 0.04\ m)$

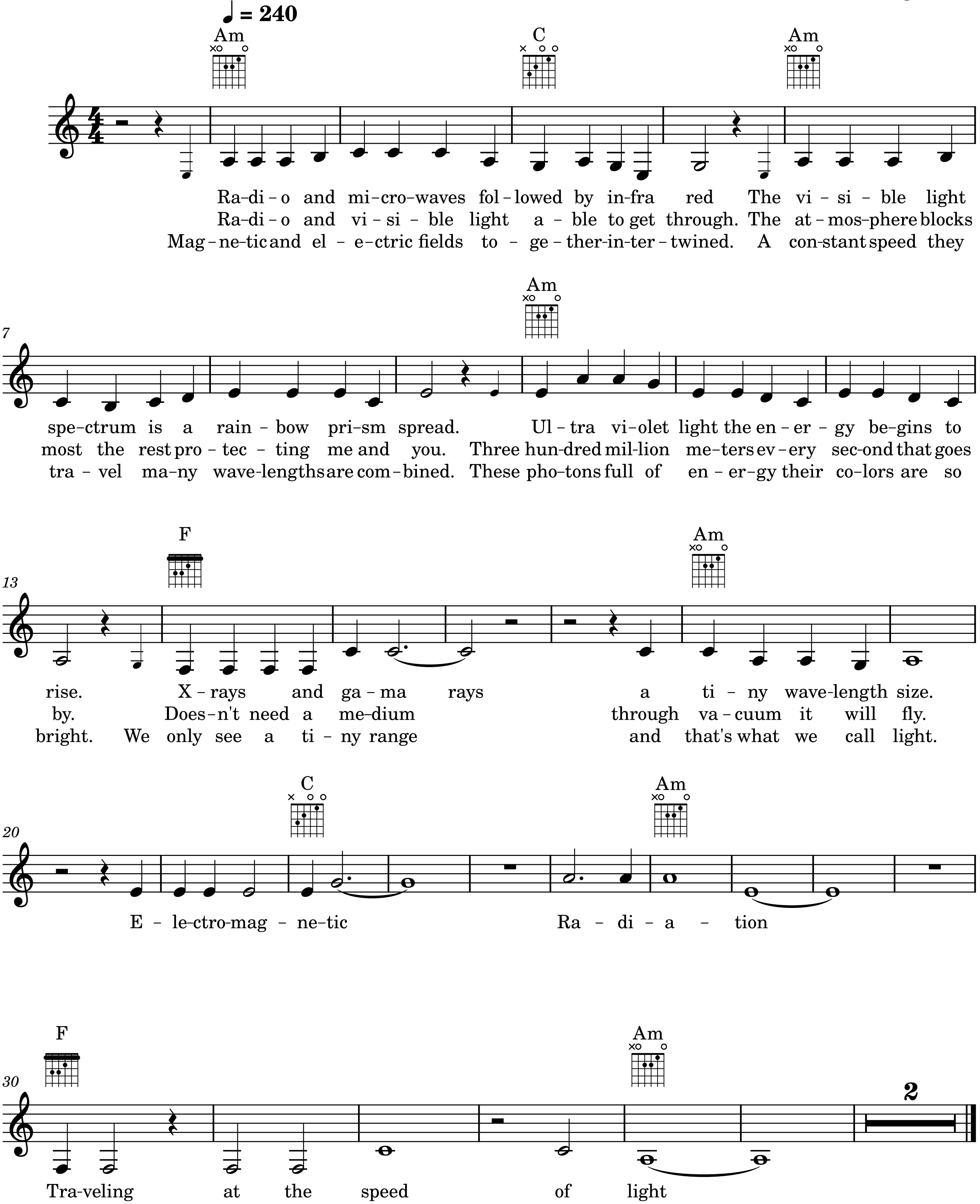
21. What quantity measures the average kinetic energy of particles in a substance?
   A. Temperature
   B. Heat
   C. Entropy
   D. Enthalpy

22. Write out the seven types of electromagnetic radiation from lowest frequency to highest frequency.
   1. Radio
   2. Microwaves
   3. Infrared
   4. Visible light
   5. Ultraviolet
   6. X-rays
   7. Gamma rays

Electromagntic Spectrum Song

adapted from Ghost Riders in the Sky

Stan Jones / Serge Ballif



Useful Formulas

Temperature

C = temp in °C, F = temp in °F

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

Density

ρ = 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, $g = 9.8\,m/s^2$

$$w = mg$$

Liquid Pressure

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

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

Boyle's Law

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

$$P_1V_1 = P_2V_2$$

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,
λ = wavelength

$$v = f\lambda$$

Electrical Power = Voltage × Current

P = power (watts), V = voltage (volts), I = current (amps)

$$P = VI$$

Ohm's Law

V = voltage (volts), I = current (amps), R = resistance (ohms)

$$V = IR$$