# Radiometer

**Inventory:**

Radiometer

Light source

**Directions:**

1) Place the radiometer in a bright light and observe what happens.
2) Move the radiometer closer to and farther from the light source. If you are using an artificial light source, find ways to partially and completely shield the radiometer from the light source. Observe what happens.
3) CHALLENGE: Can you get the radiometer to spin the other direction while still just sitting on the table in front of the light source?
4) Read the "What the heck?" on the back of this page to learn more about what you observed.

## Cool Extension

1) Place the radiometer in a bowl.
2) Pour hot water over the radiometer.
3) What happens???

# What the heck?

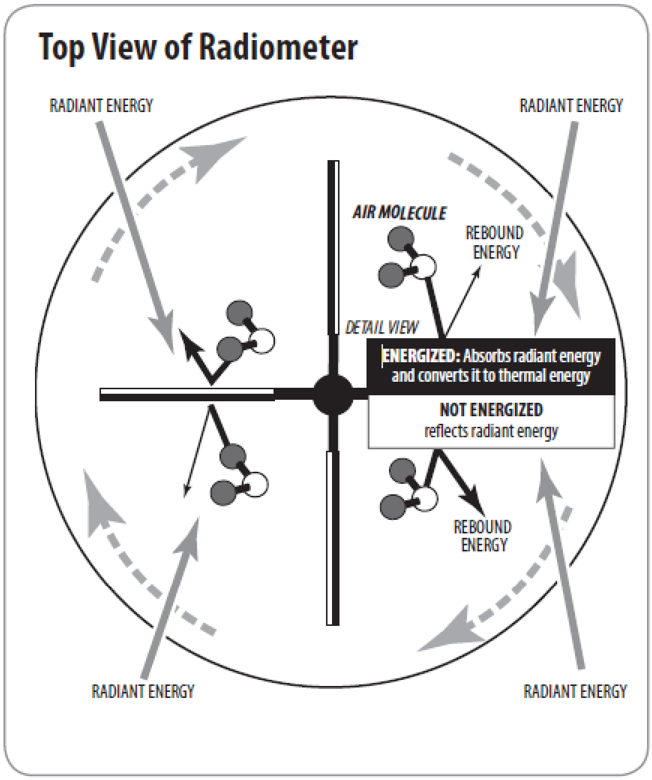
Did you realize light could make things move? In the radiometer investigation, you saw light change into thermal energy, then into motion—radiant energy into thermal energy into kinetic energy.

The radiometer has very little air inside the bulb; it is almost a vacuum. The black and white vanes are balancing on a needle. There is nothing else inside the bulb.

When you put the radiometer in the light, the vanes begin to turn. How is the light making the vanes turn? Black objects get hotter than white objects in the sun. That is why people wear light colored clothes in the summer. A black object absorbs most of the radiant energy that strikes it and reflects only a little. A white object reflects most of the radiant energy that strikes it and absorbs only a little.

When you put the radiometer in the light, the vanes absorb sunlight. The radiant energy is changed into thermal energy. The black side of the vane is absorbing more energy than the white side. When the air molecules hit the black side, they bounce back with more energy than when they hit the white side. The brighter the light, the faster the vanes turn. If both sides of the vanes were the same color, the vanes would never move because the air molecules would be bouncing off the vanes with the same amount of force.

To the right is a picture of the radiometer from the top. When the air molecules hit the white sides of the vanes, they push a little. When the air molecules hit the black sides of the vanes, they push a lot. Since there is more of a push on one side than the other, the vanes begin to turn. The more radiant energy that reaches the radiometer, the more thermal energy is transformed into motion energy, and the faster the vanes spin.




Source: The NEED Project (www.need.org) - Science of Energy Curriculum

# Happy and Sad Spheres

**Inventory:**

Two black spheres

Cup half full of hot water

Tongs

Paper towels

**Directions:**

1) Hold the black spheres about 1 meter (about three feet) above the table and let them drop at the same time, from the same height.
2) Drop them a few times and observe how high they bounce.
3) Place both spheres into the hot water for one minute. Remove them, dry them off and repeat the drop several times.
4) Observe any differences between the bounce height when the spheres were at room temperature and when they were warmed up using the hot water.
5) Read the "What the heck?" on the back of this page to learn more about what you observe.

THE STEMAZING PROJECT
WWW.STEMAZING.ORG

# What the heck?

You just dropped a happy sphere and a sad sphere! Kinetic energy comes in many forms: radiant, thermal, motion, sound, and electrical. When an object is moving, it has kinetic energy. Potential energy comes in many forms: chemical, nuclear, elastic, and gravitational. When an object is still, but is in an elevated position so gravity can move it, the object has gravitational potential energy. For example, a rock lifted to the top of a hill has gravitational potential energy. As it rolls down the hill, the gravitational potential energy transforms into sound energy, thermal energy, and kinetic energy.

A collision occurs when a moving object hits another object. When you push a sphere, your hand gives it kinetic energy. The faster it goes, the more kinetic energy it has. When the sphere runs into your other hand, there is a collision. If it stops completely, it no longer has kinetic energy. Physics tells us energy CANNOT be created or destroyed. Where does it go?

The kinetic energy is transferred into other kinds of energy—like elastic potential energy, sound energy and thermal energy. Usually, when there is a collision, an object does not stop completely. It rebounds. A rebound occurs when some of the kinetic energy is transferred into elastic potential energy due to the stretchy nature of the material making up the sphere and then back into kinetic energy to propel the sphere back into the air. This means it has not lost all of its kinetic energy. The sphere will continue bouncing until it no longer has any kinetic energy.

The happy sphere is made of *neoprene* rubber. When you did work to lift the neoprene rubber sphere above the table you gave it gravitational potential energy. If you drop the sphere, you know it will fall, due to the force of gravity. The sphere has gravitational potential energy because of its elevated position. The sphere you dropped bounced back about 65 centimeters (cm). The collision converts 35 percent of the original gravitational potential energy into sound energy and thermal energy. The sphere and the hard surface are both getting hotter every time you drop the sphere, even though you cannot really feel the difference. When the sphere hit the hard surface, could you hear the collision? About 65 percent of the original gravitational potential energy is transferred into kinetic energy after it bounces. The original gravitation potential energy first transfers into kinetic energy as gravity pulls the ball downward, then it becomes elastic potential energy as the sphere collides with the table and deforms or squishes down, and that elastic potential energy transforms back into kinetic energy as the sphere pops back to its spherical shape rebounding back toward its original position.

The other sphere you tested also had the same amount of gravitational potential energy at the beginning, but it hardly bounced. What happened?

This sphere is not broken. It is made of a different kind of rubber called *polynorbornene* rubber. Almost all of its original gravitational potential energy changes into other forms of energy. The gravitational potential energy is transferred into kinetic energy as the sphere drops. The kinetic energy is then transferred into sound energy and thermal energy when the sphere collides with the table. Feel both of the spheres. Do they feel different? Does the neoprene sphere seem harder than the polynorbornene sphere? The polynorbornene sphere is softer, so its shape can change more easily and it can absorb more energy in a collision than a neoprene sphere.

When you put the polynorbornene sphere into hot water the sphere absorbed thermal energy from the hot water. The sphere bounced higher than in the prior experiment. Since the sphere has absorbed thermal energy from the water, it cannot absorb much more thermal energy from the collision. Therefore, more of the original gravitational potential energy is transferred back into kinetic energy, causing the polynorbornene sphere to bounce higher. As the sphere cools down, it transfers its thermal energy to the air and more of the kinetic energy can once again be changed into thermal energy when it hits the hard surface. The cooler it gets, the less the sphere bounces.

These experiments show us how gravitational potential energy is changed into kinetic energy and how kinetic energy is changed into sound energy and thermal energy.

Source: The NEED Project (www.need.org) - Science of Energy Curriculum

# Baking Soda and Vinegar

**Inventory:**

Plastic Ziploc bag

Baking Soda

Vinegar

Measuring cup

Teaspoon

Waste cup

**Directions:**

1) Use the measuring cup to pour 10 mL of vinegar into an empty plastic bag.
2) Feel the bag to observe the temperature of the vinegar.
3) Carefully pour a level (not heaping) teaspoon of baking soda into the bag and gently mix. (Be careful—the chemical reaction will cause foam to fill the bag.)
4) Wait 30 seconds and feel the bag to observe the temperature again.
5) Dump the contents from the back into the waste cup so the next group can reuse the plastic bag. It does not have to be completely rinsed out.
6) Read the "What the heck?" on the back of this page to learn more about what you observe.

# What the heck?

Chemical reactions occur when you mix two chemicals together to form another chemical. All chemical reactions involve the transfer of thermal energy. Some release or emit energy and some absorb or take in energy.

An exothermic reaction releases or emits energy. *Exo*- means out and *thermal* means heat. Exothermic—the heat goes out, or is released. An endothermic reaction absorbs heat. *Endo*- means in and *thermal* means heat. Endothermic—the heat goes in, or is absorbed.

This experiment was an endothermic reaction—it absorbed, or took in, thermal energy. Combining vinegar and baking soda together made other chemicals: water, carbon dioxide, and sodium acetate.

When you added baking soda to the vinegar you were able to visually see a reaction take place. The temperature of the substance also dropped, which you could tell by feeling the bag.

The mixture felt colder because the reaction was absorbing thermal energy. It was an endothermic reaction. The energy the reaction absorbed from you and its surroundings was stored in the bonds of the new chemical that was formed. The reaction took thermal energy from the mixture and transformed it into stored chemical energy.

Most chemical reactions do not take in thermal energy like the vinegar and baking soda. Most chemical reactions give off thermal energy—they are exothermic.

Source: The NEED Project (www.need.org) - Science of Energy Curriculum

# Calcium Chloride and Water

**Inventory:**

Plastic Ziploc bag

Calcium Chloride ($CaCl_2$)

Water bottle

Measuring Cup

Teaspoon

Waste Cup

**Directions:**

1) Use the measuring cup to pour 10 mL of water from the water bottle into an empty plastic bag.
2) Feel the bag to observe the temperature of the water.
3) Carefully pour a level (not heaping) teaspoon of calcium chloride into the bag and gently mix.
4) Wait 30 seconds and feel the bag to observe the temperature again.
5) Dump the contents from the back into the waste cup so the next group can reuse the plastic bag. It does not have to be completely rinsed out.
6) Read the “What the heck?” on the back of this page to learn more about what you observe.

# What the heck?

Chemical reactions occur when you mix two chemicals together to form another chemical. All chemical reactions involve the transfer of thermal energy. Some release or emit energy and some absorb or take in energy.

An exothermic reaction releases or emits energy. *Exo*- means out and *thermal* means heat. Exothermic—the heat goes out, or is released. An endothermic reaction absorbs heat. *Endo*- means in and *thermal* means heat. Endothermic—the heat goes in, or is absorbed.

This experiment was an exothermic reaction—it released thermal energy that had been stored chemical energy.

When calcium chloride comes into contact with ice or water, it dissolves and the calcium chloride molecules dissociate into calcium and chloride ions. The attraction between the ions and water molecules leads to an overall exothermic process. Since exothermic reactions release thermal energy that had been stored in the chemical bonds of the chemicals reacting, the temperature of the solution should have increased.

A common use for calcium chloride is driveway ice melt. You can buy driveway ice melt at your local hardware store to melt the ice on your driveway during the winter.

Source: The NEED Project (www.need.org) - Science of Energy Curriculum

# Friction Wire

**Inventory:**

Pieces of wire (paper clips or hanger wire)

**Directions:**

1) Feel a piece of wire and note the temperature.
2) Bend the metal wire back and forth five to ten times really quickly right at the center.
3) Feel the metal with your finger or touch the part you were bending to your lip. Observe the temperature.
4) Read the "What the heck?" on the back of this page to learn more about what you observe.

# What the heck?

You used your own kinetic energy to bend the paperclip a few times. What happened when you did this? When you bent the paperclip, the molecules of the metal at the bend moved faster. The motion created friction, which in turn transformed kinetic energy into thermal energy. When you felt the paperclip, you should have felt it was warmer than when you started.

Let's trace the energy flow from the thermal energy in this metal back to the sun. You put motion from the muscles in your hands and arms into the paperclip. Your muscles got their energy from the stored chemical energy in the food you ate. The plants you ate transformed radiant energy from the sun into the stored chemical energy. The sun gets its energy from nuclear fusion. So the energy flow from the sun to the paperclip is: nuclear energy, to radiant energy, to stored chemical energy, to kinetic energy, to thermal energy.

You have probably converted kinetic energy into thermal energy lots of times on cold days. Try this. Put your hands on your face to note the warmth of your hands. Next, rub your hands together for about ten seconds and put them back on your face. They should feel warmer. You have just converted kinetic energy into thermal energy.

Source: The NEED Project (www.need.org) - Science of Energy Curriculum

# Nitinol "Live" Wire

**Inventory:**

Live wire

Cup hot water in it (but not boiling)

Tongs

**Directions:**

1) Twist the wire into different shapes, but do not tie it in a knot.
2) CAREFULLY drop the live wire into the hot water. Be sure you are not leaning over the cup! Observe what happens and then remove the wire using the tongs.
3) Now bend the wire in half right at the center so both ends touch. Hold one end in each hand and CAREFULLY lower the bent part of the wire into the water. Observe what you feel.
4) Read the "What the heck?" on the back of this page to learn more about what you observe.

# What the heck?

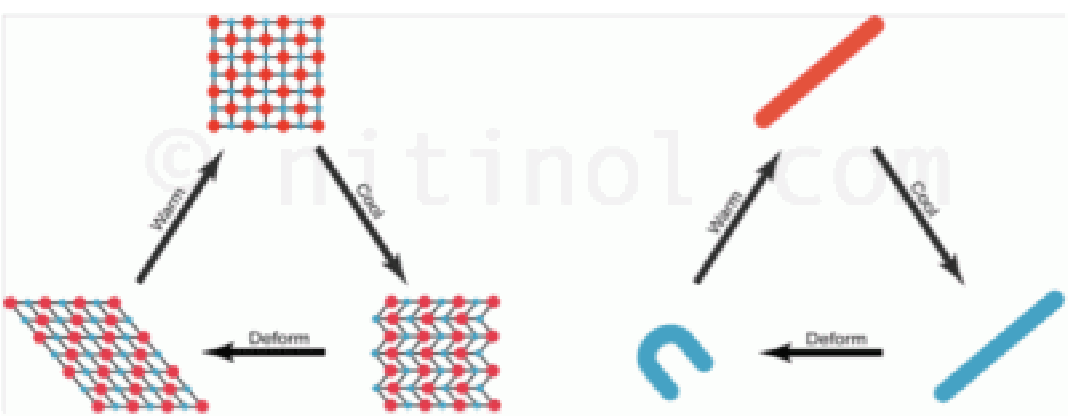
The “live wire” is a nitinol (nī-tĭn-ŏl) wire, made of nickel and titanium that has been treated in a thermal process so that it has a “memory.” Most metals stay in whatever shape you put them in, but nitinol is different. Nitinol “remembers” its original shape when it is heated. Nitinol is used in space to move robot arms. It is also used to control the temperature of greenhouses. If the temperature gets too hot, a nitinol spring opens a door to let in air. Dentists use it in braces to straighten teeth. As the wires in your mouth warm, they attempt to return to their original shape, slowly moving your teeth with them.

You were able to bend and twist the original shape of the wire any way you wanted. The thermal energy in the water made the wire return to its original shape. The thermal energy was transformed into kinetic energy.

Source: The NEED Project (www.need.org) - Science of Energy Curriculum

Shape-memory alloys flip back and forth between two solid crystalline forms called Austenite and Martensite. At lower temperatures, they take the form of Martensite, which is relatively soft, plastic, and easy to shape; at a (very specific) higher temperature, they transform into Austenite, which is a harder material and much more difficult to deform. Let's say you have a shape-memory wire and you can bend it into new shapes relatively easily. Inside, it's Martensite and that's why it's easy to deform. No matter how you bend the wire, it stays in its new shape; much like any ordinary wire, it seems to be undergoing a very ordinary plastic deformation. But now for the magic part! Heat it up a little, above its transformation temperature, and it will change into Austenite, with the heat energy you supply rearranging the atoms inside and turning the wire back into its original shape. Now cool it down and it will revert back to Martensite, still in its original shape. If the material is above its transition temperature the whole time, you can deform it but it will spring back to shape as soon as you release the force you're applying.

Source: http://www.explainthatstuff.com/how-shape-memory-works.html




Source: http://www.nitinol.com/nitinoluniversity/reference-library/a-short-orientatio

# Bi-metal Bar

**Inventory:**

Bi-metal bar

Lit candle on a drip cup

Cup of cold water

Paper towels

**Directions:**

1) Carefully hold the bi-metal bar sideways in the top of the candle flame so both sides of the bar are in the flame. Observe what happens.
2) Remove the bar from the flame, but do not touch the bar. Place the bar into the cup of cold water and observe what happens.
3) Dry the bar off and repeat this process a few times.
4) Read the "What the heck?" on the back of this page to learn more about what you observe.

# What the heck?

When substances and objects are heated, they expand. You may have noticed the spaces between sections of sidewalk. They are designed that way so that the concrete can expand on hot, sunny days without cracking.

Bridges are built with expansion joints that allow the metal and the concrete in the bridge to expand and contract according to temperature, without breaking.

All objects expand when they are heated, but they do not expand at the same rate. Gases and liquids expand very quickly when they are heated. Their molecules can move about freely. A thermometer works because the liquid inside expands and contracts according to temperature.

Solids do not expand as much as gases and liquids because their molecules cannot move freely. It is sometimes hard to see them expand. The bi-metal bar is a good example of how metals expand when heated. This bar is made of two metals – one side is nickel, the other side is stainless steel. These metals expand at different rates.

What happened when you placed the bar in the flame? Did you notice which way it bent? The stainless steel in the bar expands more quickly than the nickel, so when it is heated, the bar bends. The stainless steel side is the outside of the curve. What happened when you took the bar away from the heat?

When placed in the cup of cold water the bar bent back the other way to its original shape. If you put the bar in really cold ice water the bar would bend in the other direction. The stainless steel side also contracts faster when energy is taken away, so it is now on the inside of the curve.

Bi-metal strips like this are very useful. They are used in thermostats on furnaces and air conditioners to control the temperature. When the temperature in a room reaches a certain temperature, the bi-metal strip will bend enough to close a circuit and turn on the furnace or air conditioner. Bi-metal strips are also used in holiday lights that twinkle. When the metal gets hot it causes the strip to bend and stops the flow of electricity (breaks the circuit), which turns the light off. As the strip cools, it bends back allowing electricity to flow again, completing the circuit and turning the light on.

The coefficient of expansion of a material is the change in length or area of the material per unit length or unit area that accompanies a change in temperature of one degree Celsius. The coefficient of linear expansion of nickel is 13 x 10-6/°C and the coefficient of linear expansion of stainless steel is 17.3 x 10-6/°C.

You have just seen how thermal energy can be changed into kinetic energy.

Source: The NEED Project (www.need.org) - Science of Energy Curriculum

# Energy Band

**Inventory:**

Rubber bands

**Directions:**

1) Each person needs a rubber band.
2) Hold the rubber band firmly with your index fingers inside the ends of the rubber band and your thumbs on the outside.
3) Place the rubber band against your forehead without stretching it for about three seconds to let it match the temperature of your forehead.
4) Keeping the rubber band against your forehead, QUICKLY pull both ends apart stretching the rubber band to twice its original size and observe what it feels like against your forehead.
5) Keep the rubber band completely stretched out and still touching your forehead for about three seconds to let it again match the temperature of your forehead.
6) With the rubber band touching your forehead the whole time, QUICKLY bring the ends together allowing the rubber band to return to its original, un-stretched size and observe what it feels like against your forehead.
7) Repeat once or twice to observe the differences between stretching it quickly against your forehead and then letting in compress or come together quickly against your forehead.

# What the heck?

This experiment demonstrated an energy transformation that both released and absorbed energy.

When you quickly stretched the rubber band to twice its length against your forehead, or when you let it contract, did you feel a change in temperature? The rubber band should have felt warm when it was stretched and cool when it contracted.

When you stretched the rubber band, you put stress on the molecules and released thermal energy. When the rubber band contracted, the stress was removed and the molecules absorbed thermal energy.

Source: The NEED Project (www.need.org) - Science of Energy Curriculum

# World's Simplest Electric Motor

**Inventory:**

Copper wire

Neodymium (rare earth) magnet

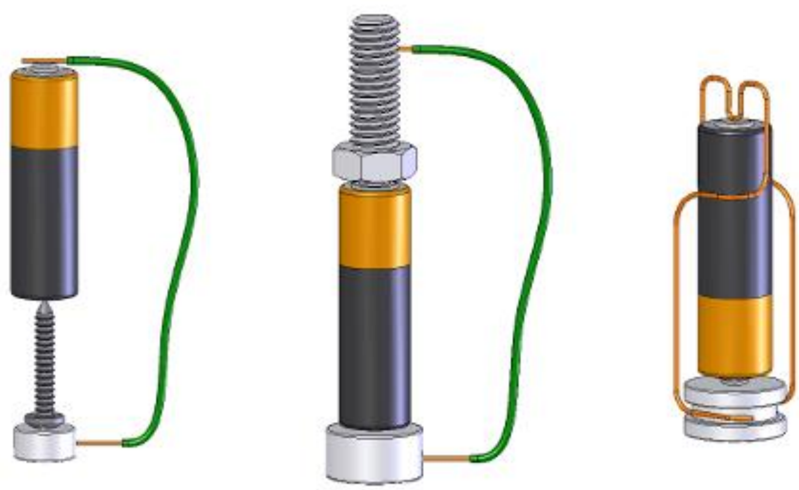
Screw

D Cell Battery

**Challenge:**

Can you set the materials up in a way so that a part of it keeps moving without you pushing it? Can you create the world's simplest electric motor?

Check under fold when you are ready to see a few solutions.



DEMO A DEMO B DEMO C

# What the heck?

Magnets affect materials in one of three ways, attraction, non-attraction (neutral) and repulsion. In a homopolar motor, the flow of electrons through a wire creates a magnetic field that is in opposition to that of the disc magnet and thus is repulsed by it. This repulsion creates a tangential force called the Lorentz force that is responsible for creating the spinning motion. Dependent on which item is fixed the opposite item will spin. So in one case of this motor, the magnet is fixed and thus the copper wire spins. In another case using the magnet on the head of the screw, the copper wire is fixed and the magnet/screw spin.

Search YouTube for homopolar motor to find all kinds of variations on these designs.

Source: http://www.imagesco.com/magnetism/homopolar-wire-motor.html

**Demonstration A**

To demonstrate the homopolar motor in action, we will show motors in 3 different configurations. The first is very simple to make, using only an AA battery, a steel screw with a pointed end, a short, 9" long piece of solid wire and a neodymium magnet. We used two D82 magnets stuck together in the video below. A single D84 magnet would be the same, though we found it would work even with a single D82 magnet.

In this configuration, we hold the current-carrying wire still, along with the battery, and the magnet and screw spin. This is fairly easy to reproduce, though we had some problems with the screw slowly migrating off to the side. We solved this by adding a piece of tape with a hole in it. We have seen other videos where the battery was hit with a chisel or other sharp object to make a small indentation for the screw-point to sit in.

**Demonstration B**

In this second setup, we hang the battery and magnet beneath a stationary steel bolt. The magnet-battery combination sticks to the bolt because a bit of the magnetic field goes up through the battery. We used the same AA battery, the same piece of wire, and a single DC6 magnet.

This produced some fun results, with the battery spinning out of control. This is a good way to demonstrate the motor in front of a large group, where you need motion that's more obvious from a distance.

**Demonstration C**

This is the most common setup we've seen, but we chose to present it last. It can be challenging to come up with a stable configuration of the wire that allows it to spin well without falling off. Be prepared to fiddle with the wire a bit to get it right.

Use a piece of solid (not stranded) wire. We used 18 gauge wire, though other sizes would work as well. We removed all the insulation from the wire before experimenting with it. Technically, you only have to remove the insulation where it contacts the battery and the magnet, but removing it all seemed easier.

You don't have to use a magnet with a stepped groove in it, but we found it helpful to get the wire to stay in contact with the magnet this way. We used our SDC6-IN magnet, though you could use a plain disc like the DC4 or DC6 just as well. You can even use smaller discs like the DA2 for this demonstration.

When describing how a homopolar motor works, most explanations describe it in terms of a force acting on the wire. This demonstration clearly shows the wire moving, so it makes matters more obvious and jives well with the technical explanation.

Source: https://www.kjmagnetics.com/blog.asp?p=homopolar-motors

# Eddy Current Tube

**Inventory:**

Copper tubes of various lengths

Neodymium (rare earth) magnets

**Directions:**

1) Drop one magnet down one of the copper tubes and observe what happens.
2) Drop two magnets stuck together down the same tube and make observations about similarities and differences between this experiment and the previous one.
3) Play with different variables and continue to make observations about what is happening.

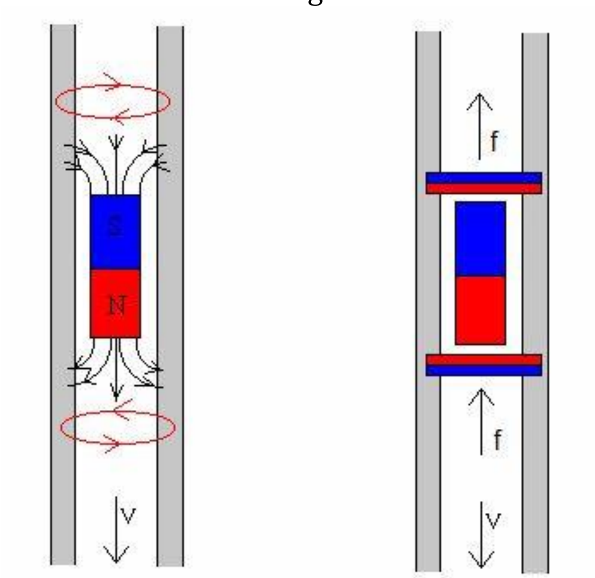
# What the heck?

**Eddy currents** are an electric phenomenon that is produced when a conductor (metal) passes through a variable magnetic field. The relative movement causes a circulation of electrons, or induced current within the conductor. These circular Eddy currents create electromagnets with magnetic fields that oppose the effect of the applied magnetic field.

The **Eddy currents** and the generated contrary fields will be stronger

- when the applied magnetic field is stronger, or
- with higher conductivity of the conductor, or
- with higher relative speed of movement.

For a practical demonstration of the **Eddy Currents**, cylindrical magnets are used that fall vertically in a copper or aluminum tube. It can be experimentally proven that the force that opposes the weight is proportional to the speed of the magnet. The experience is illustrated in the attached drawing:




Let's suppose that the cylindrical magnet descends with its North pole (color red) in front and its South pole (color blue) behind. On a magnet, the magnetic field lines are outgoing at the North pole and incoming at the South pole.

During the descent of the magnet, the flow from the magnetic field increases in the region near the magnet's North pole. An induced current originates in the tube, **Eddy Current**, which opposes the increased flow, in the direction that is indicated in the first figure.

In the following figure, the equivalency between currents (spirals or solenoids) and magnets is shown, in such a way that the induced current ahead of the North pole equals a magnet of opposing polarity, by which they repel each other. However, the induced current behind the magnet has the same polarity by which they attract each other. Both currents generate a force (f) that stops the falling movement of the magnet.

Source: http://www.regulator-cetrisa.com/eng/magnetism.php?section=foucault

### Conservation of Energy Story

The magnet has gravitational potential energy when at the top of the tube. When you drop it outside the tube, the potential energy would be converted into kinetic energy. When you drop it inside the tube, some of the potential energy is converted into electrical energy (the energy required to move the electrons in the conducting tube). Because some of the original energy is converted to the electrical energy while the magnet is falling, it won't have as much kinetic energy when it reaches the bottom of the eddy current tube.