# Heat

Heat is the transfer of energy from a one object to another due to a difference in temperature. Heat can be measured in joules, BTUs (British thermal unit), or calories.

Heat and temperature are closely related, but they are not the same thing. The temperature of an object is determined by how fast its molecules are moving. The faster the molecules are moving the higher the temperature. We say objects that have a high temperature are hot and objects with a low temperature are cold.

## Transferring of Heat

When two items are combined or touching each other, their molecules will transfer energy called heat. They will try to come to a point where they both have the same temperature. This is called equilibrium. Heat will flow from the hotter object to the colder. The molecules in the hotter object will slow down and the molecules in the colder object will speed up. Eventually they will get to the point where they have the same temperature.

This happens all the time around you. For example, when you take an ice cube and put it into a warm soda. The ice cube will become warmer and melt, while the soda will cool down.

## Hot Objects Expand

When something gets hotter it will expand, or get bigger. At the same time, when something gets colder it will shrink. This property is used to make mercury thermometers. The line in the thermometer is actually liquid mercury. As the liquid gets hotter, it will expand and rise in the thermometer to show a higher temperature. It's the expansion and contraction due to temperature that allows the thermometer to work.

## Heat Conduction

When heat transfers from one object to another, this is called conduction. Some materials conduct heat better than others. Metal, for example, is a good conductor of heat. We use metal in pots and pans to cook because it will move the heat from the flame to our food quickly. Cloth, like a blanket, isn't a good conductor of heat. Because it's not a good conductor, a blanket works well to keep us warm at night as it won't conduct the heat from our bodies out to the cold air.

## Matter Changing State

Heat has an impact on the state of matter. Matter can change state based on heat or temperature. There are three states that matter can take depending on its temperature: solid, liquid, and gas. For example, if water is cold and its molecules are moving very slow, it will be a solid (ice). If it warms up some, the ice will melt and water becomes a liquid. If you add a lot of heat to water, the molecules will move very fast and it will become a gas (steam).

Activities: Test Quiz

1) Heat is the transfer of _____ from one object to another due to a difference in temperature.

- Time
- Energy
- Force
- Velocity
- Current

2) Which of the following is a unit of measurement for heat?

- Calorie
- BTU
- Joule
- All of the above
- None of the Above

3) True or False: Heat and temperature are the same thing.

- TRUE
- FALSE

4) What is it called when two objects touching each other eventually reach the same temperature?

- Expansion
- Conduction
- Equilibrium
- All of the above
- None of the Above

5) Do substances tend to shrink or expand as they get hotter?

- They shrink
- They expand
- They stay the same

6) What happens to the molecules of a substance as it gets cooler?

- The molecules shrink
- The molecules expand
- The molecules move faster
- The molecules move slower
- Nothing

7) What is it called when heat transfers from one object to another?

- Induction
- Expansion
- Equilibrium
- Deduction
- Conduction

8) Which of the following is not a good conductor of heat?

- A steel pan
- Copper wire
- A blanket
- An iron rod
- Metal

9) In what state of matter is the temperature the highest?

- Solid
- Liquid
- Gas

The temperature doesn't matter

10) In what state of matter is the temperature of water the lowest?

- Solid
- Liquid
- Gas
- The temperature doesn't matter

# Temperature

**What is temperature?**

Temperature can be a difficult property to define. In our everyday lives we use the word temperature to describe the hotness or coldness of an object. In physics, the temperature is the average kinetic energy of the moving particles in a substance.

**How is temperature measured?**

Temperature is measured using a thermometer. There are different scales and standards for measuring temperature including Celsius, Fahrenheit, and Kelvin. These are discussed in more detail below.

**How does a thermometer work?**

Thermometers take advantage of a scientific property called thermal expansion. Most substances will expand and take up more volume as they get hotter. Liquid thermometers have some sort of substance (this used to be mercury, but today is generally alcohol) that is enclosed in a small glass tube.

As the temperature rises, the liquid expands and fills up more of the tube. When the temperature drops, the liquid contracts and takes up less of the tube. The temperature can then be read by the lines calibrated on the side of the tube.

**Temperature Scales**

There are three main temperature scales that are used today: Celsius, Fahrenheit, and Kelvin.
Celsius - The most common temperature scale in the world is Celsius. Celsius uses the unit "degrees" and is abbreviated as °C. The scale sets the freezing point of water at 0 °C and the boiling point of water at 100 °C.
Fahrenheit - The temperature scale most common in the United States is the Fahrenheit scale. Fahrenheit sets the freezing point of water at 32 °F and the boiling point at 212 °F.
Kelvin - The standard unit of temperature that is most used by scientists is Kelvin. Kelvin doesn't use the ° symbol like the other two scales. When writing a temperature in Kelvin you just use the letter K. Kelvin uses absolute zero as the 0 point of its scale. It has the same increments as Celsius in that there are 100 increments between the freezing and boiling points of water.
Converting Between Scales

**Celsius and Fahrenheit**

°C = (°F - 32)/1.8
°F = 1.8 * °C + 32°

Celsius and Kelvin

K = °C + 273.15
°C = K - 273.15°

**Absolute Zero**

Absolute zero is the coldest possible temperature that any substance can reach. It is equal to 0 Kelvin or -273.15 °C (-459.67°F).

**Temperature and the State of Matter**

Temperature has an effect on the state of matter. Each substance of matter will go through different phases as the temperature increases including solid, liquid, and gas. One example of this is water which changes from ice (solid) to water (liquid) to vapor (gas) as the temperature increases.

**Interesting Facts about Temperature**

Temperature is independent of the size or quantity of an object. This is called an intensive property.

The Fahrenheit scale is named after Dutch physicist Daniel Fahrenheit.

Temperature is a different quantity from the total amount of thermal energy in a substance, which is dependent on the size of the object.

Celsius was named after the Swedish astronomer Anders Celsius. Celsius was originally known as "centigrade."

As substances approach absolute zero they can achieve some interesting properties such as superfluidity and superconductivity.

Activities: Questions on this quiz are based on information from Physics: Temperature

1) In physics, temperature is the average ______ of the moving particles in a substance.
- Potential energy
- Electric energy
- Nuclear energy
- Kinetic energy
- Potential force

2) What device is used to measure temperature?
- Barometer
- Thermometer
- Anemometer
- Multimeter
- Voltmeter

3) Do most substances expand or contract as they get hotter?
- Expand
- Contract
- Stay the same

4) Which temperature scale uses absolute zero as the 0 point of its scale?
- Celsius
- Fahrenheit
- Kelvin
- All of the above
- None of the above

5) Which temperature scale is the most common throughout the world?
- Celsius
- Fahrenheit
- Kelvin
- All of the above
- None of the above

6) Which temperature scale is the most commonly used by scientists?
- Celsius
- Fahrenheit
- Kelvin
- All of the above
- None of the above

7) Which temperature scale is the most commonly used in the United States?
- Celsius
- Fahrenheit
- Kelvin
- All of the above
- None of the above

8) Which temperature scale uses the freezing point of water as the 0 point and the boiling point of water as the 100 point?
- Celsius
- Fahrenheit
- Kelvin
- All of the above
- None of the above

9) What is the coldest temperature possible?
- Total zero
- Freezing point
- Complete zero
- Absolute freezing
- Absolute zero

10) Which state of matter of a given substance has the highest temperature?
- Solid
- Liquid
- Gas
- They all have the same

# Waves

## What is a wave?

When we think of the word "wave" we usually picture someone moving their hand back and forth to say hello or maybe we think of a curling wall of water moving in from the ocean to crash on the beach.

In physics, a wave is a disturbance that travels through space and matter transferring energy from one place to another. When studying waves it's important to remember that they transfer energy, not matter.

## Waves in Everyday Life

There are lots of waves all around us in everyday life. Sound is a type of wave that moves through matter and then vibrates our eardrums so we can hear. Light is a special kind of wave that is made up of photons. You can drop a rock into a pond and see waves form in the water. We even use waves (microwaves) to cook our food really fast.

## Types of Waves

Waves can be divided into various categories depending on their characteristics. Below we describe some of the different terms that scientists use to describe waves.

### Mechanical Waves and Electromagnetic Waves

All waves can be categorized as either mechanical or electromagnetic.

***Mechanical waves*** are waves that require a medium. This means that they have to have some sort of matter to travel through. These waves travel when molecules in the medium collide with each other passing on energy. One example of a mechanical wave is sound. Sound can travel through air, water, or solids, but it can't travel through a vacuum. It needs the medium to help it travel. Other examples include water waves, seismic waves, and waves traveling through a spring.

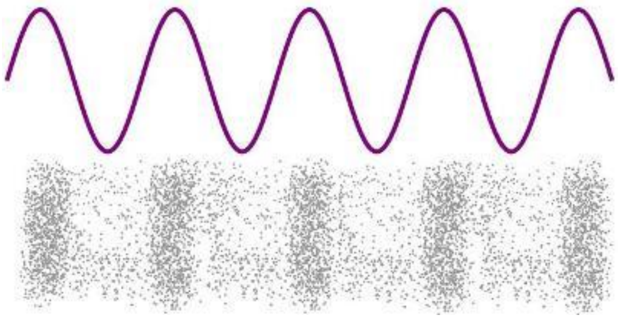
***Electromagnetic waves*** are waves that can travel through a vacuum (empty space). They don't need a medium or matter. They travel through electrical and magnetic fields that are generated by charged particles. Examples of electromagnetic waves include light, microwaves, radio waves, and X-rays.

### Transverse Waves and Longitudinal Waves

Another way to describe a wave is by the direction that its disturbance is traveling.

***Transverse waves*** are waves where the disturbance moves perpendicular to the direction of the wave. You can think of the wave moving left to right, while the disturbance moves up and down. One example of a transverse wave is a water wave where the water moves up and down as the wave passes through the ocean. Other examples include an oscillating string and a wave of fans in a stadium (the people move up and down while the wave moves around the stadium).

***Longitudinal waves*** are waves where the disturbance moves in the same direction as the wave. One example of this is a wave moving through a stretched out slinky or spring. If you compress one portion of the slinky and let go, the wave will move left to right. At the same time, the disturbance (which is the coils of the springs moving), will also move left to right. Another classic example of a longitudinal wave is sound. As sound waves propagate through a medium, the molecules collide with each other in the same direction as the sound is moving.



In the above picture the top wave is transverse
and the bottom wave is longitudinal.

**Interesting Facts about Waves**

Waves in the ocean are mostly generated by the wind moving across the ocean surface.
The "medium" is the substance or material that carries a mechanical wave.
One of the most important things to remember about waves is that they transport energy, not matter. This makes them different from other phenomenon in physics.
Many waves cannot be seen such as microwaves and radio waves.
The tallest ocean wave ever recorded was 1,720 feet tall and occurred in Lituya Bay in Alaska.

**Activities** :Test Quiz

1) A wave is a disturbance that transfers _____ from one place to another.

- Water
- Air
- Matter
- Energy
- Electrons

2) What kind of waves vibrate our eardrums so we can hear?

- Microwaves
- Water waves
- Light waves
- Sound waves
- Radio waves

3) What kind of waves require some sort of medium to travel through?

- Mechanical waves
- Electromagnetic waves
- All of the above
- None of the above

4) What kind of waves can travel through a vacuum?

- Mechanical waves
- Electromagnetic waves
- All of the above
- None of the above

5) What kind of waves transfer energy?

Mechanical waves
Electromagnetic waves
All of the above
None of the above

6) Which of the following waves is a mechanical wave?

Light
Microwaves
Radio waves
X-rays
Sound

7) Which of the following waves is an electromagnetic wave?

Water waves
Seismic waves
Waves in a spring
Light
Sound

8) In which of the following waves does the disturbance move in the same direction as the wave?

Transverse waves
Longitudinal waves
All of the above
None of the above

9) In which of the following waves does the disturbance move in a perpendicular direction to the wave?

Transverse waves
Longitudinal waves
All of the above
None of the above

10) What type of wave is a sound wave?

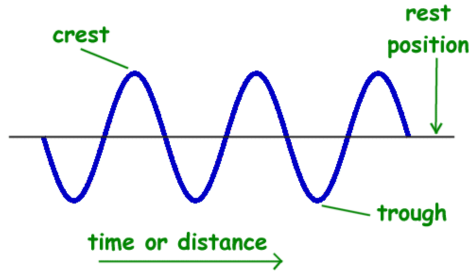
Transverse and mechanical
Transverse and electromagnetic
Longitudinal and mechanical
Longitudinal and electromagnetic

# Properties of Waves

There are many properties that scientists use to describe waves. They include amplitude, frequency, period, wavelength, speed, and phase. Each of these properties is described in more detail below.

**Graphing a Wave**

When drawing a wave or looking at a wave on a graph, we draw the wave as a snapshot in time. The vertical axis is the amplitude of the wave while the horizontal axis can be either distance or time.

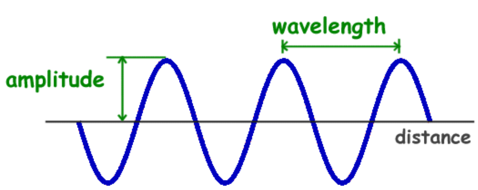



In this picture you can see that the highest point on the graph of the wave is called the crest and the lowest point is called the trough. The line through the center of the wave is the resting position of the medium if there was no wave passing through.

We can determine a number of wave properties from the graph.

**Amplitude**

The amplitude of a wave is a measure of the displacement of the wave from its rest position. The amplitude is shown on the graph below.




Amplitude is generally calculated by looking on a graph of a wave and measuring the height of the wave from the resting position.

The amplitude is a measure of the strength or intensity of the wave. For example, when looking at a sound wave, the amplitude will measure the loudness of the sound. The energy of the wave also varies in direct proportion to the amplitude of the wave.

**Wavelength**

The wavelength of a wave is the distance between two corresponding points on back-to-back cycles of a wave. This can be measured between two crests of a wave or two troughs of a wave. The wavelength is usually represented in physics by the Greek letter lambda ($\lambda$).

**Frequency and Period**

The frequency of a wave is the number of times per second that the wave cycles. Frequency is measured in Hertz or cycles per second. The frequency is often represented by the lower case "f."

The period of the wave is the time between wave crests. The period is measured in time units such as seconds. The period is usually represented by the upper case "T."

The period and frequency are closely related to each other. The period equals 1 over the frequency and the frequency is equal to one over the period. They are reciprocals of each other as shown in the following formulas.

period = 1/frequency or $T = 1/f$

frequency = 1/period or $f = 1/T$

**Speed or Velocity of a Wave**

Another important property of a wave is the speed of propagation. This is how fast the disturbance of the wave is moving. The speed of mechanical waves depends on the medium that the wave is traveling through. For example, sound will travel at a different speed in water than in air.

The velocity of a wave is usually represented by the letter "v." The velocity can be calculated by multiplying the frequency by the wavelength.

velocity = frequency * wavelength

or

$v = f * \lambda$

## Activities

1) When graphing a wave, what does the horizontal axis usually represent?
   - Amplitude
   - Trough
   - Time or distance
   - Crest
   - Rest position

2) What does the horizontal line through the center of the wave on a graph represent?
   - Amplitude
   - Trough
   - Time or distance
   - Crest
   - Rest position

3) When graphing a wave, what does the vertical axis usually represent?
   - Amplitude
   - Trough
   - Time or distance
   - Crest
   - Rest position

4) What do we call the highest point of the wave on a graph?
   - Amplitude
   - Trough
   - Time or distance
   - Crest
   - Rest position

5) What do we call the lowest point of the wave on a graph?
   - Amplitude
   - Trough
   - Time or distance
   - Crest
   - Rest position

6) What wave measurement represents the number of times per second that the wave cycles?
   - Wavelength
   - Period
   - Amplitude
   - Frequency
   - Velocity

7) What wave measurement would you find by measuring the distance between the crests of back-to-back wave cycles?
   - Wavelength
   - Period
   - Amplitude
   - Frequency
   - Velocity

8) What wave measurement would you find by measuring the time between the crests of back-to-back wave cycles?
   - Wavelength
   - Period
   - Amplitude
   - Frequency
   - Velocity

9) What wave measurement represents the strength or intensity of the wave?
   - Wavelength
   - Period
   - Amplitude
   - Frequency
   - Velocity

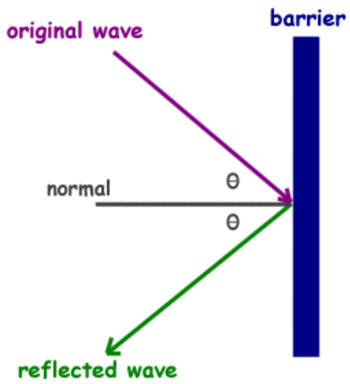
10) What wave measurement represents how fast the disturbance of the wave is moving?
   - Wavelength
   - Period
   - Amplitude
   - Frequency
   - Velocity

# Wave Behavior

When waves encounter new mediums, barriers, or other waves they can behave in different ways. In physics these behaviors are described using some of the terms below.

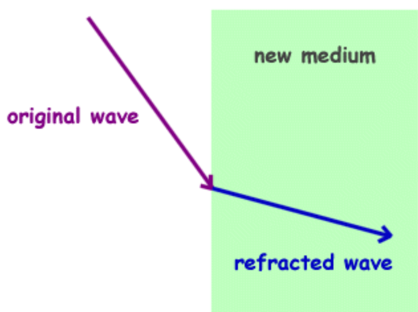
**Reflection**

The word "reflection" is used in everyday life to describe what we see in a mirror or on the surface of the water. In physics, a reflection is when a wave encounters a new medium that acts as a barrier, causing the wave to return to the original medium. The wave "reflects" off the barrier at an angle that is incident to the angle of the wave hitting the barrier (see below).




**Refraction**

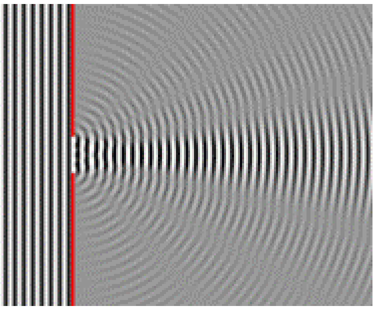
Refraction of a wave occurs when a wave changes direction upon moving from one medium to another. Along with the change of direction, refraction also causes a change in the wavelength and the speed of the wave. The amount of change in the wave due to refraction is dependent on the refractive index of the mediums.




One example of refraction is a prism. When white light enters the prism, the different wavelengths of light are refracted. The different wavelengths of light are each refracted differently and the light is split into a spectrum of colors.

**Diffraction**

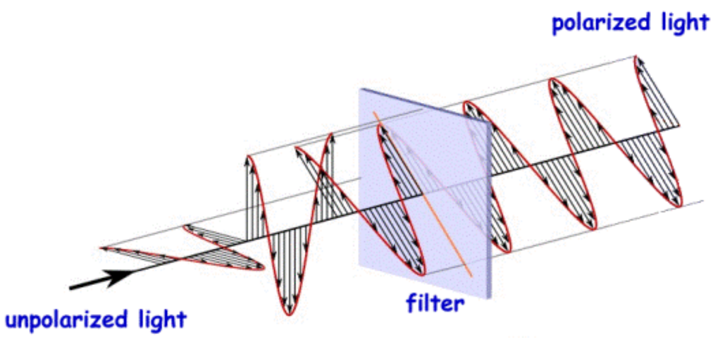
Diffraction occurs when a wave stays in the same medium, but bends around an obstacle. This can occur when the wave encounters a small object in its path or when the wave is forced through a small opening. An example of diffraction is when a water wave hits a boat and bends around the boat. The waves after the boat are changed or diffracted.



An example of a diffracted wave passing through a small opening.

**Polarization**

Polarization is when a wave oscillates in one particular direction. Light waves are often polarized using a polarizing filter. Only transverse waves can be polarized. Longitudinal waves, such as sound, cannot be polarized because they always travel in the same direction of the wave.




In this picture the unpolarized light wave travels through the filter and then is polarized along a single plane.

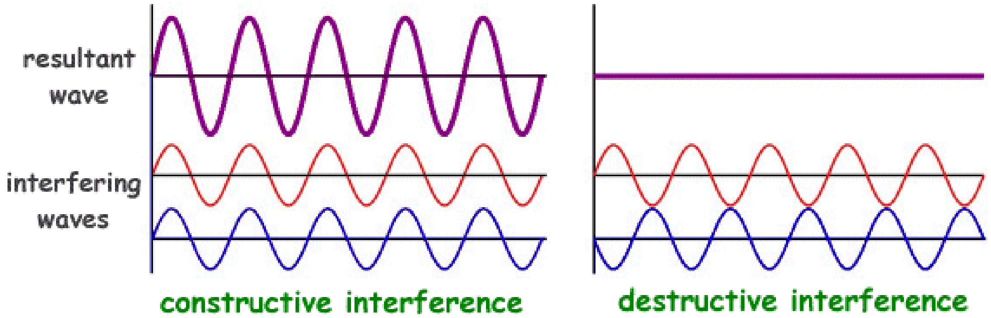
**Absorption**

Absorption is when a wave comes into contact with a medium and causes the medium's molecules to vibrate and move. This vibration absorbs or takes some of the energy away from the wave and less of the energy is reflected.

One example of absorption is black pavement which absorbs energy from light. The black pavement becomes hot from absorbing the light waves and little of the light is reflected making the pavement appear black. A white stripe painted on the pavement will reflect more of the light and absorb less. As a result the white stripe will be less hot.

**Interference**

When one wave comes into contact with another wave this is called interference. When the waves meet the resulting wave will have the amplitude of the sum of the two interfering waves.




Depending on the phase of the waves the interference can be constructive or destructive. If the resulting wave has a higher amplitude than the interfering waves, this is constructive interference. If it has a lower amplitude, this is called destructive interference.

**Activities**

1) What type of wave behavior occurs when a wave oscillates in one particular direction?
- Reflection
- Refraction
- Diffraction
- Polarization
- Absorption

2) What type of wave behavior occurs when a wave stays in the same medium, but bends around an obstacle?
- Reflection
- Refraction
- Diffraction
- Polarization
- Absorption

3) What is it called when a wave encounters a barrier and returns to the original medium?
- Reflection
- Refraction
- Diffraction
- Polarization
- Absorption

4) What is it called when a wave encounters a new medium and the medium takes some of the energy of the wave away?
- Reflection
- Refraction
- Diffraction
- Polarization
- Absorption

5) What is it called when a wave changes direction upon moving from one medium to a new medium?
- Interference
- Refraction
- Diffraction
- Polarization
- Absorption

6) When sunlight hits black pavement, the pavement becomes hot. This is an example of what type of wave behavior?
- Interference
- Refraction
- Diffraction
- Polarization
- Absorption

7) What is it called when two waves come into contact with each other?
- Interference
- Refraction
- Diffraction
- Polarization
- Absorption

8) Light striking a prism is an example of what type of wave behavior?
- Interference
- Refraction
- Diffraction
- Polarization
- Absorption

9) What type of waves cannot be polarized?
- Transverse waves
- Light waves
- Radio waves
- Sound waves
- All of the above

10) What type of wave interference results in a wave with a smaller amplitude than the two original waves?
- Destructive
- Constructive

# Sound Wave Characteristics

A sound wave is a special kind of wave that can be detected by the human ear. Sound waves have special characteristics that make them unique.

## Mechanical Waves

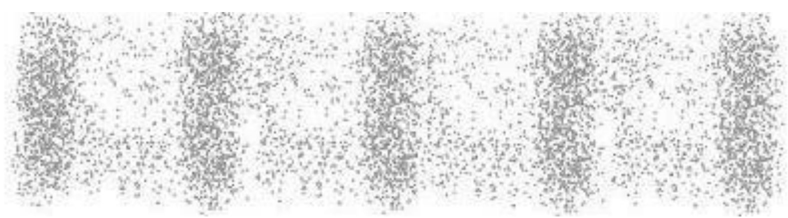
One important characteristic of sound waves is that they are mechanical waves. This means that they travel through a medium. Sound waves can travel through all sorts of mediums. Normally, we hear sound waves that have traveled through air, but sound can also travel through water, wood, the Earth, and many other substances. Sound cannot travel through a vacuum like outer space, however.

The source of sound waves is something vibrating. This vibration causes a disturbance in the molecules around the source. The energy of the wave is transferred from molecule to molecule within the medium.

## Longitudinal Waves

Another characteristic of sound waves is that they are longitudinal waves. This means that the disturbance of the wave travels in the same direction as the wave. As the molecules vibrate and transfer energy to each other they cause a wave that moves in the direction of the vibration.

The longitudinal characteristic of sound waves can be seen the picture below. Here you can see how the molecules move in a left to right motion causing the wave and the disturbance to move in the same direction. In some areas of the wave the molecules get bunched together. This is called compression. In other areas the molecules become spread out. This is called rarefaction.



## What is the wavelength of a sound wave?

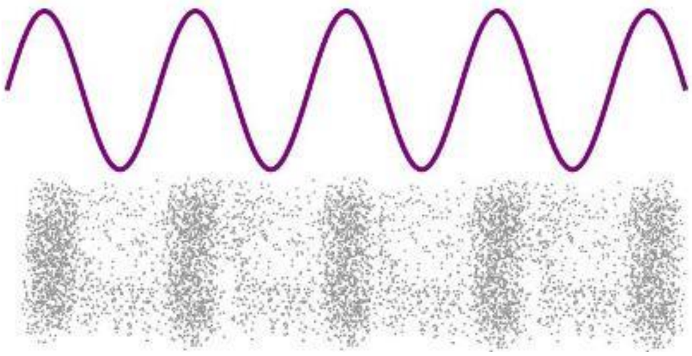
We studied how the wavelength of a transverse wave is measured from crest to crest or trough to trough. This is fairly easy to see when looking at a graph. However, sound waves are different as they are longitudinal. To determine the wavelength of a sound wave you measure from compression to compression or rarefaction to rarefaction.

## Pressure Waves

Sound waves can also be thought of as pressure waves. This is because the compressions and rarefactions that move through sound waves have different pressures. The compressions are areas of high pressure while the rarefactions are areas of low pressure.

## What is the amplitude of a sound wave?

Sometimes you will see a graph of a sound wave that looks like a sine wave (see below). This is different from the graph of a transverse wave. The peaks and valleys of this wave graph the changes in pressure that occur in the wave. From this graph we can determine the amplitude of the sound wave. The amplitude is the peak of the compression or rarefaction on the graph.



## Intensity of a Sound Wave

Sound waves are sometimes measured using a quantity called intensity. The intensity of a sound wave (I) is equal to the sound power (P) over the area (A):

$$I = P/A$$

## Activities

1) Sound waves are a special kind of wave that can be detected by _______.
   - The human eye
   - Computers
   - The human ear
   - Electronic instruments
   - Antennas

2) A sound wave cannot travel through which of the following?
   - Air
   - Water
   - Metal
   - Vacuum
   - All of the above

3) Because a sound wave must travel through a medium, it is called a ________ wave.
   - Mechanical
   - Electrical
   - Light
   - Electromagnetic
   - Induction

4) What is the source of a sound wave?
   - Electricity
   - Vibration
   - Light waves
   - Conduction
   - Tiny nuclear explosions

5) What does it mean that a sound wave is a longitudinal wave?
   - The disturbance moves perpendicular to the wave
   - The period of the wave is very long
   - The disturbance moves in the same direction as the wave
   - The wave has a very low frequency
   - The waves last for a long time

6) What do we call the region of a sound wave where the molecules are bunched closer together?
   - Interference
   - Refraction
   - Polarization
   - Rarefaction
   - Compression

7) What do we call the region of a sound wave where the molecules are spread out?
   - Interference
   - Refraction
   - Polarization
   - Rarefaction
   - Compression

8) What do we call the areas of low pressure of a sound wave ?
   - Interference
   - Refraction
   - Polarization
   - Rarefaction
   - Compression

9) The intensity of a sound wave is equal to the sound power (P) divided by the _______.
   - Area
   - Time
   - Distance
   - Energy
   - Amplitude

10) True or False: Sound waves are described as both mechanical waves and longitudinal waves.
   - TRUE
   - FALSE

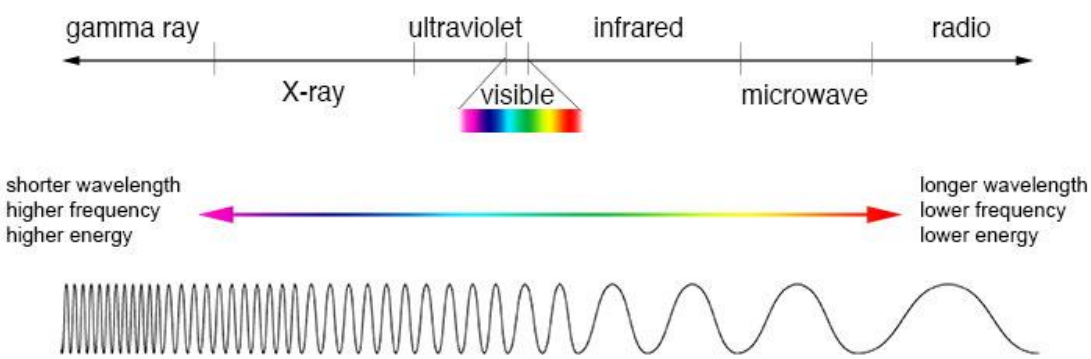
# Light

### What is light made of?
This is not an easy question. Light has no mass and is not really considered matter. So does it even exist? Of course it does! We couldn't live without light. Today scientists say light is a form of energy made of photons. Light is unique in that it behaves like both a particle and a wave.

### Why does light go through some things and not others?

Depending on the type of matter it comes into contact with, light will behave differently. Sometimes light will pass directly through the matter, like with air or water. This type of matter is called transparent. Other objects completely reflect light, like an animal or a book. These objects are called opaque. A third type of object does some of both and tends to scatter the light. These objects are called translucent objects.

### Electromagnetic Spectrum




### Light helps us to survive

Without sunlight our world would be a dead dark place. Sunlight does more than just help us see (which is pretty great, too). Sunlight keeps the Earth warm, so it's not just a frozen ball in outer space. It also is a major component in photosynthesis which is how most of the plant life on Earth grows and gets nutrients. Sunlight is a source of energy as well as a source of vitamin D for humans.

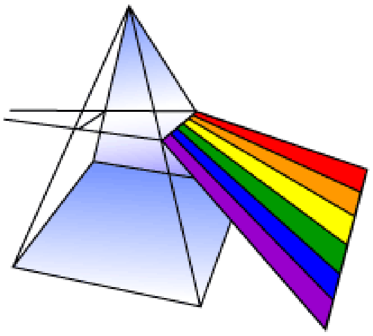
### The speed of light

Light moves at the fastest known speed in the universe. Nothing moves faster than (or even close to) the speed of light. In a vacuum, where there is nothing to slow it down, light travels 186,282 miles per second ($3\times10^{8}$ $ms^{-1}$)! Wow, that's fast! When light travels through matter, like air or water, it slows down some, but it's still pretty fast.

To give you an idea as to how fast light is, we'll give you some examples. The Sun is almost 93 million miles from the Earth. It takes around 8 minutes for light to get from the Sun to the Earth. It takes around 1.3 seconds for light to go from the moon to the Earth.

### Refraction

Normally, light travels in a straight path called a ray, however, when passing through transparent materials, like water or glass, light bends or turns. This is because different materials or mediums have different qualities. In each type of medium, whether it is air or water or glass, the wavelength of the light will change, but not the frequency. As a result, the direction and speed of the traveling light wave will change and the light will appear to bend or change directions.



One example of refraction is a prism. Prisms are unique in that each color of light is refracted to a different angle. So it can take white light from the Sun and send out light of various colors.

Lenses use refraction to help us see things. Telescopes help us to see things far away and microscopes enable us to see very small things. Even glasses use refraction so that we can see everyday things more clearly.

**Activities**

1) What particles make up light?
- Protons
- Neutrons
- Electrons
- Photons
- Quarks

2) Light behaves like both a particle and a ______.
- Current
- Mass
- Wave
- Voltage
- Field

3) What type of matter allows light to pass directly through it?
- Translucent
- Opaque
- Transparent
- All of the above
- None of the Above

4) What type of matter completely reflects light?
- Translucent
- Opaque
- Transparent
- All of the above
- None of the Above

5) What type of matter completely scatters light?
- Translucent
- Opaque
- Transparent
- All of the above
- None of the Above

6) What process do plants use to turn sunlight into energy they can use?
- Photoinduction
- Hydropower
- Nuclear fusion
- Geothermal power
- Photosynthesis

7) True or False: Light is faster than almost everything except for sound.
- TRUE
- FALSE

8) What is it called when light bends or turns when it enters a new medium?
- Reflection
- Diffraction
- Refraction
- Polarization
- Absorption

9) Which of the following is a practical use of refraction?
- Telescope
- Microscope
- Glasses
- All of the above
- None of the Above

10) True or False: Light travels at different speeds in different kinds of matter.
- TRUE
- FALSE

# The Atom

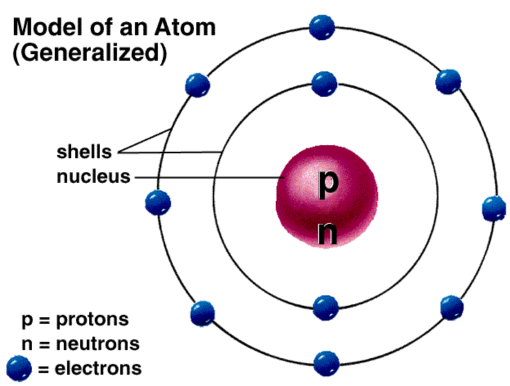
The atom is the basic building block for all matter in the universe. Atoms are extremely small and are made up of a few even smaller particles. The basic particles that make up an atom are electrons, protons, and neutrons. Atoms fit together with other atoms to make up matter. It takes a lot of atoms to make up anything. There are so many atoms in a single human body we won't even try to write the number here. Suffice it to say that the number is trillions and trillions (and then some more).

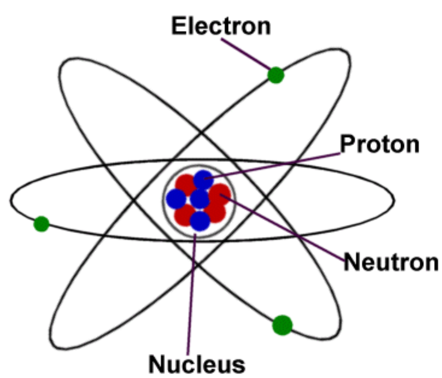
There are different kinds of atoms based on the number of electrons, protons, and neutrons each atom contains. Each different kind of atom makes up an element. There are 92 natural elements and up to 118 when you count in man-made elements.

Atoms last a long time, in most cases forever. They can change and undergo chemical reactions, sharing electrons with other atoms. But the nucleus is very hard to split, meaning most atoms are around for a long time.

## Structure of the Atom

At the center of the atom is the nucleus. The nucleus is made up of the protons and neutrons. The electrons spin in orbits around the outside of the nucleus.




## The Proton

The proton is a positively charged particle that is located at the center of the atom in the nucleus. The hydrogen atom is unique in that it only has a single proton and no neutron in its nucleus.

## The Electron

The electron is a negatively charged particle that spins around the outside of the nucleus. Electrons spin so fast around the nucleus, scientists can never be 100% sure where they are located, but scientists can make estimates of where electrons should be. If there are the same number of electrons and protons in an atom, then the atom is said to have a neutral charge.

Electrons are attracted to the nucleus by the positive charge of the protons. Electrons are much smaller than neutrons and protons. About 1800 times smaller!

**The Neutron**

The neutron doesn't have any charge. The number of neutrons affects the mass and the radioactivity of the atom.

**Other (even smaller!) particles**

**Quark** - The quark is a really small particle that makes up neutrons and protons. Quarks are nearly impossible to detect and it's only recently that scientists figured out they existed. They were discovered in 1964 by Murray Gell-Mann. There are 6 types of quarks: up, down, top, bottom, charm, and strange.

**Neutrino** - Neutrinos are formed by nuclear reactions. They are like electrons without any charge and are usually travelling at the speed of light. Trillions and trillions of neutrinos are emitted by the sun every second. Neutrinos pass right through most solids including humans!

**Activities** Test Quiz

1) What is the basic building block for all matter in the universe?

Cell
Electron
Nucleus
Atom
Molecule

2) What is a substance called that consists of a single type of atom?

Element
Compound
Quark
Proton
Molecule

3) Around how long do Atoms last?

Only a few seconds
4 to 5 days
100 years
10,000 years
Nearly forever

4) What two basic particles make up the nucleus of an atom?

Proton and Electron
Neutrino and Neutron
Neutron and Proton
Electron and Quark

5) What positively charged particle is located at the center of the atom in the nucleus?

Electron
Proton
Neutron
Quark
Neutrino

6) What particle has no charge and affects the mass of the atom?

Electron
Proton
Neutron
Quark
Neutrino

7) What particle has no charge, is formed by nuclear reactions, and travels at the speed of light?

- Electron
- Proton
- Neutron
- Quark
- Neutrino

8) What negatively charged particle spins around the nucleus of the atom?

- Electron
- Proton
- Neutron
- Quark
- Neutrino

9) What tiny particle is described using the terms up, down, top, bottom, charm, and strange?

- Electron
- Proton
- Neutron
- Quark
- Neutrino

10) An atom is said to have a neutral charge if it contains the same number of what two particles?

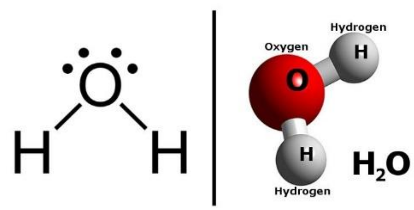
- Neutrons and neutrinos
- Neutrons and protons
- Electrons and protons
- Electrons and quarks
- Quarks and protons

# Molecules

Any time two atoms join together, they make a molecule. All the stuff around you is made up of molecules. This includes you! You are actually made up of trillions and trillions of different types of molecules.

**Compounds**

When atoms of different types of elements join together, they make molecules called compounds. Water consists of compound molecules made up of 2 hydrogen atoms and 1 oxygen atom. This is why it's called $H_2O$. Water will always have 2 times the number of hydrogen atoms as oxygen atoms.




Water Molecule showing 1 Oxygen atom and 2 hydrogen atoms

**Molecular Formula**

There are only just over 100 types of atoms, but there are millions and millions of different types of substances out there. This is because they are all made up of different types of molecules. Molecules are not only made up of different types of atoms but also different ratios. Like in the water example above, a water molecule has 2 hydrogen atoms and 1 oxygen atom. This is written as $H_2O$.

Other examples are carbon dioxide ($C0_2$), ammonia ($NH_3$), and sugar or glucose ($C_6H_{12}O_6$). Some formulas can get quite long and complex.

**Let's look at the molecule for sugar:**

$C_6$ - 6 carbon atoms
$H_{12}$ - 12 hydrogen atoms
$O_6$ - 6 oxygen atom

It takes these specific atoms in these specific numbers to make up a sugar molecule.

**Bonds**

Molecules and compounds are held together by forces called chemical bonds. There are two main types of bonds that hold most compounds together: covalent bonds and ionic bonds. Some compounds can have both types of bonds.

Both main types of bonds involve electrons. Electrons orbit atoms in shells. These shells want to be "full" of electrons. When they aren't full, they will try to bond with other atoms to get the right amount of electrons to fill their shells.

**Covalent Bonds** - Covalent bonds share electrons between atoms. This happens when it works out for atoms to share their electrons in order to fill their outer shells.

**Ionic Bonds** - Ionic bonds form when one electron is donated to another. This happens when one atom gives up an electron to another in order to form a balance and, therefore, a molecule or compound.

### Fun Facts about Molecules

Oxygen gas normally is the molecule $O_2$, but it can also be $O_3$ which we call ozone.
66% of the mass of the human body is made up of oxygen atoms.
Molecules can have different shapes. Some are long spirals while others may be pyramid shaped.
Organic compounds are compounds that contain carbon.
A perfect diamond is a single molecule made of carbon atoms.
DNA is a super long molecule that has information uniquely describing every human being.

### Activities

1) Molecules are made up of more than one _______.
   - Electron
   - Neutron
   - Proton
   - Atom
   - Element

2) Compounds are molecules that are made up of more than one _______.
   - Electron
   - Neutron
   - Proton
   - Atom
   - Element

3) What is the common name for the compound H2O?
   - Water
   - Carbon dioxide
   - Sugar
   - Ammonia
   - Glucose

4) How are molecules held together?
   - Elements
   - Bonds
   - Protons
   - Elemental tape
   - Molecular glue

5) How many carbon atoms are in the molecule CO2?
   - 1
   - 2
   - 3
   - 4
   - 5

6) Bonds between atoms are generally formed by what particles?
   - Neutrons
   - Protons
   - Quarks
   - Electrons
   - Neutrinos

7) What is the most common element in the human body?
   - Hydrogen
   - Carbon
   - Oxygen
   - Iron
   - Magnesium

8) What type of chemical bonds share electrons between atoms?
   - Ionic
   - Elemental
   - Iconic
   - Electronic
   - Covalent

9) What type of chemical bond is formed when one atom donates an electron to another atom?
   - Ionic
   - Elemental
   - Iconic
   - Electronic
   - Covalent

10) What element is needed to form an organic compound?
   - Hydrogen
   - Oxygen
   - Iron
   - Carbon
   - Helium

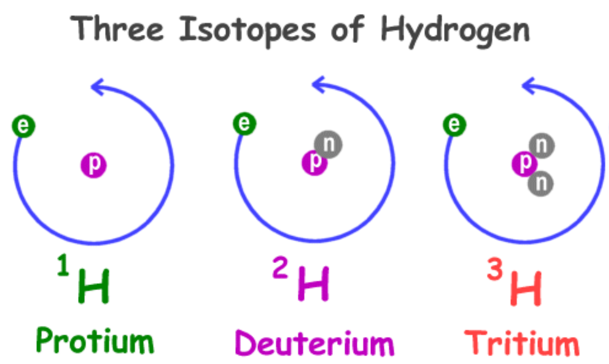
# Isotopes

**About Atoms and Elements**

We learned in the atoms and elements sections that each element has its own unique atom which is made up of a specific number of protons. The number of protons determines the atomic number of the element. Each atom also has the same number of electrons as protons.

**What is an isotope?**

Isotopes are atoms that have the same number of protons and electrons, but a different number of neutrons. Changing the number of neutrons in an atom does not change the element. Atoms of elements with different numbers of neutrons are called "isotopes" of that element.




**Naming Isotopes**

Since neutrons have no electrical charge, changing the number of neutrons does not affect the chemistry of the element. It does, however, change the mass of the element. Isotopes are identified by their mass, which is the total number of protons and neutrons.

There are two ways that isotopes are generally written. They both use the mass of the atom where **mass = (number of protons) + (number of neutrons)**. The first way is to put the mass as a superscript before the symbol of the element:
$^{4}$He
$^{14}$C
$^{235}$U
The other way is to write out the element and write the mass after a dash next to the element's name:
helium-4
carbon-14
uranium-238

**Hydrogen**

Hydrogen is the only element where the isotopes are given specific names. Common hydrogen, which has zero neutrons, is called protium. Hydrogen with one neutron is called deuterium and hydrogen with two neutrons is called tritium. See the picture at the top of the page.

**How many isotopes can an element have?**

All elements have a number of isotopes. Hydrogen has the fewest number of isotopes with only three. The elements with the most isotopes are cesium and xenon with 36 known isotopes.

## Stable and Unstable Isotopes

Some isotopes are stable and some are unstable. When an isotope is unstable it will decay over time and eventually it will turn into another isotope or element. Unstable isotopes are considered radioactive. Most elements that are found in nature are made up of stable isotopes. The element with the most stable isotopes is tin which has ten different stable isotopes.

## Interesting Facts about Isotopes

Many elements only exist in an unstable or radioactive form.
All non-natural or man-made elements are radioactive isotopes.
Heavier isotopes tend to react more slowly than lighter isotopes of the same element.
Deuterium (the hydrogen isotope with one neutron) can form water with oxygen. This is called "heavy water" as deuterium has twice the mass of normal hydrogen (protium).
There are 254 known stable isotopes and 80 elements which have at least one stable isotope.
Twenty-six elements only have one stable isotope. These elements are called monoisotopic.

## Activities

1) What particle determines the atomic number of an atom?
   - Neutron
   - Quark
   - Element
   - Proton
   - Nucleus

2) Atoms always have the same number of what two atomic particles?
   - Neutrons and neutrinos
   - Neutrons and protons
   - Electrons and protons
   - Electrons and quarks
   - Quarks and protons

3) The number of what atomic particle varies between different isotopes of the same element?
   - Neutron
   - Quark
   - Element
   - Proton
   - Nucleus

4) What characteristic of an element differs between isotopes?
   - Negative charge
   - Mass
   - Positive charge
   - Chemistry
   - All of the Above

5) In the isotope Carbon-14, what does the number 14 represent?
   - The total charge
   - The number of electrons
   - Mass of the atom
   - All of the above
   - None of the Above

6) What is the name given to the element hydrogen when it has no neutrons?
   - Protium
   - Deuterium
   - Tritium
   - This isotope does not exist

7) True or False: Most elements only have 1 or 2 isotopes and several elements do not have any isotopes.
   - TRUE
   - FALSE

8) Which of the following is true about unstable isotopes?
   - They decay over time
   - They can turn into another isotope
   - They can turn into another element
   - They are radioactive
   - All of the Above

9) What element has the most stable isotopes?
   - Iron
   - Hydrogen
   - Oxygen
   - Tin
   - Carbon

10) What is the nickname for water made with the Hydrogen isotope deuterium?
   - Hard water
   - Purified water
   - Heavy water
   - Soft Water
   - Isotropic water

# Solids, Liquids, and Gases

We learned in some of our other lessons that matter is made up of atoms and molecules. Millions and millions of these tiny objects fit together to form larger things like animals and planets and cars. Matter includes the water we drink, the air we breathe, and the chair we are sitting on.

**States or Phases**

Matter usually exists in one of three states or phases: solid, liquid, or gas. The chair you are sitting on is a solid, the water you drink is liquid, and the air you breathe is a gas.

**Changing State**

The atoms and molecules don't change, but the way they move about does. Water, for example, is always made up of two hydrogen atoms and one oxygen atom. However, it can take the state of liquid, solid (ice), and gas (steam). Matter changes state when more energy gets added to it. Energy is often added in the form of heat or pressure.

**Water**

Solid water is called ice. This is water with the lowest energy and temperature. When solid, the molecules in water are held tightly together and don't move easily.

Liquid water is just called water. As ice heats up it will change phases to liquid water. Liquid molecules are looser and can move about easily.

Gas water is called steam or vapor. When water boils it will turn to vapor. These molecules are hotter, looser, and moving faster than the liquid molecules. They are more spread apart and can be compressed or squished.


The three states of Water

**More States**

There are actually two more states or phases that matter can take, but we don't see them much in our everyday life.

One is called plasma. Plasma occurs at very high temperatures and can be found in stars and lightning bolts. Plasma is like gas, but the molecules have lost some electrons and become ions.

Another state has the fancy name Bose-Einstein condensates. This state can occur at super low temperatures.

**Fun Facts about Solids, Liquids, Gases**

Gases are often invisible and assume the shape and volume of their container.
The air we breathe is made up of different gases, but it is mostly nitrogen and oxygen.
We can see through some solids like glass.
When liquid gasoline is burned in a car, it turns into various gases which go into the air from the exhaust pipe.
Fire is a mixture of hot gases.
Plasma is by far the most abundant state of matter in the universe because stars are mostly plasma.

**Activities**

1) Which of the following is an example of a solid?
- Air you breathe
- Coffee you drink
- A chair you sit on
- Water you swim in
- All of the Above

2) Which of the following is the common name for the solid state of water?
- Liquid
- Rain
- Steam
- Ice
- Vapor

3) Which of the following states of matter is the most abundant state of matter in the universe?
- Solid
- Liquid
- Gas
- Plasma
- Bose-Einstein condensates

4) Which of the following states of matter is water in when it's in the form of steam or vapor?
- Solid
- Liquid
- Gas
- Plasma
- Bose-Einstein condensates

5) Which of the following states of matter occur between solid and gas as the energy is increased?
- Solid
- Liquid
- Gas
- Plasma
- Bose-Einstein condensates

6) What unique state of matter only occurs at extremely low temperatures?
- Solid
- Liquid
- Gas
- Plasma
- Bose-Einstein condensates

7) In which of the following three states of matter are the particles moving the fastest?
- Solid
- Liquid
- Gas
- They are all moving the same

8) In which of the following three states of matter are the particles the closest together?
- Solid
- Liquid
- Gas
- They are all spaced the same

9) Which of the following states of matter assume the volume and shape of their container?
- Solids
- Liquids
- Gases
- All of the above
- None of the Above

10) Which of the following statements is true about plasma as a state of matter?
- It occurs at very high temperatures
- It is found in stars
- It's like gas, but some molecules have become ions
- It is found in lightning bolts
- All of the Above

# Crystals

Amethyst Crystal

### What are crystals?

Crystals are a special kind of solid material where the molecules fit together in a repeating pattern. This pattern causes the material to form all sorts of unique shapes.

### How do they form?

The process of crystal forming is called crystallization. Crystals often form in nature when liquids cool and start to harden. Certain molecules in the liquid gather together as they attempt to become stable. They do this in a uniform and repeating pattern that forms the crystal.

In nature, crystals can form when liquid rock, called magma, cools. If it cools slowly, then crystals may form. Many valuable crystals such as diamonds, rubies, and emeralds form this way.

Another way crystals form is when water evaporates from a mixture. Salt crystals often form as salt water evaporates.

### What unique properties do crystals have?

Crystals can have very flat surfaces called facets. They can form geometric shapes such as triangles, rectangles, and squares. The shapes are a direct result of the type of molecules and atoms that make up the crystal. Smaller crystals and larger crystals that were formed of the same molecules and in the same method should have similar shapes.

There are seven basic crystal shapes, also called lattices. They are Cubic, Trigonal, Triclinic, Orthorhombic, Hexagonal, Tetragonal, and Monoclinic.

### Interesting Types of Crystals

**Snowflakes** - Snowflakes are ice crystals that are formed high in the clouds when water freezes. They always have six sides or arms, but every one of them is unique.

**Timing crystals** - When an electric current is sent through some crystals they vibrate at a very precise frequency. Quartz crystals are used in watches and other electronics to keep an accurate time.

**Quartz** - Quartz is a common mineral and crystal. It is one of the hardest common minerals. The gemstone amethyst is a purple type of quartz.

**Diamonds** - Diamonds are one of the most valuable minerals on Earth. Not only for jewelry, but diamond is also the hardest substance on earth and is used for special tools such as diamond saws. Diamond is a form of the element carbon.

**Fun facts About Crystals**

Crystallography is the science of studying crystals and how they form.
Some crystals, like diamonds, are really just one giant molecule made from lots of atoms of a single element.
A lot of computer screens use liquid crystals for their display.
They are very popular in jewelry because they can sparkle and come in many different colors.
Some living organisms are able to produce crystals.

**Activities**

1) What state or phase of material are crystals?
- Gas
- Plasma
- Liquid
- Solid
- All of the Above

2) Which of the following best describes a crystal?
- Molecules fit together in a random pattern
- Molecules fit together in a repeating pattern
- All of the above
- None of the above

3) Which of the following is a way that crystals can form in nature?
- When liquids cool and start to harden
- When magma cools
- When water evaporates from a mixture
- All of the above
- None of the Above

4) What is crystallization?
- When crystals melt into liquid
- The formation of solids in the form of random molecules
- The formation of crystals
- When crystals dissolve in a solution

5) What are the flat surfaces on crystals called?
- Facets
- Lattices
- Quartz
- Plateaus
- Smooth

6) Which of the following is not one of the seven basic crystal shapes?
- Cubic
- Trigonal
- Hexagonal
- Monoclinic
- Pentagonal

7) What type of crystal is the hardest substance found on Earth?
- Quartz
- Garnet
- Amethyst
- Diamond
- Jasper

8) What type of crystals are used for timing in watches and electronics?
- Quartz
- Garnet
- Amethyst
- Diamond
- Jasper

9) What are the seven basic shapes formed by crystals called?
- Facets
- Lattices
- Quartz
- Shapelets
- Formations

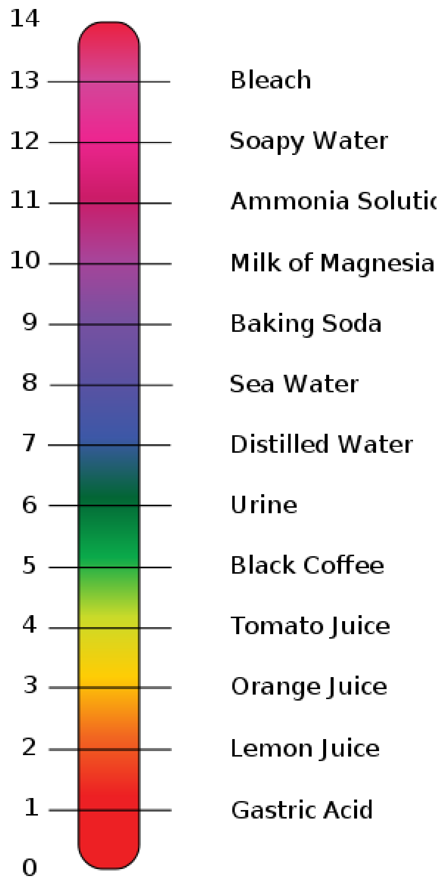
10) What type of crystals are formed in clouds when water freezes?
- Quartz
- Garnet
- Snowflakes
- Diamond
- Amethyst

# Acids and Bases

Acids and bases are two special kinds of chemicals. Almost all liquids are either acids or bases to some degree. Whether a liquid is an acid or base depends on the type of ions in it. If it has a lot of hydrogen ions, then it is an acid. If it has a lot of hydroxide ions, then it is a base.

**pH Scale**

Scientists use something called a pH scale to measure how acidic or basic a liquid is. pH is a number from 0 to 14. From 0 to 7 are acids, with 0 being the strongest. From 7 to 14 are bases with 14 being the strongest base. If a liquid has a pH of 7, it's neutral. This would be something like distilled water.




**Strong Acids and Bases**

Acids with a low pH of around 1 are very reactive and can be dangerous. The same is true for bases of a pH near 13. Chemists use strong acids and bases to get chemical reactions in the lab. Although they can be dangerous, these strong chemicals can also be helpful to us.


*** Never handle acids or bases in a chemistry lab unless supervised by your teacher. They can be very dangerous and can burn your skin.

**Acids and Bases in Nature**

There are many strong acids and bases in nature. Some of them are dangerous and used as poisons by insects and animals. Some are helpful. Many plants have acids and bases in their leaves, seeds, or even their sap. Citrus fruits like lemons and oranges have citric acid in their juice. This is what makes lemons taste so sour.

**Acids and Bases in our Bodies**

Our bodies use acids and bases too. Our stomachs use hydrochloric acid to help digest foods. This strong acid also kills bacteria and helps to keep us from getting sick. Our muscles produce lactic acid when we exercise. Also, our pancreas uses a base called an alkali to help with digestion. These are just a few examples of how the chemistry of bases and acids help our bodies function.

**Other Uses**

Science and technology makes good use of acids and bases. Car batteries use a strong acid called sulphuric acid. Chemical reactions between the acid and lead plates in the battery help make electricity to start the car. They are also used in many household cleaning products, baking soda, and to make fertilizer for crops.

**Fun Facts**

Acids and bases can help neutralize each other.
Acids turn litmus paper red, bases turn it blue.
Strong bases can be slippery and slimy feeling.
Acids taste sour, bases taste bitter.
Proteins are made up of amino acids.
Vitamin C is also an acid called ascorbic acid.
Ammonia is a base chemical.

**Activities**

1) A liquid is determined to be an acid or base depending on the type of ____ in the liquid.

- Electrons
- Protons
- Ions
- Elements
- Neutrons

2) What is the pH scale?

- A method for measuring the protons in a solution
- A measurement of how acidic or basic a liquid is
- A special microscope used to look at acids
- All of the above
- None of the Above

3) What measurement of the pH scale is considered a neutral liquid?

- 0
- 3
- 7
- 9
- 14

4) A liquid is considered an acid if it has a lot of __________.

- Hydrogen ions
- Helium ions
- Positive ions
- Negative ions
- Hydroxide ions

5) A liquid is considered a base if it has a lot of _________.

- Hydrogen ions
- Helium ions
- Positive ions
- Negative ions
- Hydroxide ions

6) True or False: Acids with a low pH and bases with a high pH are considered very dangerous.

- TRUE
- FALSE

7) Which of the following is a way that acids and bases are used in science and technology?

- Batteries
- Household cleaning products
- Baking soda
- Fertilizer
- All of the Above

8) What kind of acid is produced by our muscles when we exercise?

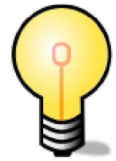
- Sulfuric acid
- Hydrochloric acid
- Boric acid
- Lactic acid
- Acetic acid

9) What is the range of the pH scale from lowest to highest?

- 0 to 100
- 0 to 10
- 1 to 10
- 0 to 14
- 0 to 7

10) How do acids taste compared to bases?

- Acids are sweet and bases are bitter
- Acids are sour and bases are bitter
- Acids are bitter and bases are sweet
- Acids are spicy and bases are sour
- Acids are bitter and bases are sour

# Electricity 

On this page we will describe some of the basic concepts of electricity. Knowing what these terms mean will help you to better understand the rest of our pages on electricity.

**What are some important things to know about electricity?**

**Conductors and insulators** - Conductors are materials that allow electricity to flow easily. Most types of metal are good conductors, which is why we use metal for electrical wire. Copper is a good conductor and isn't too expensive, so it's used a lot for the wiring in homes today.

Insulators are the opposite of conductors. An insulator is a material that doesn't carry electricity. Insulators are important because they can protect us from electricity. Materials like rubber, plastic, and paper are good insulators.

**Voltage** - Voltage is the name for the electric force that causes electrons to flow. It's the measure of potential difference between two points in the circuit. Voltage may come from a battery or a power plant.

**Current** - Current is the measure of the flow of electrons in a circuit. Current is measured in Amps or Amperes.

**Power (Watts)** - The power or energy used by a circuit is measured in Watts. You can calculate the number of Watts by multiplying the Voltage times the Current. When your parents get their electrical bill it's generally in kilowatt hours. This is the measurement of power over time or how much power was used that month.

**Resistance** - Resistance measures how well a material or object conducts electricity. Low resistance means the object conducts electricity well, high resistance means the object does not conduct electricity well.

**Battery**

A battery can act as a source of electricity in circuits. It stores up electric power and then provides a voltage across a circuit causing power to flow through the circuit.


Batteries use chemicals that react to make electricity. They have a positive connection called the anode and a negative connection called the cathode. When a circuit with a load is placed across the anode and cathode, the chemicals react causing electricity to flow through the circuit. The chemicals in batteries only last so long, so batteries have a limited amount of electricity and eventually will run out.

## Alternate and Direct Current

There are two main types of current used in electrical systems today: alternate current (AC) and direct current (DC). Batteries, and most electronics, use direct current. This is where current always flows in one direction. Power stations that generate power for our homes generate current that constantly changes direction (60 times each second). Therefore the power that we get from our wall outlets is AC current.

## Static Electricity

Sometimes electric charges can build up on the surface of objects. This is called static electricity. When you put on your clothes and they sometimes "stick" to your body or have an attraction to you, this is static electricity. When your hair sometimes goes straight up for no reason, this can be static electricity. If you rub a balloon against your clothes, you can build up a static electricity charge on the balloon that will cause it to stick to a wall. Static electricity can sometimes damage electronic components. There are anti-static bags and other ways to protect components from getting damaged.

## Activities

1) What measurement represents the potential difference between two points in an electrical circuit?
   - Conductor
   - Current
   - Insulator
   - Voltage
   - Resistance

2) What materials are the opposite of conductors?
   - Conductor
   - Current
   - Insulator
   - Voltage
   - Inductors

3) What is the unit of measurement used for current?
   - Amps
   - Volts
   - Farads
   - Watts
   - Ohms

4) What do we call materials that allow electricity to flow easily?
   - Conductor
   - Current
   - Insulator
   - Voltage
   - Inductors

5) What is the unit of measurement used for power?
   - Amps
   - Volts
   - Farads
   - Watts
   - Ohms

6) Resistance measures how well a material or object conducts _______.
   - Water
   - Electricity
   - Fire
   - Heat
   - Music

7) What is the positive connection of a battery called?
   - Insulator
   - Cathode
   - Conductor
   - Anode
   - Current

8) What is the source of electricity in batteries?
   - Sunlight
   - Gasoline
   - Chemical reactions
   - Natural gas
   - Hydropower

9) What type of power comes from the typical wall outlet in the United States?
   - AC
   - DC

10) What do we call an electric charge that builds up on the surface of an object?
   - Resistive charge
   - Capacitance
   - Watts
   - Ampere charge
   - Static charge

# Electric Current

Current is the flow of an electric charge. It is an important quantity in electronic circuits. Current flows through a circuit when a voltage is placed across two points of a conductor.

**Flow of Electrons**

In an electronic circuit, the current is the flow of electrons. However, generally current is shown in the direction of the positive charges. This is actually in the opposite direction of the movement of the electrons in the circuit.

**How is current measured?**

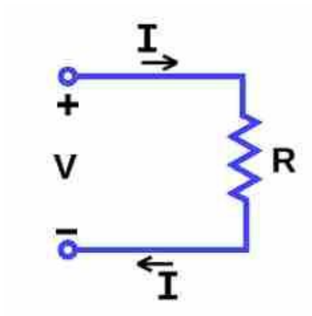
The standard unit of measurement for current is the ampere. It is sometimes abbreviated as A or amps. The symbol used for current is the letter "i".

Current is measured as the flow of electric charge over time through a given point in an electric circuit. One ampere is equal to 1 coulomb over 1 second. A coulomb is a standard unit of electric charge.

**Calculating Current**

Current can be calculated using Ohm's Law. It can also be used to figure out the resistance of a circuit if the voltage is also known or the voltage of a circuit if the resistance is known.

**I = V/R**
where I = current, V = voltage, and R = resistance




Current is also used to calculate power using the following equation:

**P = I * V**
where P = power, I = current, and V = voltage.

**AC versus DC**

There are two main types of current used in most electronic circuits today. They are alternating current (AC) and direct current (DC).
Direct Current (DC) - Direct current is the constant flow of electric charge in one direction. Batteries generate direct current to power handheld items. Most electronics use direct current

for internal power often converting alternating current (AC) to direct current (DC) using a transformer.
Alternating Current (AC) - Alternating current is current where the flow of electric charge is constantly changing directions. Alternating current is mostly used today to transmit power on power lines. In the United States the frequency at which the current alternates is 60 Hertz. Some other countries use 50 Hertz as the standard frequency.

**Electromagnetism**
Current also plays an important role in electromagnetism. Ampere's law describes how a magnetic field is generated by an electric current. This technology is used in electric motors.

**Interesting Facts about Current**
The direction of the current flow is often shown with an arrow. In most electronic circuits the current is shown as flowing towards ground.
The current in a circuit is measured using a tool called an ammeter.
The flowing of electric current through a wire can sometimes be thought of like the flowing of water through a pipe.
The electrical conductivity of a material is the measurement of the ability of the material to allow for the flow of electrical current.

**Activities**

1) What is electrical current?
   - The potential difference between two points in an electric circuit
   - The rate at which electrical energy is transferred
   - The flow of electric charge
   - All of the above
   - None of the Above

2) What is the unit of measurement for electrical current?
   - Volt
   - Ampere
   - Watt
   - Coulomb
   - Ohm

3) What letter is used to represent current in an electrical diagram or formula?
   - c
   - e
   - v
   - p
   - i

4) What is the standard unit of measurement for electrical charge?
   - Volt
   - Ampere
   - Watt
   - Coulomb
   - Ohm

5) According to Ohm's Law, current equals the voltage divided by the _________.
   - Resistance
   - Inductance
   - Capacitance
   - Power
   - Conductance

6) If you have a 12 Volt battery placed across a 6 Ohm resistor, what will the current be?
   - 0.5 Amps
   - 1 Amp
   - 2 Amps
   - 4 Amps
   - 5 Amps

7) If you place a 50 Volt power source across a 10 Ohm resistor, what will the current be?
   - 0.5 Amps
   - 1 Amp
   - 2 Amps
   - 4 Amps
   - 5 Amps
   - 8) If the current is 2 Amps and the voltage is 8 Volts, what is the power?
   - 4 Watts
   - 6 Watts
   - 10 Watts
   - 16 Watts
   - 28 Watts

9) What do we call current that only flows in one direction?
   - AC current
   - DC current

10) What do we call current that constantly changes direction?
   - AC current
   - DC current

# Electricity-Uses and Applications

We use electricity constantly in our daily lives. It is one of the most important types of power and energy that we use.

**Electricity in our House**

Electricity travels to our house over power lines from a big power plant somewhere far away. Your parents actually have to pay for how much electricity is used. There is an electric meter outside of your house that keeps track of this. The more the lights are on or the TV is running, the higher the bill will be from the electric company.

Once the power comes to our house, it gets sent out on wires to sockets in the walls. We can plug all sorts of things into these sockets and use the power from electricity. In our homes we power lights, air conditioning, televisions, ovens, and more from electricity. Without it, we'd be bored, hot, and sitting in the dark.

**Batteries**

Some electricity comes from batteries. Batteries use chemicals to store up electricity that can power devices like cell phones, radio controlled cars, handheld video games, and flashlights. Batteries run out of power after a while and either need to be recharged or recycled. Remember to always recycle your batteries as there are dangerous chemicals in them!

**Other uses**

Electricity is used in cars too. There is a big battery to help the engine get started. Then the engine generates electricity for the radio, lights, and other cool features. Some cars run 100% on electricity by using big batteries that get charged up from a wall socket.

Electricity also can make magnetism. This can be used to create giant powerful magnets as well as fast and quiet magnetic trains. Electric motors generate magnetism to turn the motor and cause movement for all sorts of uses.

**History**

One of the first great uses of electricity was for communication using Morse Code and the Telegraph in 1840. This allowed messages to be sent long distances in an instant. After that came the telephone and the radio and, in 1880, electric light. These inventions and the use of electricity changed the world. Electricity continued to change the world with new inventions such as the TV and, even more recently, the personal computer and the cell phone.

**Fun facts about the Uses of Electricity**

25% of the city of San Francisco's energy is generated by wind power.

Electric eels use electricity to ward off enemies. They can produce a shock of around 500 volts.

Our bodies use electricity to communicate including telling our heart to keep beating.

Two famous scientists, Thomas Edison and Nikola Tesla, once had an argument over what kind of electricity we should use in our homes, AC or DC. Tesla won and AC is delivered to most homes still today.

Electricity was first used in homes for lighting.

**Activities**

1) True or False: The electricity you use in your house or apartment is free.
  - TRUE
  - FALSE

2) How does electricity typically get to a home or apartment?
  - Through the air
  - Through cable
  - Over power lines
  - From satellite
  - Using radio frequency waves

3) Where do batteries get the energy to produce electricity?
  - Sunlight
  - Gasoline
  - Hydropower
  - Natural gas
  - Chemical reactions

4) True or False: Batteries eventually run out of power and need to be recycled or recharged.
  - TRUE
  - FALSE

5) Which of the following is an example of how electricity is used in a home?
  - Air conditioning
  - Television
  - Lights
  - Oven
  - All of the above

6) Which of the following electrical items is typically powered by a battery?
  - Air conditioning
  - Cell phone
  - Refrigerator
  - All of the above
  - None of the Above

7) What early electrical invention allowed messages to be sent using Morse Code?
  - Telephone
  - Automobile
  - Telegraph
  - Internet
  - Computer

8) What scientist argued with Thomas Edison over AC versus DC electrical power?
  - Albert Einstein
  - Marie Curie
  - Eli Whitney
  - Nikola Tesla
  - Isaac Newton

9) What was the first use of electricity in homes?
  - Lighting
  - Television
  - Air conditioning
  - Wi-Fi
  - Cooking

10) True or False: Some animals use electricity to fight off enemies.
  - TRUE
  - FALSE

## Resistors, Capacitors, and Inductors

The three basic elements used in electronic circuits are the resistor, capacitor, and inductor. They each play an important role in how an electronic circuit behaves. They also have their own standard symbols and units of measurement.

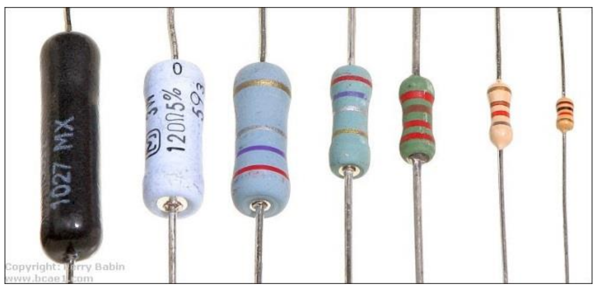
### Resistors

A resistor represents a given amount of resistance in a circuit. Resistance is a measure of how the flow of electric current is opposed or "resisted." It is defined by Ohm's law which says the resistance equals the voltage divided by the current.

Resistance = voltage/current
or
**R = V/I**

Resistance is measured in Ohms. The Ohm is often represented by the omega symbol: Ω.

The symbol for resistance is a zigzag line as shown below. The letter "R" is used in equations.




Resistor Symbol

### Capacitors

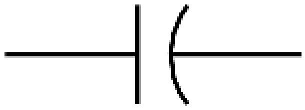
A capacitor represents the amount of capacitance in a circuit. The capacitance is the ability of a component to store an electrical charge. You can think of it as the "capacity" to store a charge. The capacitance is defined by the equation

**C = q/V**
where q is the charge in coulombs and V is the voltage.

In a DC circuit, a capacitor becomes an open circuit blocking any DC current from passing the capacitor. Only AC current will pass through a capacitor.

Capacitance is measured in Farads.

The symbol for capacitance is two parallel lines. Sometimes one of the lines is curved as shown below. The letter "C" is used in equations.


Capacitor Symbol

**Inductors**

An inductor represents the amount of inductance in a circuit. The inductance is the ability of a component to generate electromotive force due to a change in the flow of current. A simple inductor is made by looping a wire into a coil. Inductors are used in electronic circuits to reduce or oppose the change in electric current.

In a DC circuit, an inductor looks like a wire. It has no affect when the current is constant. Inductance only has an effect when the current is changing as in an AC circuit.

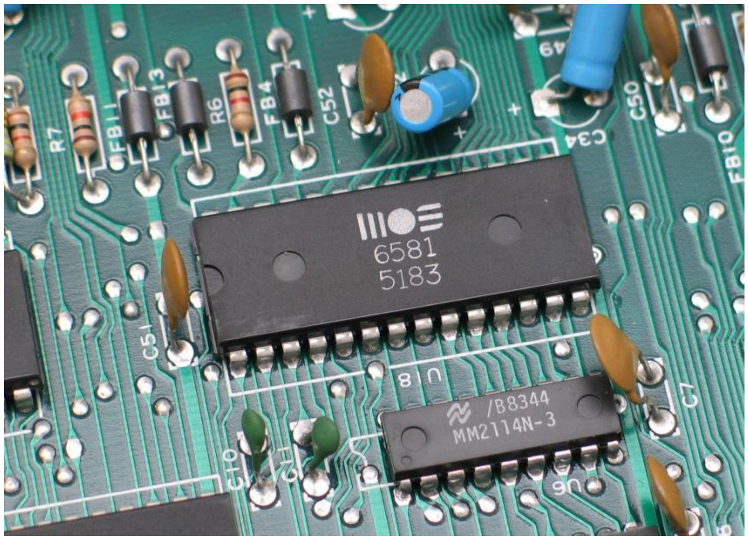
Inductance is measured in Henrys.

The symbol for inductance is a series of coils as shown below. The letter "L" is used in equations.

Inductor Symbol

**Interesting Facts about Resistors, Capacitors, and Inductors**
The resistance of a material is the opposite or the inverse of the conductivity.
The Ohm is named after German physicist Georg Ohm.
The Farad is named after English physicist Michael Faraday.
The Henry is named after American scientist Joseph Henry.
Combinations of capacitors, inductors, and resistors are used to build passive filters that will only allow electronic signals of certain frequencies to pass through.




## Activities

1) Which of the following represents the ability of a component to store an electrical charge?
- Resistance
- Capacitance
- Inductance
- All of the above
- None of the Above

2) Which of the following represents the ability of a component to generate electromotive force due to a change in the flow of current?
- Resistance
- Capacitance
- Inductance
- All of the above
- None of the Above

3) Which of the following represents the ability of a component to oppose the flow of current?
- Resistance
- Capacitance
- Inductance
- All of the above
- None of the Above

4) What is the standard unit of measurement for resistance?
- Volt
- Henry
- Farad
- Ampere
- Ohm

5) What is the standard unit of measurement for capacitance?
- Volt
- Henry
- Farad
- Ampere
- Ohm

6) What is the standard unit of measurement for inductance?
- Volt
- Henry
- Farad
- Ampere
- Ohm

7) What does the schematic symbol for a capacitor look like?
- A zigzag line
- A series of coils
- Two parallel lines

8) What does the schematic symbol for an inductor look like?
- A zigzag line
- A series of coils
- Two parallel lines

9) What does the schematic symbol for a resistor look like?
- A zigzag line
- A series of coils
- Two parallel lines

10) According to Ohm's Law, current equals the voltage divided by the _________.
- Power
- Inductance
- Capacitance
- Resistance
- Conductance

# Ohm's Law

One of the most important and basic laws of electrical circuits is Ohm's law which states that the current passing through a conductor is proportional to the voltage over the resistance.

### Equation

Ohm's law may sound a bit confusing when written in words, but it can be described by the simple formula:

$$I = \frac{V}{R}$$

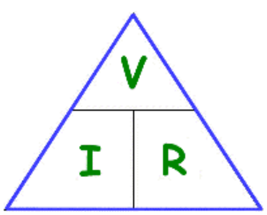
where I = current in amps, V = voltage in volts, and R = resistance in ohms

This same formula can be also be written in order to calculate for the voltage or the resistance:

$$I = \frac{V}{R} \quad \text{or} \quad V = IR \quad \text{or} \quad R = \frac{V}{I}$$

### Triangle

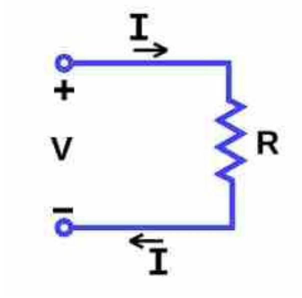
If you ever need help in remembering the different equations for Ohm's law and solving for each variable (V, I, R) you can use the triangle below.




As you can see from the triangle and the equations above, voltage equals I times R, current (I) equals V over R, and resistance equals V over I.

### Circuit Diagram

Here is a diagram showing I, V, and R in a circuit. Any one of these can be calculated using Ohm's law if you know the values of the other two.




**How Ohm's Law Works**

Ohm's law describes the way current flows through a resistance when a different electric potential (voltage) is applied at each end of the resistance. One way to think of this is as water flowing through a pipe. The voltage is the water pressure, the current is the amount of water flowing through the pipe, and the resistance is the size of the pipe. More water will flow through the pipe (current) the more pressure is applied (voltage) and the bigger the pipe is (lower the resistance).

**Example Problems**

1. If the resistance of an electrical circuit is increased, what will happen to the current assuming the voltage remains the same?

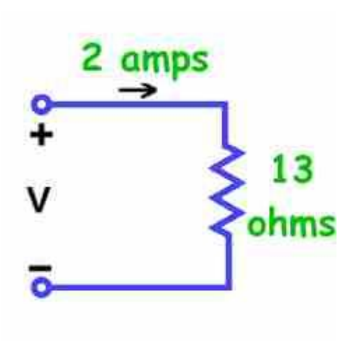
Answer: The current will decrease.

2. If the voltage across a resistance is doubled, what will happen to the current?

Answer: The current will double as well.

Explanation: If you look at the equation V= IR, if R stays the same then if you multiple V*2 (double the voltage), you must also double the current for the equation to remain true.

3. What is the voltage V in the circuit shown?




Answer: V = I * R = 2 x 13 = 26 volts

**Interesting Facts about Ohm's Law**
It is generally applied only to direct current (DC) circuits, not alternating current (AC) circuits. In AC circuits, because the current is constantly changing, other factors such as capacitance and inductance must be taken into account.
The concept behind Ohm's law was first explained by German Physicist Georg Ohm who the law is also named after.

The tool for measuring volts in an electric circuit is called a voltmeter. An ohmmeter is used for measuring resistance. A multimeter can measure several functions including voltage, current, resistance, and temperature.

## Activities

1) According to Ohm's Law, current equals the voltage divided by the _________.
   - Resistance
   - Inductance
   - Capacitance
   - Power
   - Conductance

2) What equation would you use to solve for voltage?
   - V = I/R
   - V = PR
   - V = CI
   - V = IR
   - V = R/I

3) What does the letter 'I' stand for in Ohm's Law?
   - Resistance
   - Inductance
   - Capacitance
   - Voltage
   - Current

4) What does the letter 'R' stand for in Ohm's Law?
   - Resistance
   - Inductance
   - Capacitance
   - Reactance
   - Rate of change

5) If the current in an electrical circuit is constant, what will happen to the voltage if the resistance is increased?
   - The voltage will decrease
   - The voltage will increase
   - The voltage will stay the same

6) If there are 10 Volts across a 5 Ohm resistor, what is the current?
   - 0.5 Amps
   - 1 Amp
   - 2 Amps
   - 15 Amps
   - 50 Amps

7) If there are 40 Volts and 5 Amps running through an electrical circuit, what is the resistance of the circuit?
   - 1 Ohm
   - 2 Ohms
   - 4 Ohms
   - 6 Ohms
   - 8 Ohms

8) If there are 7 Amps running through a 3 Ohm resistor, what will the voltage be across the resistor?
   - 2.5 Volts
   - 10 Volts
   - 17 Volts
   - 21 Volts
   - 42 Volts

9) If you increase the voltage across a resistor, what will happen to the current?
   - The current will decrease
   - The current will increase
   - The current will stay the same

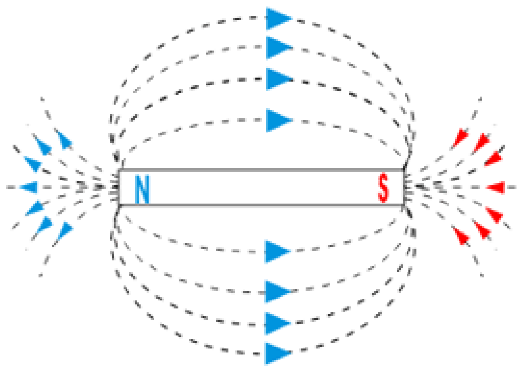
10) If you increase the size of the resistor and keep the voltage the same, what will happen to the current?
   - The current will decrease
   - The current will increase
   - The current will stay the same

# Magnetism

Magnetism is an invisible force or field caused by the unique properties of certain materials. In most objects, electrons spin in different, random directions. This causes them to cancel each other out over time. However, magnets are different. In magnets the molecules are uniquely arranged so that their electrons spin in the same direction. This arrangement of atoms creates two poles in a magnet, a North-seeking pole and a South-seeking pole.

**Magnets Have Magnetic Fields**

The magnetic force in a magnet flows from the North pole to the South pole. This creates a magnetic field around a magnet.




Have you ever held two magnets close to each other? They don't act like most objects. If you try to push the South poles together, they repel each other. Two North poles also repel each other.

Turn one magnet around, and the North (N) and the South (S) poles are attracted to each other. Just like protons and electrons - opposites attract.

**Where do we get magnets?**

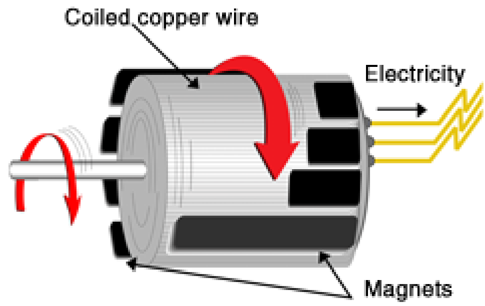
Only a few materials have the right type of structures to allow the electrons to line up just right to create a magnet. The main material we use in magnets today is iron. Steel has a lot of iron in it, so steel can be used as well.

**The Earth is a giant magnet**

At the center of the Earth spins the Earth's core. The core is made up of mostly iron. The outer portion of the core is liquid iron that spins and makes the earth into a giant magnet. This is where we get the names for the north and south poles. These poles are actually the positive and negative poles of the Earth's giant magnet. This is very useful to us here on Earth as it lets us use magnets in compasses to find our way and make sure we are heading in the right direction. It's also useful to animals such as birds and whales who use the Earth's magnetic field to find the right direction when migrating. Perhaps the most important feature of the Earth's magnetic field is that it protects us from the Sun's solar wind and radiation.

**The Electric Magnet and Motor**

Magnets can also be created by using electricity. By wrapping a wire around an iron bar and running current through the wire, very strong magnets can be created. This is called electromagnetism. The magnetic field created by electromagnets can be used in a variety of applications. One of the most important is the electric motor.




## Activities

1) The magnetic force of a material comes from the spinning of what atomic particle?
- Proton
- Nucleus
- Neutron
- Electron
- Photon

2) What happens if you hold the north poles of two different magnets close to each other?
- They will attract each other
- They will repel each other
- They will grow very hot
- Nothing will happen

3) What happens if you hold the south pole of one magnet close to the north pole of another magnet?
- They will attract each other
- They will repel each other
- They will grow very hot
- Nothing will happen

4) What is the main element used to create a magnet?
- Carbon
- Gold
- Magnesium
- Oxygen
- Iron

5) What creates the protective magnetic field around the Earth?
- Volcanoes
- The movement of the ocean
- The Earth's core
- The Moon
- Photons from the Sun

6) What does the Earth's magnetic field protect us from?
- The Moon crashing into the Earth
- Solar winds and radiation from the Sun
- The atmosphere from escaping into space
- Meteorites
- Nothing

7) True or False: Compasses point north because the Earth is basically a giant magnet.
- TRUE
- FALSE

8) Powerful magnets can be created by wrapping a wire around iron and running _____ through the wire.
- Heat
- Water
- Cold
- Electricity
- None of the Above

9) In magnetic materials, all the electrons are spinning in ______ .
- Opposite directions
- The same direction
- Random directions

10) True or False: Some animals use the Earth's magnetic field to find the right direction when migrating.
- TRUE
- FALSE