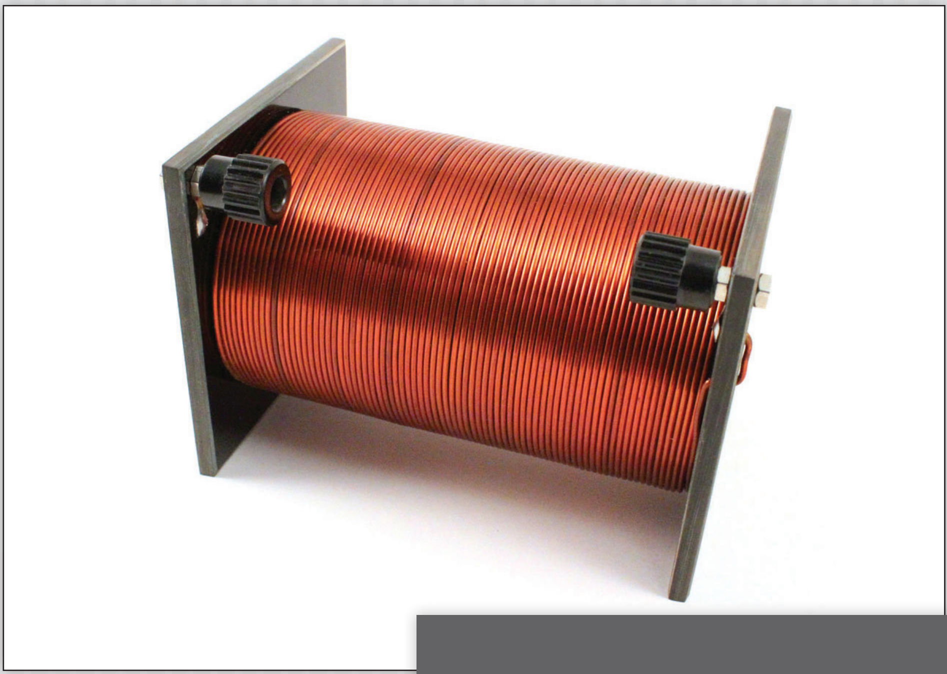
TEACHERS GUIDE



AIR CORE SOLENOID
ITEM # 3172-00

ENERGY - ELECTRICITY

Demonstrate a major application of electromagnetic fields by using an air core solenoid. This device can be used as part of a simple circuit to create a strong magnetic field to repel or attract various types of cores and demonstrate how a basic solenoid operates.
By using this with different core materials, the operation of the solenoid can change and demonstrate different applications.

Materials

- insulated wires
- alligator clips (connectors)
- 6 V battery (low voltage source)
- cores of different materials (rods up to 5.4 cm in diameter)
- assorted materials to make valves or switches

Goals & Objectives

See page 8 for Next Generation Science Standards (NGSS)

HISTORY

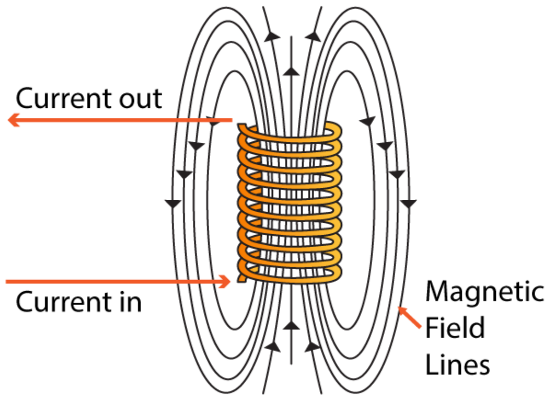
After the first electromagnets were invented in 1820s, researchers observed that an air gap in an electromagnet caused the magnetic field to concentrate toward the inside of the electromagnet. This allowed a core (of different materials) to be moved based on the strength of the electromagnet. By moving the core with a change in magnetic field, the core could be used to perform work. Common modern uses of solenoids includes valves and electronic locks.

TECHNICAL DATA

- Number of turns per layer: 77+
- Total number of turns: 550-570
- Wire Gauge: 16
- Capacity: 10 Amps If used intermittently, and 5 Amps continuously
- Core ID 5.5cm (about 2.5”)

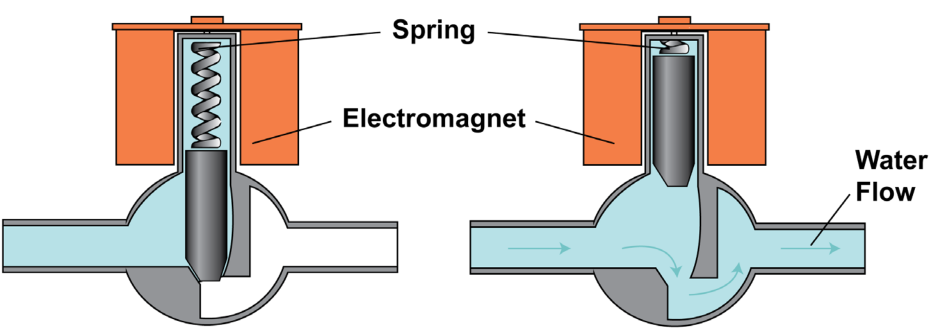
HOW IT WORKS

Electricity (current) flows through loops of insulated wire in an air core electromagnet. The loops of wire concentrates the magnetic field inside the air core and there is a weak magnetic field outside the core, when the current reverses, the polarity of the magnetic field reverses also.
Soft ferromagnetic materials (Iron) are pulled into the air core solenoid when the device has power (turned on).



APPLICATIONS

Air core solenoids are used in a variety of applications. They can be used to electronically move an object to change the flow of water or act as an electric switch. A common use is to control the flow of water for washing machines.



Power OFF -- Valve Closed **Power ON -- Valve Open**

INSTRUCTIONS

1. The air core solenoid operates within a simple, DC circuit. Attach wires to both connectors on the air core solenoid and connect the other end to a low voltage source with 10 amp maximum, short duration, or 5 amp continuous.

2. Include an ammeter in series to measure the current draw. These values can also be used for calculations (optional).

3. Include a switch in the circuit for easier operation (optional).

4. With the power on, use a compass or iron fillings to observe the change in the magnetic field with distance and orientation to the air core. This is a check on the operation and make sure the device is operating properly.

5. Place one rod at a time inside the inner diameter of the air core solenoid and observe the effects. Starting with a soft iron rod, observe the force on the rod as it moves toward the center of the air core solenoid.

6. Use rods of different materials to observe the effects of magnetic field on different materials or use the device in an engineering challenge to create a solenoid valve or electronic switch.

Helpful Equations

B = μnI (written out; Beta = mu n I)
Magnetic field =
magnetic permiability x turn density x current

n = N/L
turn density = number of turns / length (m)

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POINTS OF ATTENTION

If students use the device in wet projects (design/build valves), be sure to use low voltage sources (less than 12v) and make sure there is no standing water. Dry cell batteries can limit the amount of current draw during a short situation. Resistance heating can occur in the wires by using more than 10 amperes for short duration. Using five or fewer amperes prevents the build up of heat in the coils.

ACTIVITIES

1 Observe the magnetic field lines of an electromagnet by using iron filings. Set up and power the air core solenoid with a sheet of paper on top. Sprinkle iron fillings on top of the paper. Move the paper around the top and sides of the powered solenoid and observe how the iron fillings change position as it moves. Turn off the solenoid and repeat showing that the iron fillings no longer move. This helps show the presence of a magnetic field due to electricity (moving current).

2 Introduce students to the variables that affect electromagnets. Show that an air core solenoid can pull an iron bar when it's turned on. Have the students investigate the performance of the air core solenoid by changing the amount of current, the core size, or voltage and observe the pull force on an iron core (qualitative observations). For enrichment, students could change the temperature of the loops of the electromagnet and observe the effect on the pull of the iron core. For quantitative investigations, attach a spring to the iron core and measure the amount of pull force by the air core solenoid.

3 Other variables that affect the performance of air core solenoids is the type of materials that the core is made of. Students can use different rods in the air core and varying the current or voltage to investigate the performance of the solenoid. Using a magnet for a core gives the potential to push or pull by changing the polarity of the current. (See Fig. 1 on page 6)

4 Design challenge 1:
Students can apply knowledge of a working solenoid by making a locking mechanism (or an electric switch). Students design and modify a device that can lock or unlock a door by adding a switch and a locking mechanism to the simple circuit with the air core solenoid. Students can choose the material of the core and determine what type of locking mechanism could work with an electric switch. For instance, should the locking mechanism pull or push to unlock the door? Students can redesign their device to meet criteria for voltage or current or the force of the locking mechanism.

5 Design challenge 2:
Students can also apply

***Note**

It is always wise to DO an experiment ahead of time to be able to best present it to the class.

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ACTIVITIES

Activities continued

5 knowledge of a working solenoid by making a valve. Similarly to building a locking mechanism, students can build and design a valve that controls the flow of water. Keep in mind that voltages and currents should be low when working with water. If students work with a water system, students could build simple valves by using a flap of plastic with a plastic container. Legos can be used to create fairly water tight seal and gives flexibility of design shapes.

The flow of water doesn't have to be completely off. The valve closing mechanism can be designed with a variety of materials that are water resistant including wood, plastic, or metal. Set up a switch and the air core solenoid in a simple circuit. Students can consider the criteria for current, voltage, or force required to close the valve. Also, several solenoids can be used together to control the flow of water through different branches in a water system.

Permanent Magnet in a Solenoid

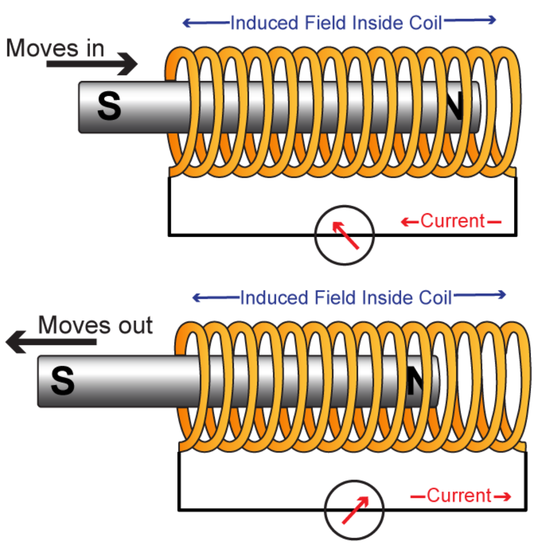

Figure 1

DISCUSSION

Additional Discussion and Real Life Applications

1. How does current affect the pull/push strength of the solenoid? How does voltage affect it?

2. How do different cores perform in the air core solenoid? What is there pull/push strength?

3. What type of cores would be pushed when the solenoid is turned on? What type would not be affected?

GLOSSARY

Vocabulary:

- battery
- current
- electromagnet (parts)
- magnetic field
- simple circuits (DC)
- solenoid

RESOURCES

- http://www.societyofrobots.com/actuators_solenoids.shtml (solenoid basics)
- http://physics.kenyon.edu/EarlyApparatus/Electricity/Electromagnet/Electromagnet.html (history)
- http://american-scientific.com/AIR_CORE_SOLENOID

Next Generation Science Standards

Students who demonstrate understanding can:

Grade K-5

3-PS2-3. Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.

3-PS2-4. Define a simple design problem that can be solved by applying scientific ideas about magnets.*

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.*

Grade 6-8

MS-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

Grade 9-12

HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.

HS-PS2-5. Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

Standards Key

K = Kindergarten
3 = 3rd Grade
(numbered by grade)
MS = Middle School
HS = High School
PS = Physical Science

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