

PHYSICS E&M LECTURE DEMONSTRATIONS

(faculty edition)

Colleagues,

In order to facilitate the use of the electromagnetic lecture demonstrations in the department, Professors Katrin Becker, Melanie Becker and Wayne Saslow have provided detailed descriptions of what to do, how they work, and the principles involved.

Their work has been incorporated into my original 2010 Electricity and Magnetism Demonstration Manual.

If you are interested in using one of these demonstrations in your classroom, you may send me an email with your class information and the demonstration number and name. Please allow at least two class days notice for the demonstration requests. In cases of shorter notice, your request will still be taken but possible conflicts may prevent it from being set up (for that particular class time). v 5

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Electricity and Magnetism

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Charging by Friction -- Triboelectricity

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E8 AC Circuits

E8-01 AC VS DC VOLTAGE ON AN INDUCTIVE COIL

Charging by Friction -- Triboelectricity

Rubbing materials A and B together can yield charge transfer – static electricity. Numerical tables can be found, via google, for the *triboelectric series* (tribo from friction), which gives a numerical value for each material, running from negative to positive. If material A is -1.5 and material B is -2.3, and both are initially uncharged, then rubbing the two together should transfer positive charge to A from B (that is, negatively charged electrons would go from B to A).

Unexpected charge transfer occurs frequently, since rubbing produces only *partial* and *temporary* contact between two materials. If the contact were complete and permanent, then the triboelectric series would, in principle, be the same as the electron affinity series (equivalent to Volta's electrochemical series).

In the triboelectric series glass (vitreous) is very positive and PVC (like amber, or resinous) is very negative.

Likewise, the animal fur we rub against the (negative) PVC tends to be positive and the paper towel that we rub against the (positive) glass tends to be negative.

The word *electric* came from *amber*, which may explain why (c. 1745), when Franklin conceived of a positively charged electric fluid, he took amber to have an excess of (positively charged) electric fluid. In 1897 J. J. Thomson learned that the typical charge-carrier in matter (which he called a corpuscle), is the negatively charged electron.

The Electroscope

Note: *Typical Electroscopes respond to a charge-charge interaction*, and therefore can only give an ordered measure of the **MAGNITUDE** of the electric charge on its disk, but neither its sign nor a quantitative measure of its charge.

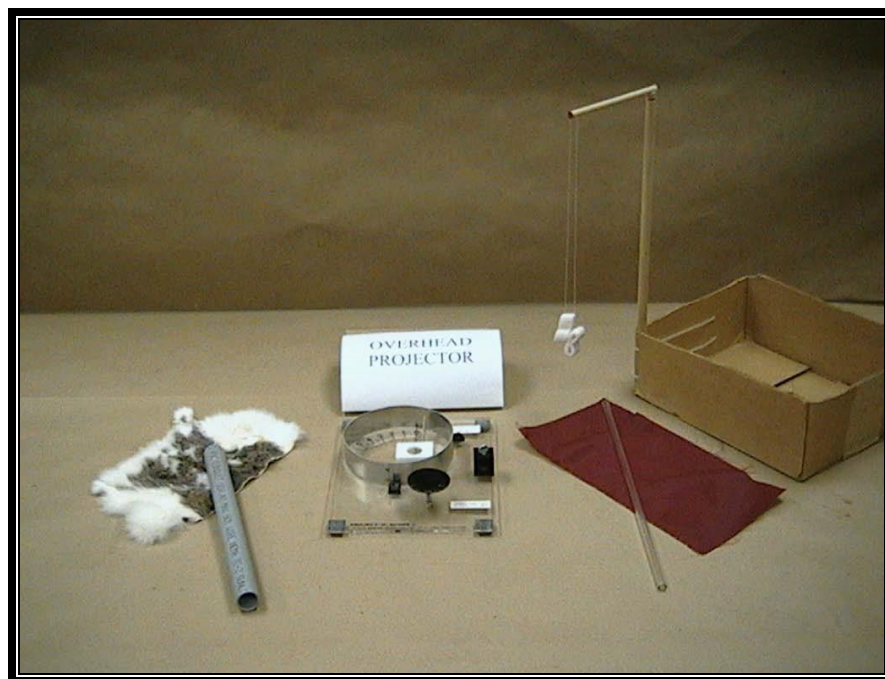
The heart of the electroscope we currently employ (see below) consists of a spring-return conducting needle that is attached to a fixed aluminum strip and to a black-painted aluminum disk (the paint seems to be reasonably conducting). A large circular aluminum strip surrounds the needle to "screen out" unwanted electrical effects. The black aluminum disk is external to the circular strip. Any charge placed on or induced on the disk induces charge of the same sign on the conducting needle and on the fixed aluminum strip, which by "likes repel" is why the needle moves away from the fixed aluminum strip.

RESOURCE INFORMATION ABOUT TRIBOELECTRICITY ON YOUTUBE...

<https://www.youtube.com/watch?v=Fph08eKTVZM>



E1-01 PRODUCING ELECTROSTATIC CHARGES [DCS# 5A10.10]



Apparatus:

- Electroscope
- PVC tube and animal fur
- Glass tube and paper towel
- Pith balls on a stand (pith ball electroscope)

Purpose: Demonstrate electric charge by repulsion

Place the electroscope on the Elmo projector. Rub the PVC tube with animal fur, thus inducing a negative charge on the tube. Now “slide” the edge of the PVC tube across the black metal disk of the electroscope, thus transferring negative charge to the disk. The electroscope should deflect. [One may discharge the electroscope by touching the ring on it and the black disk at the same time.]

Next charge a glass rod positively by rubbing it with a paper towel or silk. If the disk of the electroscope is touched, positive charge is transferred to the disk. The electroscope should deflect less, indicating a reduced charge on the disk (PVC and glass transfer opposite charge)

This experiment can also be performed with a “pith ball” electroscope. This uses two hanging insulating strings at whose ends are *pith balls* (made from the center of less dense wood or reed) or packing material like polystyrene (as in the figure). The pith balls are non-conducting, and have no permanent dipole moment (dipole moments point from negative to positive charge). However, like all materials they are polarizable. Therefore, in response to a positively (negatively) charged object the pith balls develop a temporary dipole moment pointing away from (towards) themselves. The pith balls and the charged tube will attract (no matter if the source is positively or negatively charged). Historically, this has been called the *amber effect*, but it is much more general.

RESOURCE INFORMATION ON ELECTRIC CHARGE FROM WIKIPEDIA

https://en.wikipedia.org/wiki/Electric_charge

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E1-02 USING A CHARGE ON A ROD TO MOVE A COKE CAN [DCS# 5A40.20]



Apparatus:

PVC tube and animal fur
Glass tube and paper towel
Metal can

Purpose: Demonstrate polarization and electrostatic induction

Rub a PVC tube with animal fur, thus charging it negatively. Move the tube next to the metal coke can. The charges on the tube will attract ('induce') positive charges to the surface of the (conducting) can near the tube, so by opposites attract the can is attracted to the PVC tube. Repeat this demo with a glass tube rubbed with a paper towel. The glass tube now has positive charge. The coke can will have negative charge induced on the surface of the can near the tube, and again will be attracted by the glass tube. (This demo works for both conducting and insulating tabletops.)

RESOURCE INFORMATION ON THIS DEMO IN U TUBE

<https://www.youtube.com/watch?v=1I9hkFsA8J0>

<https://www.youtube.com/watch?v=kB8khJtf8tA>

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E1-03 ELECTROSTATIC FORCE IN MOVING A WOOD BOARD [DSC# 5A30.40]



Apparatus:

- Long wooden stick
- Watch glass (or large lens) on which stick is balanced
- PVC tube and animal fur

Purpose: Demonstrate polarization and electrostatic force

As preparation, balance the wood stick on a watch glass, which can rotate, forming what Gilbert (c.1600) called a *versorium* (a *turner*). Now rub a PVC tube with animal fur to charge the tube negatively. Bring the long side of the tube near either end on the wood stick, which is uncharged and an insulator. This polarizes the molecules of the wood stick, with its dipoles such that the end of the dipole with opposite charge is closer to the charged tube. The wood stick will be attracted to the charged tube (no matter if positively or negatively charged), as can be seen by rotation of the wood on the watch glass.

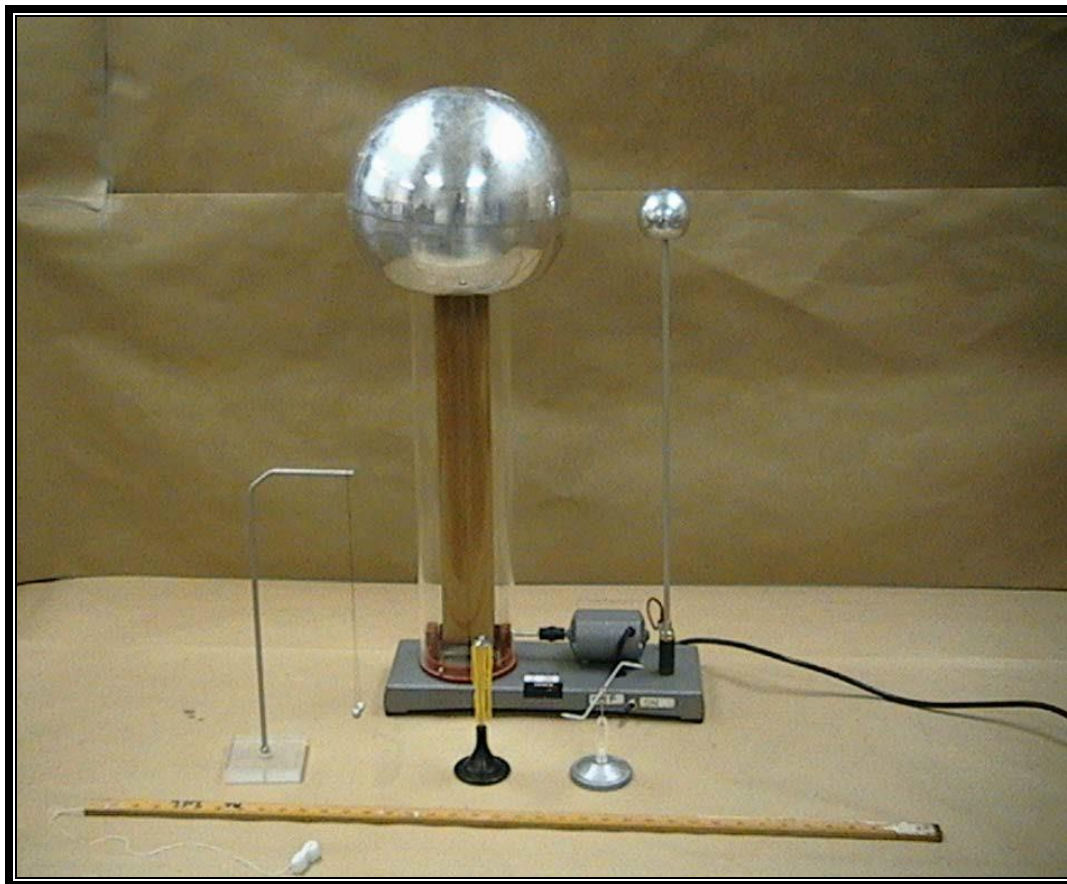
The force between a charged and polarizable but neutral object is always attractive. It is analogous to a charged comb attracting neutral paper.

RESOURCE INFORMATION ON STATIC ELECTRICITY FROM ALTERNATIVE PHYSICS ORG....

<http://www.alternativephysics.org/book/StaticElectricity.htm>

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E1-04 VAN DE GRAAFF GENERATOR [DSC# 5A50.30]



Apparatus:

- Van de Graaff generator (VDG)
- Meter stick to turn off the VDG
- Pithballs on a stand
- Whirler on a stand

Purpose:

Demonstrate charging of the VdG

To show that the VdG is charged, tape the whirler with cork on sharp metal tips (below, between VdG and meter stick, on right) or alternatively use the threads apparatus (below, in middle) to the top of the VdG. Pith balls (below, on left) may also be brought close to the top of the VdG.

Note: If you come too close to the VdG, when it discharges you will feel a noticeable shock. This is not due to the VdG discharging through you, but rather that the large charge of the VdG polarizes you, and then when it discharges suddenly, you suddenly *depolarize*.

History: **Robert Jemison Van de Graaff**, (born Dec. 20, 1901, Tuscaloosa, Ala., U.S.—died Jan. 16, 1967, Boston, Mass.), American physicist and inventor of the Van de Graaff generator, a type of high-voltage electrostatic generator that serves as a type of particle accelerator. This device has found widespread use not only in atomic research but also in medicine and industry. Ref - Encyclopædia Britannica

RESOURCE INFORMATION ON VDG FROM WIKIPEDIA

https://en.wikipedia.org/wiki/Van_de_Graaff_generator

ALSO – FROM YOUTUBE <https://www.youtube.com/watch?v=rNEY3Yv9kC8>

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E1-05 VAN DE GRAAFF GENERATOR WITH PIE PANS



Apparatus:

Van de Graaff generator (VDG)
Metallic pie pans

Demonstrates electric forces electrostatic repulsion

Use a stack of metallic pie pans on top of the VDG. The pie pans will fly away one after the other, indicating that the pie pans get the same charge as the VDG, and are then repelled. Moreover, it shows that the electric force is stronger than gravity.

RESOURCE INFORMATION ON VDG FROM YOUTUBE -
<https://www.youtube.com/watch?v=rNEY3Yv9kC8>

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E1-06 VAN DE GRAFF GENERATOR WITH STREAMERS



Apparatus:

Two Van De Graff generators with tissue streamers attached

Demonstrates electric field lines of a configuration of electric charges.

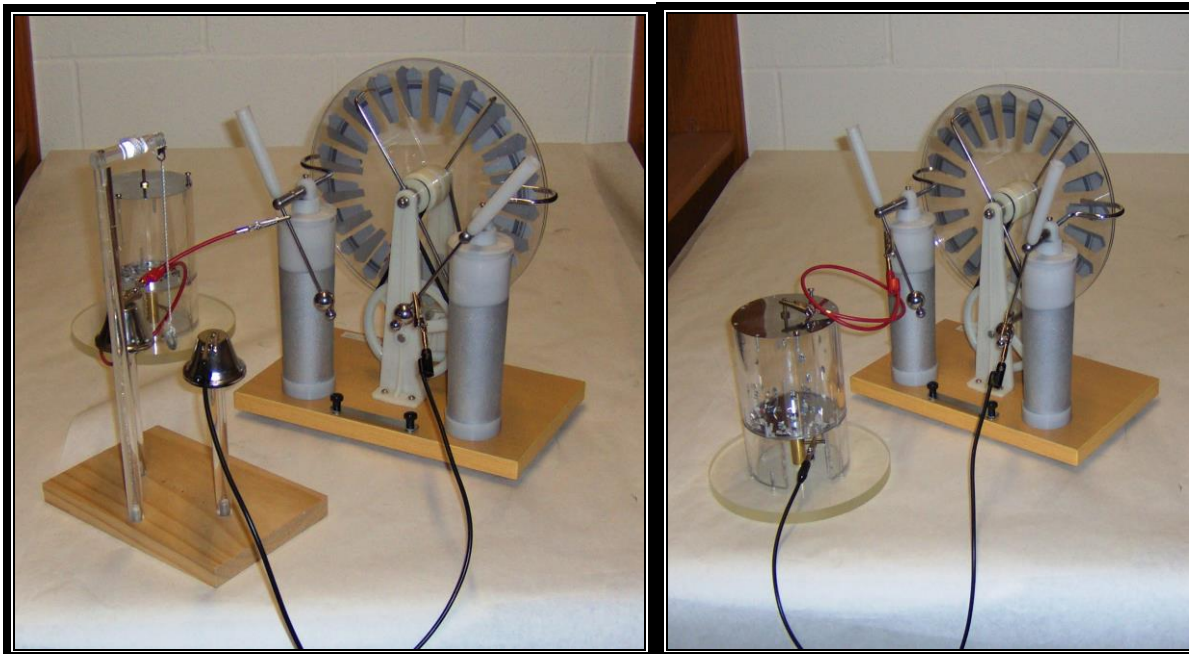
Use tissue streamers to show the electric field lines of a charged sphere. With the aid of a second VDG show the electric field lines of two identically charged spheres.

RESOURCE INFORMATION ON VDG FROM UNIVERSITY OF MARYLAND DEMOS

<http://lecdem.physics.umd.edu/j3/j3-08.html>

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E1-07 WIMSHURST GENERATOR AND FRANKLIN'S BELLS (DSC# 5B10.31)



Apparatus:

Wimshurst generator
Assorted components including Franklin Bells

Notes: A hollow cylinder contains vermiculite. The ends of the cylinder are capped with aluminum plates.

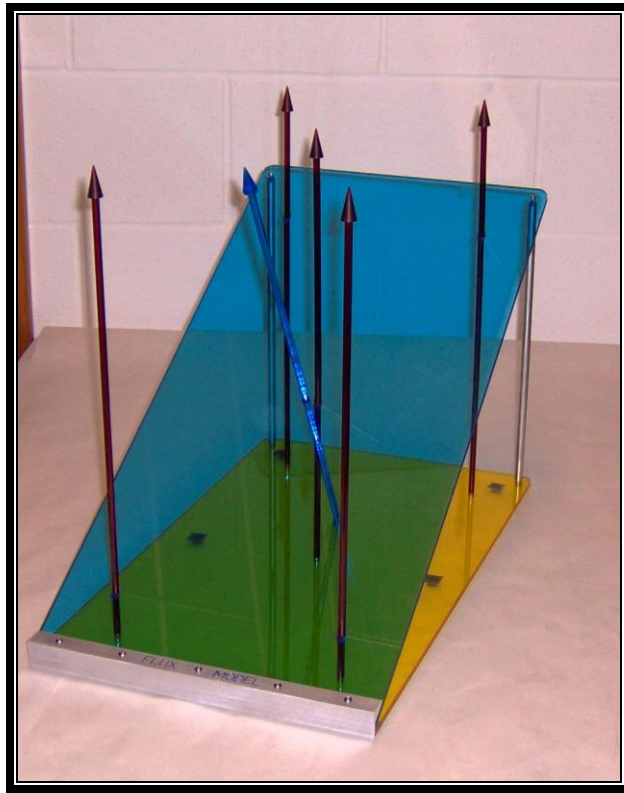
The Wimshurst Generator is an electrostatic generator that generates high voltages through "induction" rather than through friction. This is accomplished by having two counter rotating glass disks each with a number of separate conducting pads on their surface that are connected to a pair of "neutralizing contacts" and "charging contacts" by metal "brushes". Any residual static charge present on these pads will gradually be amplified through induction as the disks begin to rotate and the charge is collected. Franklin's Bells are often used to demonstrate the presence of a static charge. The system consists of two bells and a clapper with each of the elements electrostatically isolated from the other. One of the bells is connected to a voltage generator and the other is connected to ground and the "clapper" is suspended between the bells on an insulating thread. Once there is charge present, the "clapper" will be attracted to one of the bells and make contact. In so doing the clapper will receive charge from that bell and be repelled toward the second bell.

RESOURCE – WIMSHURST INFO FROM CSUN <http://www.csun.edu/scied/1-demo/wimshurst/>
ALSO INFO IN WIKIPEDIA - https://en.wikipedia.org/wiki/Wimshurst_machine

This demonstration was made available for classroom use by the Physics Festival group headed by Tatiana Erukhimova. This demonstration was developed by the DEEP students involved in the Festival, funded by DEEP and built by our Physics machine shop and Electronic Shop.

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E1-08 FLUX MODEL



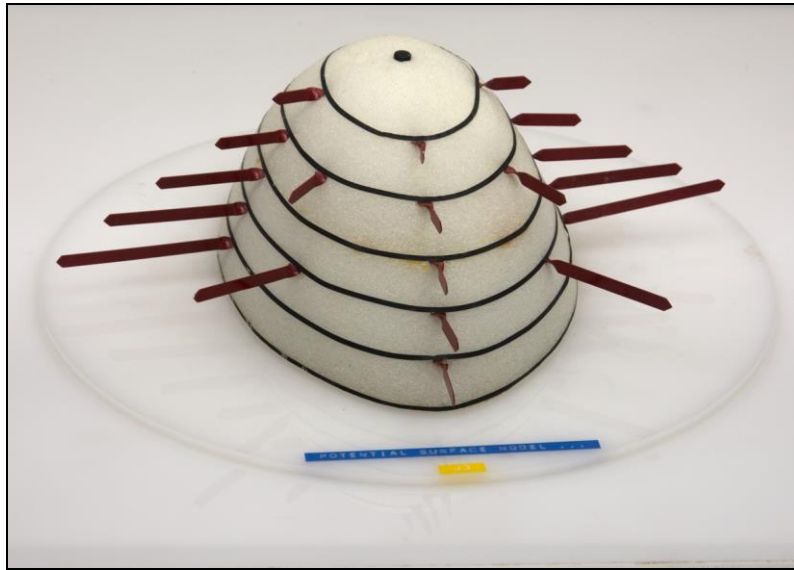
Visualizes flux at an angle through a surface

A field e.g. an electric field (red arrow) penetrates a surface that has an angle with the horizontal. The surface vectors (in blue) are orthogonal to the inclined surface.

RESOURCE INFORMATION ON YOUTUBE AND UNIVERSITY OF MARYLAND -
<https://www.youtube.com/watch?v=1ID8Wm7mJDE>
<http://lecdem.physics.umd.edu/j/j3/j3-14.html>

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E1-09 EQUIPOTENTIAL SURFACES AND E-FIELD VECTORS



Visualizes equipotential surfaces on a Styrofoam model and the corresponding E-field lines.

[Picture from University of Maryland Physics Demonstration site]

(Under construction – due to be completed Sept 1, 2016)

RESOURCE INFORMATION FROM UNIVERSITY OF MARYLAND -

<http://lecdem.physics.umd.edu/j3/j3-13.html>

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E2-01 FARADAY “ICE PAIL” [DSC# 5B20.10]



Apparatus:

- PVC tube and animal fur
- Metal cup on a stand
- Electroscope
- Proof plane

Purpose: Demonstrate that for a (nearly) closed conducting surface, electric charges vanish inside but not outside

Rub the PVC tube with animal fur and touch the inside of the metal cup with the tube. Take the proof plane and touch the inside of the metal cup with the plane. Then touch the black disk of the electroscope with the proof plane.

Do this a few times to verify that there is no charge inside the cup. Now with the proof plane touch the outside of the metal cup. Do this a few times. The electroscope will show charges on the outside of the cup.

RESOURCE INFORMATION ON FARADAY’S CAGE FROM WIKIPEDIA -
https://en.wikipedia.org/wiki/Faraday%27s_ice_pail_experiment

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E2-02 FARADAY CAGE AND ELECTRIC CHARGES



Apparatus:

Metallic cylinder (wire cage)
PVC tube and animal fur
Pith balls hanging on a thread

Demonstrates that charges vanish inside a closed metallic surface

Use a metallic wire cage and put same charges on it by using a PVC tube rubbed with fur. Using some pith balls hanging on a thread will show that the pith balls are attracted to the outside of the cage, as there are electric charges. Positioning the pith balls on the inside shows no effect on them.

RESOURCE INFORMATION FROM UNIVERSITY OF MARYLAND
AND FARADAY'S CAGE INFO FROM WIKIPEDIA -

<http://lecdem.physics.umd.edu/j/j3/j3-21.html>

https://en.wikipedia.org/wiki/Faraday_cage

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E2-03 FARADAY CAGE AND RADIO [DCS# 5B20.35]



Apparatus:

Wire cage
Small radio

Demonstrates that radio waves cannot penetrate a Faraday cage.

The radio can be heard by students when it is out of the cage. Once the radio is inside of the cage, the cage stops the radio waves and the sound ceases.

RESOURCE INFORMATION ON FARADAY'S CAGE AND RADIO FROM UNIVERSITY OF MARYLAND -
<http://lecdem.physics.umd.edu/j/j3/j3-23.html>

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E3-01 ASSORTMENT OF CAPACITORS [DSC# 5C10.10]



Apparatus:

Assortment of capacitors (mica, air, variable, electrolytic, supercap).

Purpose: Demonstrate different types of capacitors

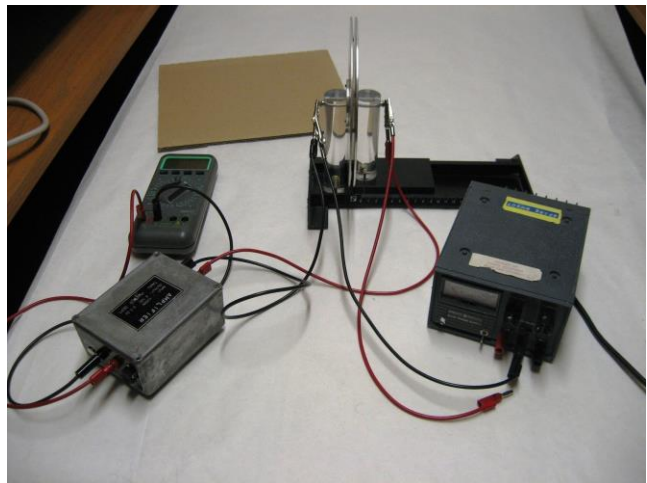
Show students different types of capacitors. At least one of them is a “supercapacitor” (1.0 F, 5.6 volt), as used in electronic clocks to keep the time even when the power is temporarily out. Other uses for capacitors are e.g. in a camera flashlight, for which a large amount of energy is needed in a short time, or more generally any device that needs energy to be stored.

RESOURCE INFORMATION ON CAPACITORS FROM WIKIPEDIA -

<https://en.wikipedia.org/wiki/Capacitor>

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E3-02 PARALLEL PLATE CAPACITOR [DSC# 5C10.20]



Apparatus:

- Electroscope
- Parallel plate capacitor
- Overhead projector or Elmo projector
- High Voltage (HV) generator and AC adapter
- Co-axial leads

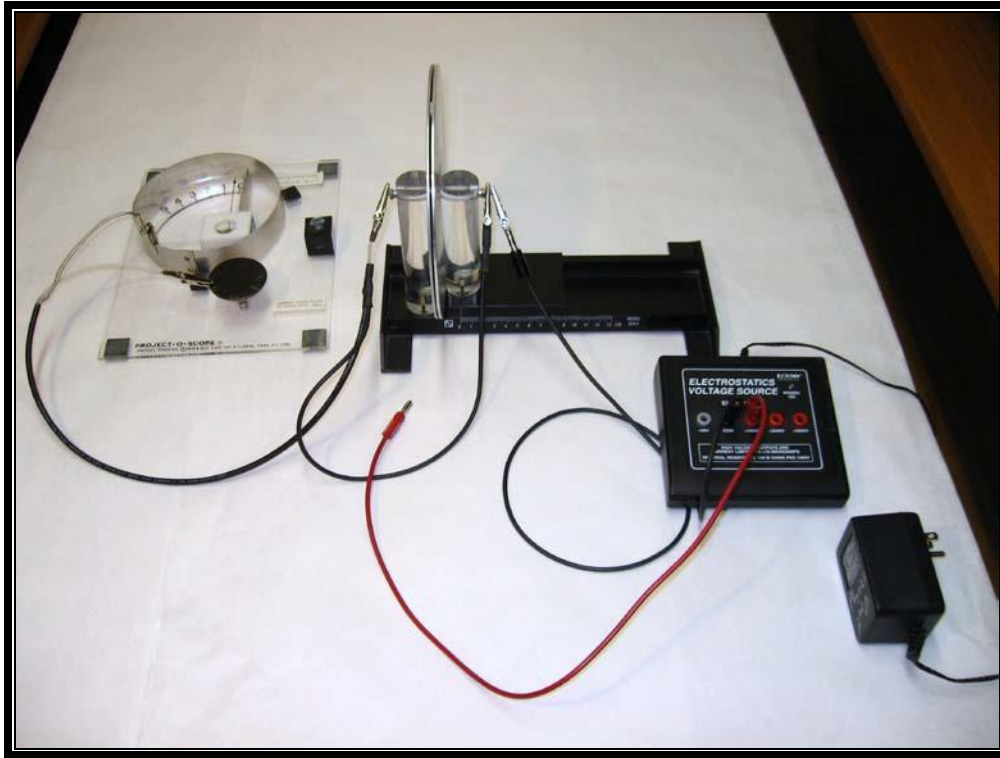
Purpose: Demonstrate that the potential difference across the capacitor increases with the plate separation.

In the figure above, the capacitor has two vertical circular aluminum plates whose separation can be adjusted by moving the track. Place the electroscope on the overhead projector or Elmo projector. The connections from the capacitor plates to the electroscope (via “BNC” cable) are not obvious; they are red-to-red and black-to-metallic sheathing. After turning on the HV generator (about 3000 V) charge the capacitor by briefly touching either plate with the leads to the side of the plates, giving an electrometer response. Use of two sets of alligator clips leads gives more transparent electrical connections, but the electrometer reading is susceptible to change if the leads are shaken. Move the plates of the capacitor closer together and apart and observe the reading of the electroscope, which shows the potential increases with the plate distance. Because the electroscope does not give a quantitative response we cannot test the predicted linearity of voltage with distance.

RESOURCE INFORMATION ON A VARIABLE PLATE CAPACITOR ON YOUTUBE -
<https://www.youtube.com/watch?v=ogUnayGxttw>

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E3-03 PARALLEL PLATE CAPACITOR AND IONIZATION OF AIR



Apparatus:

- Electroscope
- Parallel plate capacitor
- Overhead projector or Elmo projector
- High voltage generator and AC adapter
- Co-axial leads
- Box of matches or striker

Demonstrates ions moving in an electric field

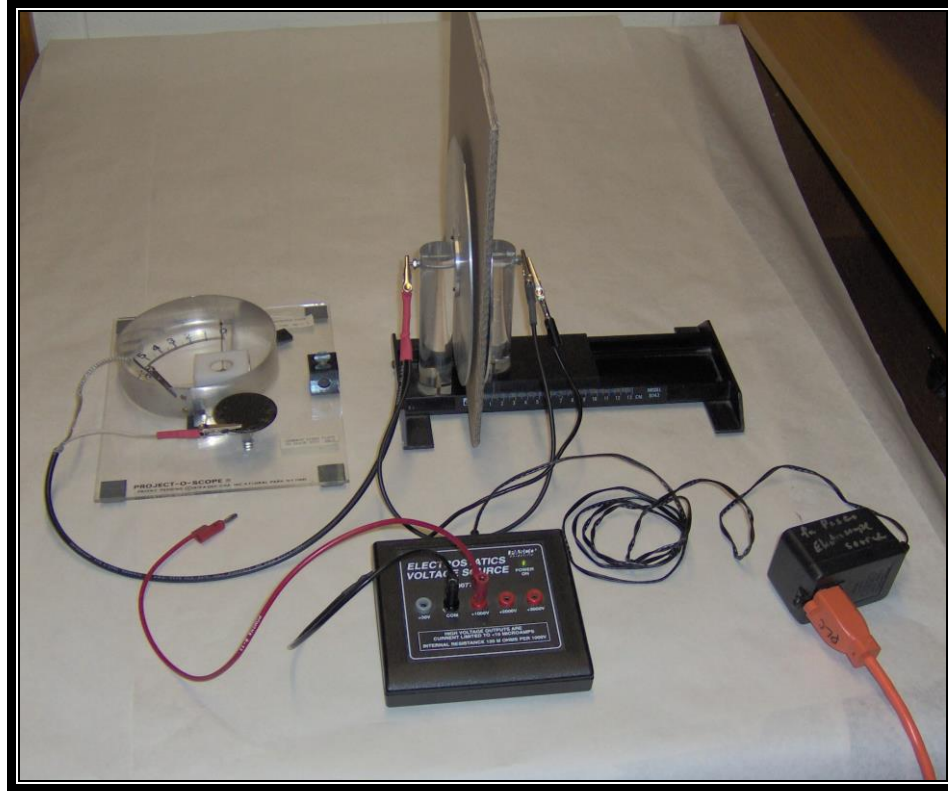
Charge the capacitor and separate the plates. Bring a lighted match between the plates. The ionization of the air creates free positive and negative charges which migrate to the capacitor plates and discharges the capacitor.

RESOURCE INFORMATION ON IONIZATION OF CHARGE BETWEEN THE PLATES FROM UNIV OF MARYLAND-

<https://lecдем.physics.umd.edu/j/j4/j4-04.html>

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E3-04 PARALLEL PLATE CAPACITOR WITH A DIELECTRIC



Apparatus:

- Electroscope
- Parallel plate capacitor
- Overhead projector or Elmo projector
- High voltage generator and AC adapter
- Co-axial leads
- Dielectric sheet (cardboard sheet)

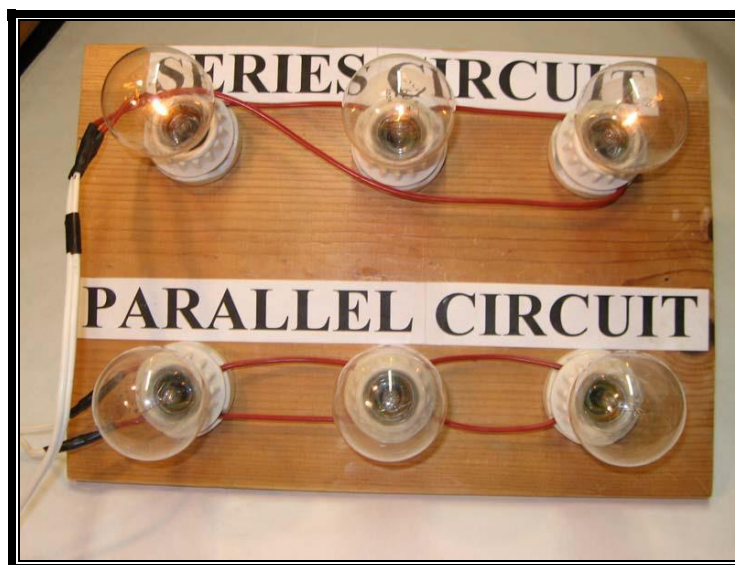
Demonstrates that inserting a dielectric material into the capacitor increases the capacitance

The parallel plate capacitor is charged by the power supply and the plates are separated, increasing the voltage between the plates. A thick dielectric sheet is inserted between the capacitor plates, decreasing the voltage. Because the charge on the plates remained the constant, it means that the insertion of the dielectric increased the capacitance. This allows more charge to be stored by the capacitor at the same voltage.

RESOURCE INFORMATION ON CAPACITOR WITH A DIELECTRIC FROM WIKIPEDIA -
<https://en.wikipedia.org/wiki/Dielectric>

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E4-01 SERIES AND PARALLEL LIGHT BULBS [DSC# 5F20.50]



Apparatus: Circuit board with light bulbs in parallel and in series.

Purpose: Demonstrate current flow and voltage drop in a series and parallel circuit

Three identical light bulbs (in other words, three identical resistors) in both a parallel circuit and a series circuit are connected to an AC power outlet, which supplies the same 120 V ac voltage to each circuit.

The brightness of a light bulb increases with the electrical power dissipated in the bulb, according to $P=IV$, where I is the current going through the bulb and V is the voltage drop across the bulb. Further, for a linear response, $I=V/R$ relates the current to the voltage and resistance R . However, R depends on temperature, which varies with the current and voltage.

Plug in the power cord to the AC power outlet. For the series circuit the light bulbs are much dimmer relative to the light bulbs in the parallel circuit.

For the parallel circuit each bulb has the full voltage drop (120 V), and the full current. The total current is the sum of the currents through each bulb.

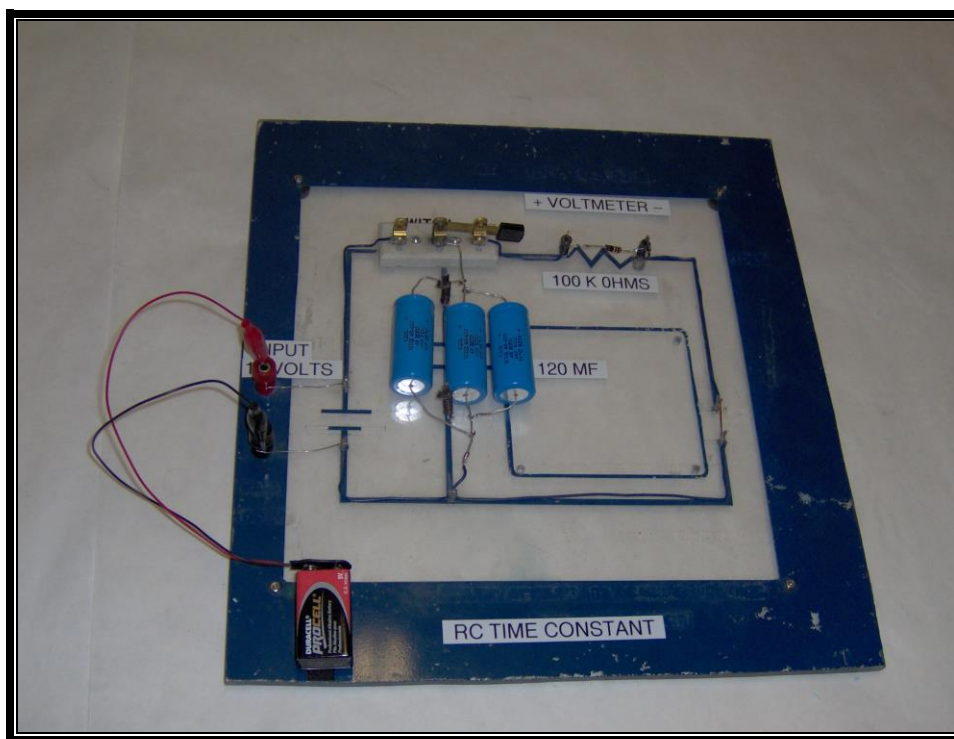
For the series circuit the voltage across each bulb is 40 V, but the voltages sum to 120 V. The current through each bulb is correspondingly lower by a factor of three. By $P=IV$ the power is lower by a factor of 9 if the resistance is constant. Qualitatively, this means that less current flows through bulbs in series.

For the series circuit, disconnecting a bulb breaks the circuit, so all the bulbs go off. For the parallel circuit the non-disconnected bulbs retain the same brightness, because the dissipated power through each bulb remains the same. This is why wiring in buildings is in parallel.

RESOURCE INFORMATION ON SERIES AND PARALLEL LIGHT BULBS FROM WIKIPEDIA -
https://en.wikipedia.org/wiki/Series_and_parallel_circuits

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E5-01 RC TIME CONSTANT [DSC# 5F30.20]



Apparatus:

- Elmo projector (to project the meter image)
- RC time constant apparatus
- 9 volt battery
- Simpson meter
- Long leads (for the meter)

Demonstrates charging/discharging of an RC circuit

Place the RC apparatus on the overhead projector or Elmo and connect the battery to the input jacks. Connect the meter across the 100K-Ohm resistor.

Charge the capacitor by moving the switch to the right (across the capacitor and battery to charge up the capacitors. Now move the switch to the nearest side of the 100K-Ohm resistor. This discharges the capacitor across this resistor. The voltage drop across the resistor is shown on the meter.

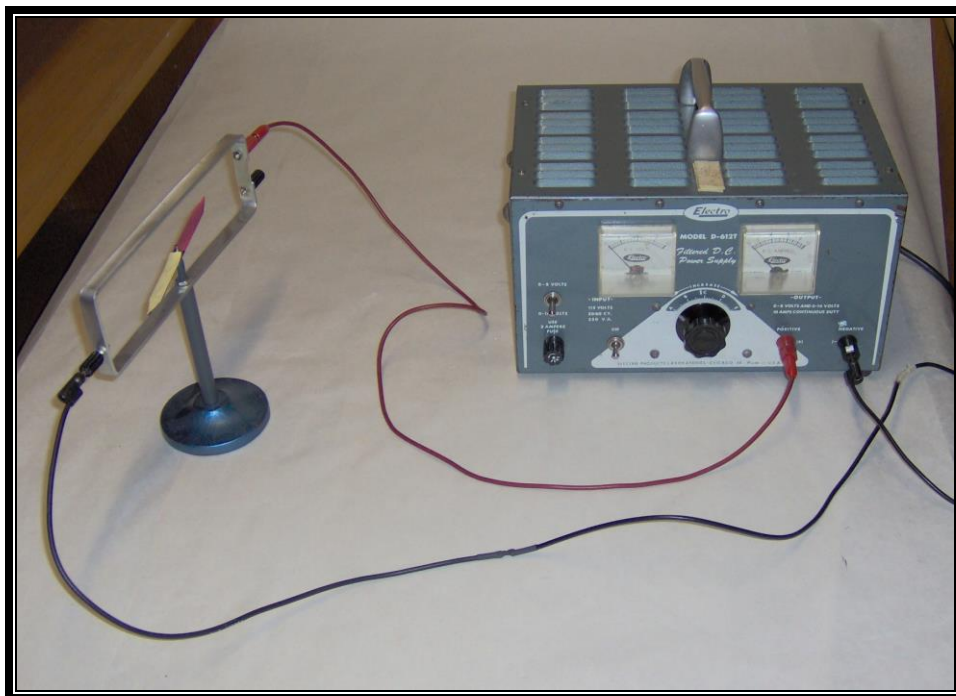
Notes: Values for R (100 k-ohm) and C (120 micro-F) were chosen to give a time constant $RC=12$ s, which can be followed by the human eye. Additional resistors and capacitors to be placed in series or parallel would let the time constant vary.

RESOURCE INFORMATION ON RC TIME CONSTANT FROM WIKIPEDIA -

https://en.wikipedia.org/wiki/RC_time_constant

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E6-01 OERSTED'S EXPERIMENT (WIRE OVER A COMPASS) [DSC# 5H10.20]



Apparatus:

- Compass apparatus
- DC power supply
- Connecting leads

Demonstrates that magnetic fields are generated around current carrying wires

Align the compass such that it is parallel to the N-S field of the earth. Connect the power supply to the compass apparatus. When the current passes through the conducting frame, the compass needle aligns in the direction of the magnetic field.

Notes: The leads can be connected on the apparatus such that the current is flowing below the needle.

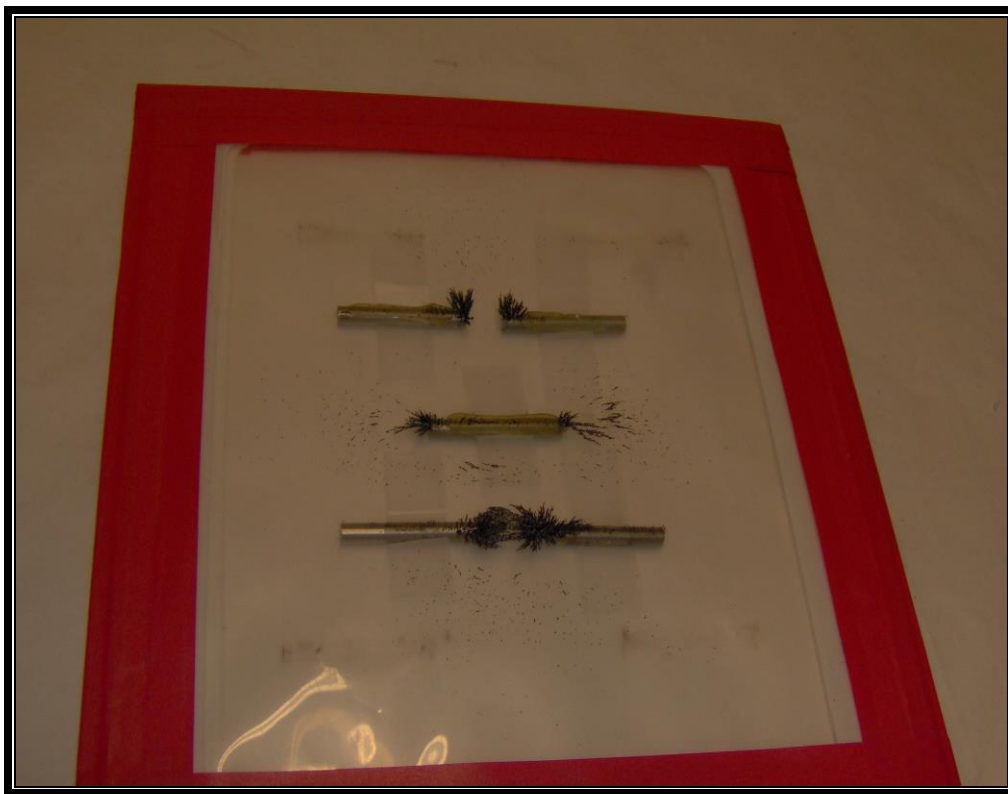
The voltage source can be easily changed, so that we can demonstrate that the deflection increases with increasing voltage and current.

RESOURCE INFORMATION ON OERSTED'S LAW FROM WIKIPEDIA -

https://en.wikipedia.org/wiki/Oersted%27s_law

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E6-02 MAGNETS AND IRON FILINGS [DSC# 5H10.30]



Apparatus:

Clear plastic sheets with magnets glued to the inside
Iron filings container
Elmo projector

Purpose: To visualize the magnetic field of bar magnets.

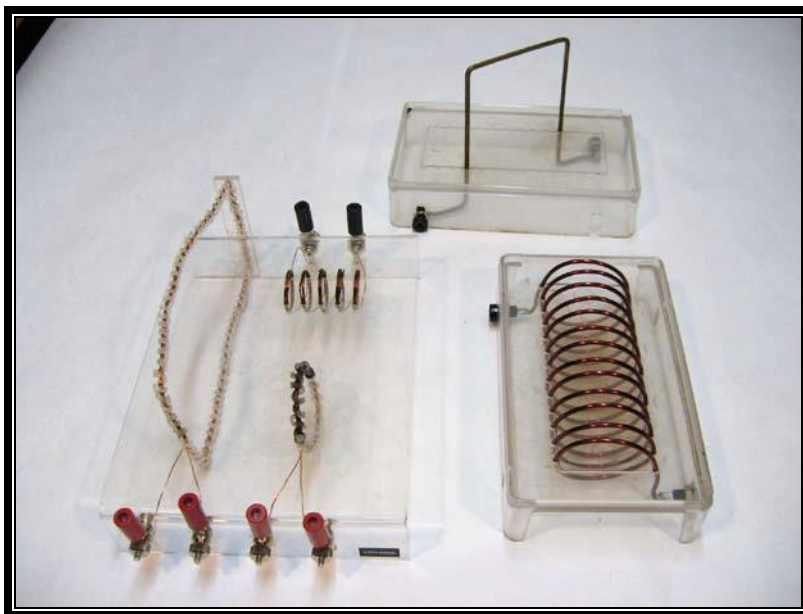
Sprinkle a small amount of filligs on top of the magnets

RESOURCE INFORMATION ON MAGNETS AND IRON FILINGS ON YOU TUBE

<https://www.youtube.com/watch?v=snNG481SYJw>

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E6-03 MAGNETIC FIELD AROUND A WIRE AND SOLENOIDS [DSC# 5H15.10]



Apparatus:

- Overhead projector or Elmo projector
- Field sources (assortment)
- Iron fillings
- Large DC power supply and leads.

Purpose: Visualize magnet field produced by current-carrying conductors

Place the field sources on the projector. Connect the power supply to the jacks on the plastic boxes. Sprinkle iron fillings on top of the sources to display the magnetic fields. **Do not exceed 5 A through the wires.**

RESOURCE INFORMATION ON MAGNETIC FIELDS FROM YOU TUBE...

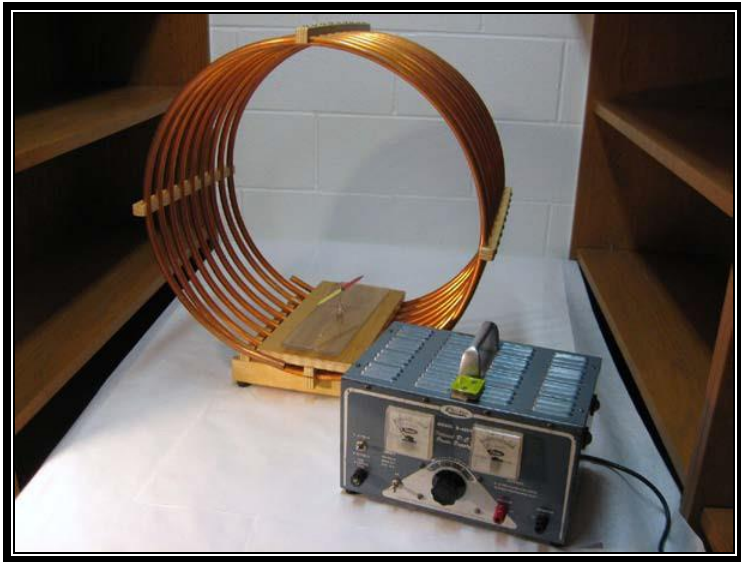
https://en.m.wikipedia.org/wiki/Magnetic_field#Magnetic_field_lines

RESOURCE INFORMATION ABOUT MAGNETIC FIELDS FROM PEARSON HIGHER ED (page 7)

<https://www.pearsonhighered.com/knight-3e-info/assets/pdf/knight-ch24.pdf>

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E6-04 MAGNETIC FIELD AROUND A LARGE COIL [DSC# 5H15.40]



Apparatus:

- Large coil on wood stand
- Compass needle on stand
- Large DC power supply and long leads with clips

Purpose: Illustrate magnetic field around and within a conducting coil.

Attach the power supply to the ends of the large coil. Use the compass needle to illustrate the magnetic field.

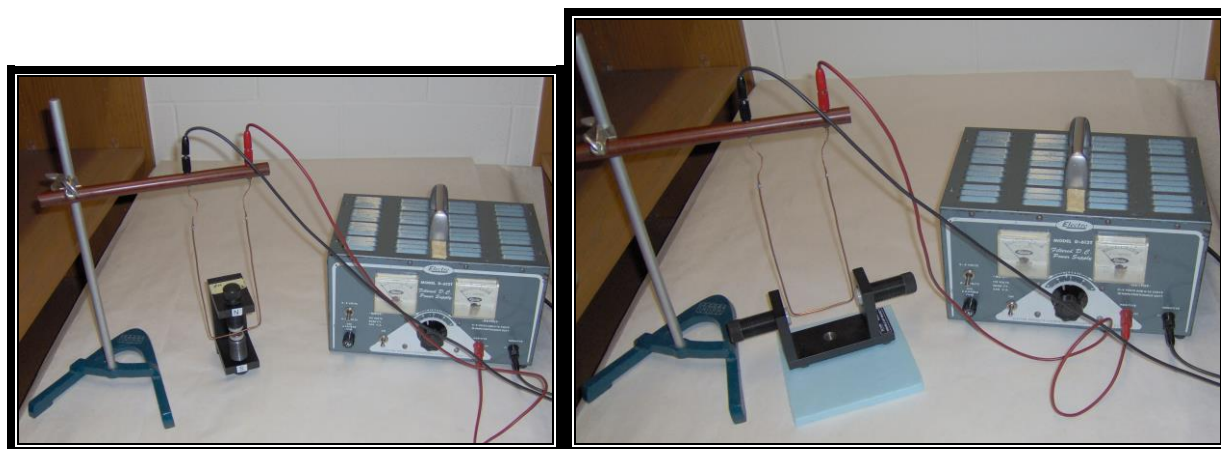
Note the compass needle on the wooden board. The deflection will reverse if the leads from the power supply (not shown) are reversed.

RESOURCE INFORMATION ON MAGNETIC FIELDS FROM YOU TUBE...

https://en.m.wikipedia.org/wiki/Magnetic_field#Magnetic_field_lines

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E6-05 MAGNETIC FORCE ON A CURRENT CARRYING WIRE [DSC# 5H40.30]



Apparatus:

- Deflected bar apparatus
- Two Pasco magnets with N and S labels
- DC power supply and leads

Purpose: Demonstrate magnetic force on current-carrying wire in the field of a fixed permanent magnet.

See figure on the left - Connect the power supply leads to the jacks on the deflected bar apparatus. Once the current is flowing (LIMIT TO 3 AMPS), the wire will deflect. Reverse the direction of the current to show that the deflection of the wire is now opposite and in agreement with the right hand rule. The effect is linear in the strength of the magnet.

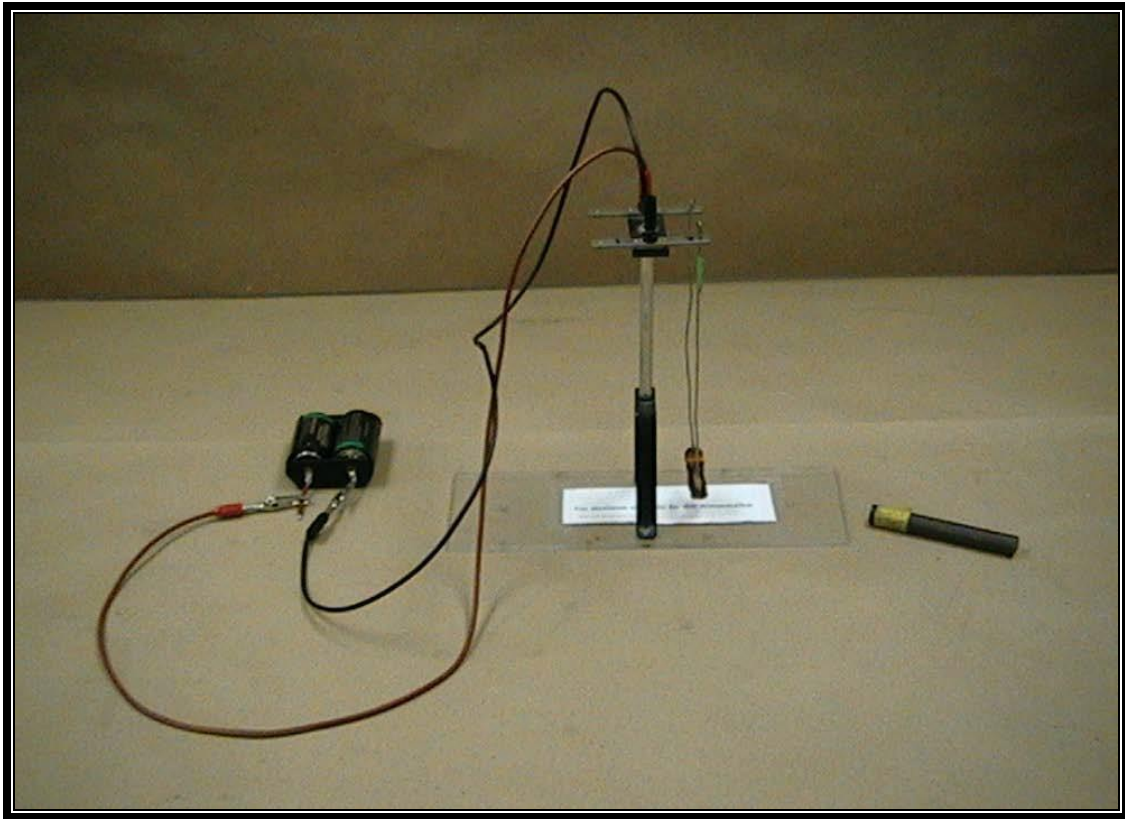
(Set up info – be careful with the brown tube, it is thin and fragile.)

See figure on the right – Using the magnet with the poles separated, connect the power supply leads to the jacks on the deflected bar apparatus. Once the current is flowing (LIMIT TO 3 AMPS), note that the wire will not deflect (although it will tend to move due to the part of the wire that is perpendicular to the magnet). Shows that current along the field causes no deflection.

RESOURCE VIDEO OF DEFLECTED BAR FROM NORTH CAROLINA STATE UNIV -
<https://www.youtube.com/watch?v=pU6MEAXLmk4>

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E6-06 MAGNETIC FORCE ON CURRENT CARRYING COIL [DSC# 5H40.35]



Apparatus:

- Coil on mount
- Bar magnet
- Two batteries on holder and leads

Purpose: Demonstrate magnetic force on current-carrying coil due to a bar magnet that induces current in the coil.

Connect the batteries to the coil. Use the bar magnet to cause the coil to swing back and forth, showing the magnetic force on the conductor.

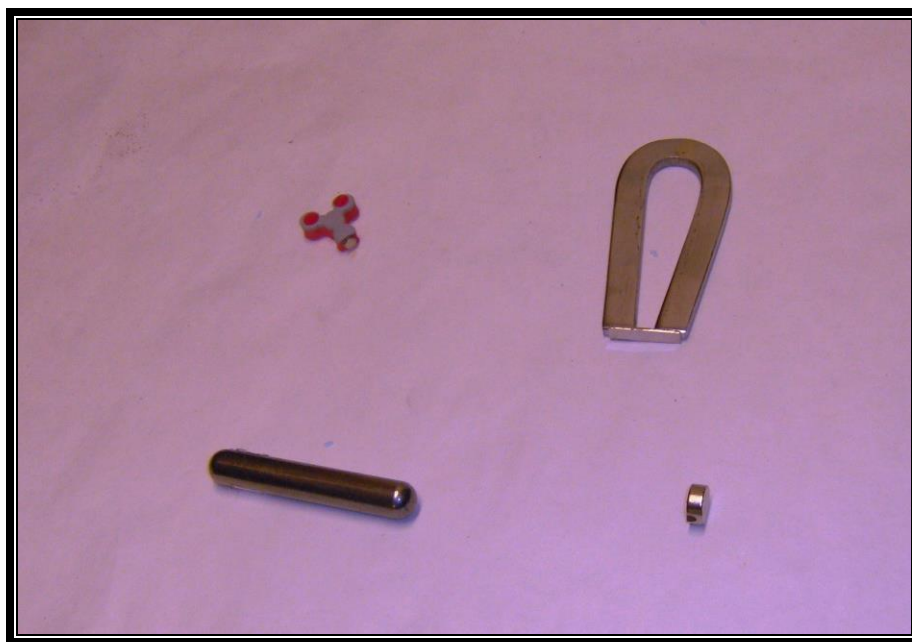
Since the current is induced by the motion of the magnet, the effect is quadratic in the strength of the magnet.

RESOURCE INFORMATION ON INTERACTING COILS FROM UCALGARY.CA ---

http://phas.ucalgary.ca/files/phas/5h40_15_interacting_coils.pdf

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E6-07 MAGNETS [5G10.10]



Apparatus:

Different types of magnets.

Shows different types of magnets, including a horseshoe magnet, a bar magnet and a ring magnet.

RESOURCE INFORMATION ON MAGNETS FROM WIKIPEDIA -
<https://en.wikipedia.org/wiki/Magnet>

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E6-08 MAGNETIC SPINNER



Apparatus:

Axle with two magnets attached
Magnetic base

Demonstrates magnetic levitation

The axle with the two magnets attached levitates about the magnetic base as it spins. Be sure to insert small glass plate at one end. **Careful with the glass plate.**

RESOURCE INFORMATION ON THE MAGNETIC SPINNER FROM UCLA PHYSICS
AND FROM A SUPPLIER OF THE SPINNER -

<http://www.physics.ucla.edu/marty/levitron/spinstab.pdf>

<http://www.officeplayground.com/magnetic-levitator-classic-p1241.html?gclid=CNmG1vPbhM4CFZCKaQodQKwE3A>

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E6-09 MAGNET BROKEN BUT NO MONOPOLE (5G10.20)



Apparatus:

- Bar magnet
- Iron fillings
- Elmo projector

Demonstrates that there are no magnetic monopoles, the poles of a magnet always come in pairs.

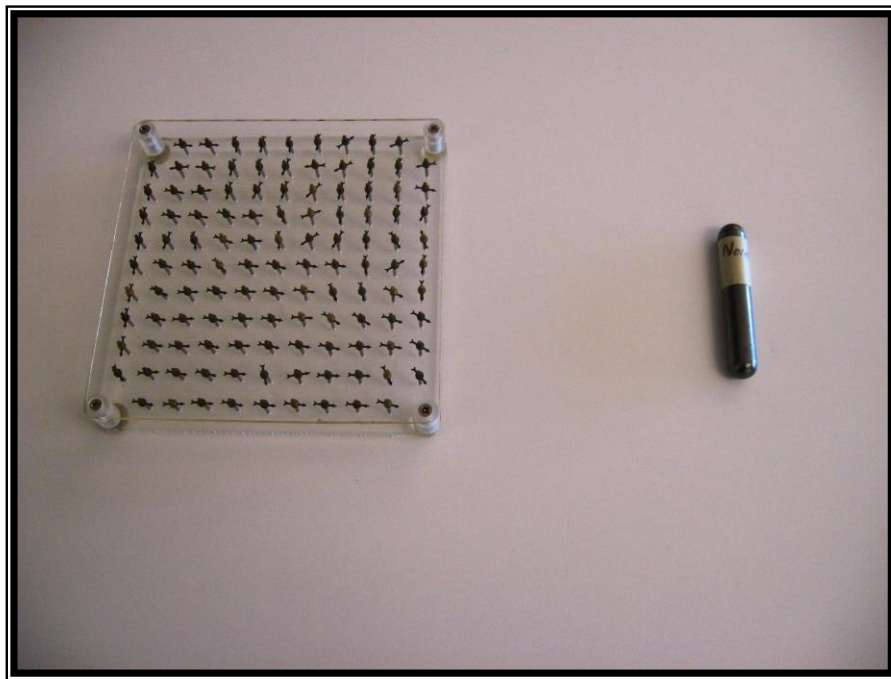
The magnetic field of a bar magnet is shown using iron fillings on the Elmo projector. The magnet is then broken and the demonstration repeated. Each half magnet has again two poles.

RESOURCE INFORMATION ON A MAGNET AFTER BREAKING IT -

<http://www.dailymail.co.uk/sciencetech/article-2548880/Scientists-create-ONE-poled-magnet-unlock-secrets-surrounding-birth-universe.html>

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E6-10 MAGNETIC FIELD LINE MODEL



Apparatus:

- Elmo projector
- Bar magnet
- Array of compass needles

Visualizes the magnetic field of a bar magnet

Bring the bar magnet **close** on top of an array of small compass needles that is on the Elmo projector. The compass needles show the magnetic field lines. (Do not place the magnet on top of the array)

RESOURCE INFORMATION ON A MAGNETIC FIELD MODEL FROM ARBOR SCIENTIFIC -
<http://www.arborsci.com/magnetic-field-model>

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E6-11 TORQUE OF A BAR MAGNET



Apparatus:

Bar magnet
Horseshoe magnet on a rotating pivot

Demonstrates the torque of a bar magnet in magnetic field

A small bar magnet is suspended on a rotating pivot between the poles of a horseshoe magnet. If the bar magnet is turned and released it rotates back to its original position due to the torque applied by the magnetic field of the horseshoe magnet.

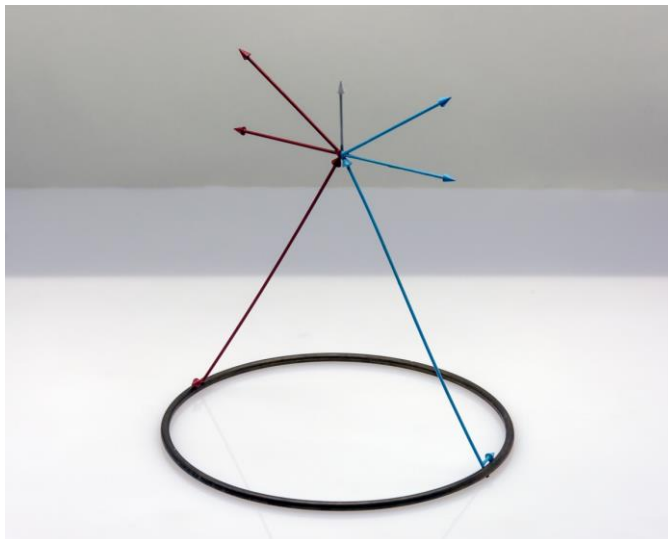
[Picture from University of Maryland Physics Demonstration site]

(Under construction – due to be completed Sept 1, 2016)

RESOURCE INFORMATION ON MAGNETIC FIELDS FROM PEARSON HIGHER ED (page 3)
<https://www.pearsonhighered.com/knight-3e-info/assets/pdf/knight-ch24.pdf>

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E6-12 MAGNETIC FIELD OF A CURRENT LOOP—MODEL



Apparatus:

Model for the magnetic field of a current ring.

Illustrates the magnetic field along the axis of a ring of current.

[Picture from University of Maryland Physics Demonstration site]

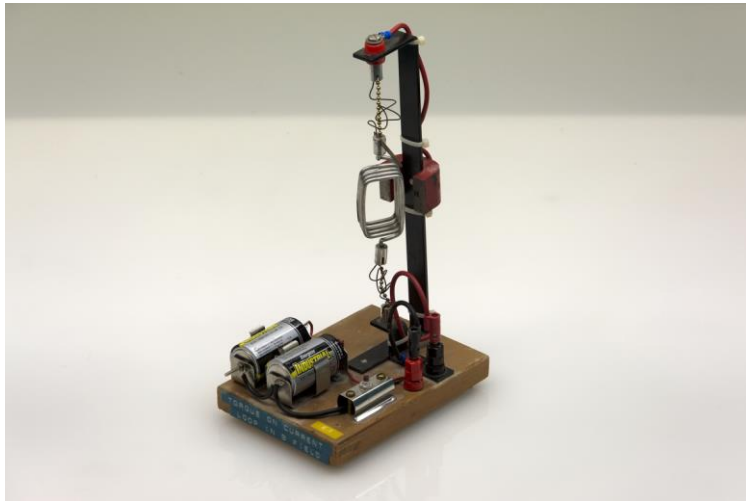
(Under construction – due to be completed Sept 1, 2016)

RESOURCE INFORMATION ON CURRENT LOOPS FROM PEARSON HIGHER ED (page 12)

<https://www.pearsonhighered.com/knight-3e-info/assets/pdf/knight-ch24.pdf>

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E6-13 TORQUE OF A CURRENT LOOP IN A MAGNETIC FIELD



Apparatus:

Coil and horseshoe magnet
Power supply

Demonstrates the torque on a current loop in a magnetic field

A small coil is positioned in the magnetic field of a horseshoe magnet. Turning on the power supply so that current flows through the coil creates a torque making the coil rotate about its axis. Reversing the current reverses the direction of the torque.

[Picture from University of Maryland Physics Demonstration site]

(Under construction – due to be completed Sept 1, 2016)

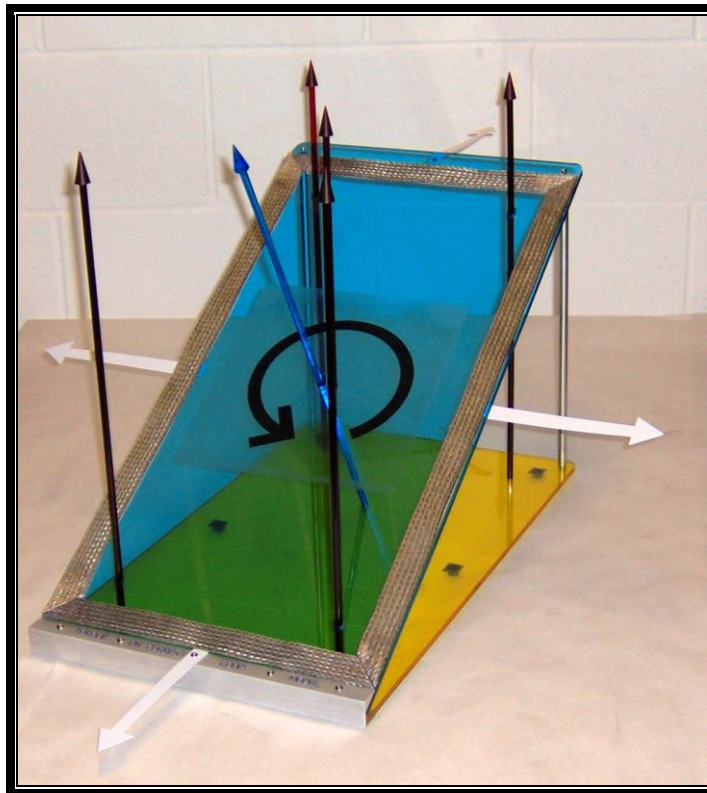
RESOURCE INFORMATION ON TORQUE ON A CURRENT LOOP FROM UNIV OF FLORIDA AND MIT

http://www.phys.ufl.edu/courses/phy2054/s08/lectures/2054_ch19B.pdf

http://web.mit.edu/8.02t/www/materials/InClass/IC_Sol_W07D1_1.pdf

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E6-14 TORQUE ON CURRENT LOOP - MODEL



Apparatus:

Torque on a current loop model

Shows a model for the torque of a current loop in a magnetic field.

A uniform magnetic field is represented by red arrows. A current-carrying coil is positioned at an angle with respect to the magnetic field. It carries a current indicated by the black arrows and experiences a torque due to the magnetic field (blue vectors). The torque is created by the forces on the four sides of the coil, shown by white arrows.

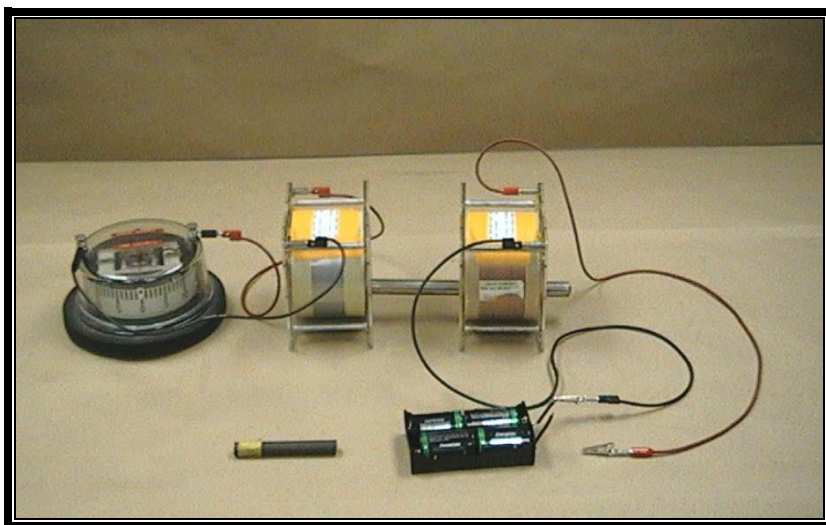
RESOURCE INFORMATION ON TORQUE ON A CURRENT LOOP FROM UNIV OF FLORIDA AND MIT

http://www.phys.ufl.edu/courses/phy2054/s08/lectures/2054_ch19B.pdf

http://web.mit.edu/8.02t/www/materials/InClass/IC_Sol_W07D1_1.pdf

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E7-01 INDUCED EMF IN A COIL [DSC# 5K10.20]



Apparatus: Galvanometer Two large coils
Bar magnet Battery pack of 4 batteries
Steel bar for coupling Leads

The demonstration can be performed in two ways:

Using a current source.

Connect the coil on the left (in the photo) to the galvanometer and the coil on the right to the battery pack as shown (but leave one lead disconnected to the battery pack). The steel bar should be inserted inside the two coils. “Touch” but do not connect the loose end of the battery pack lead to the terminal of coil on the right. Note the response of the galvanometer needle. Remove the lead and at the same time, note the response on the galvanometer. What is the response?

Using a magnet.

Separate the first coil from the second coil. Bring one of the pole ends of a magnet close to the opening of coil connected to the galvanometer. Quickly insert the magnet into the coil. The galvanometer should respond in one direction. Quickly remove the magnet. The galvanometer should respond in the other direction.

Reversing the end of the magnet and reversing the side into which the magnet is inserted should yield reversals of the galvanometer response. Slow insertion of the magnet into the coil should yield a small – or no -- effect

Notes: The solenoid on the right is given a current by the batteries. The solenoid on the left is connected to a sensitive galvanometer. The metal rod resting between the two solenoids is a very magnetizable (a soft ferromagnet). It serves to extend the field of one solenoid to the other.

RESOURCE INFORMATION ON INDUCED EMF IN A COIL FROM WIKIPEDIA -
https://en.wikipedia.org/wiki/Electromagnetic_coil

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E7-02 EDDY CURRENT PENDULUM [DSC# 5K20.10]



Apparatus:

Eddy current apparatus and set of attachments
Pasco magnet (as shown)

Purpose: Show the damping of pendula due to eddy currents.

Attach one of the attachments to the support rod and allow it to swing through the opening between the magnet poles (as shown). Note the difference (in damping) between the attachment with slits and the one without slits.

An undergraduate's view on eddy currents:

<http://www.physlink.com/Education/AskExperts/ae527.cfm>

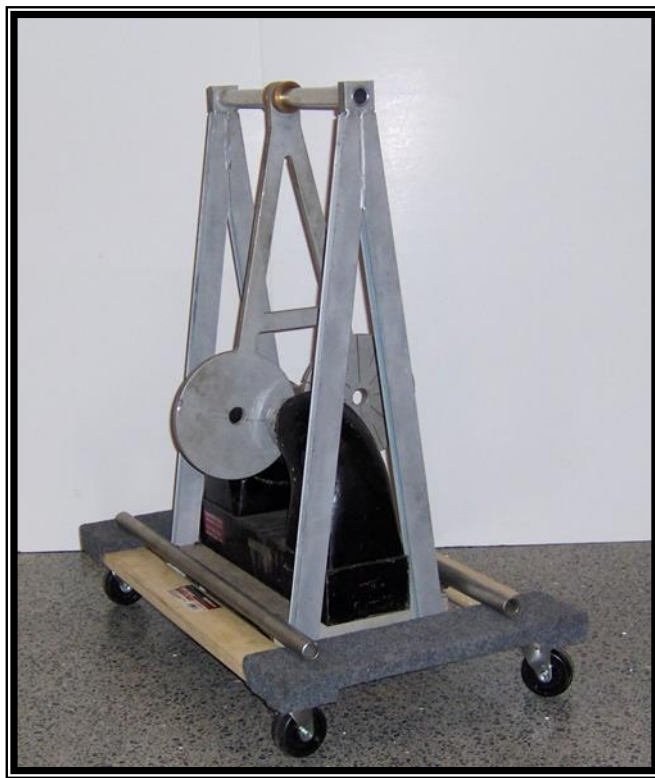
Notes: One may think about this as the swinging metal sheet “not wanting” to permit the field within it to change, and thus inducing eddy currents in the plane of the sheet that make the sheet an electromagnet with polarity that opposes the motion. [If possible, use sheets of different material to produce different amounts of Eddy currents.]

RESOURCE INFORMATION ON EDDY CURRENTS FROM WIKIPEDIA -

https://en.wikipedia.org/wiki/Eddy_current

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E7-13 MAGNETIC BRAKE (DSC# 5K20.11)



Apparatus:

Large magnet with solid and slotted pendulums mounted on frame

This is another larger Eddy current pendulum that can be used to demonstrate magnetic braking using these Eddy currents. There are two pendula that can swing into the region of magnetic field, one slotted and one solid.

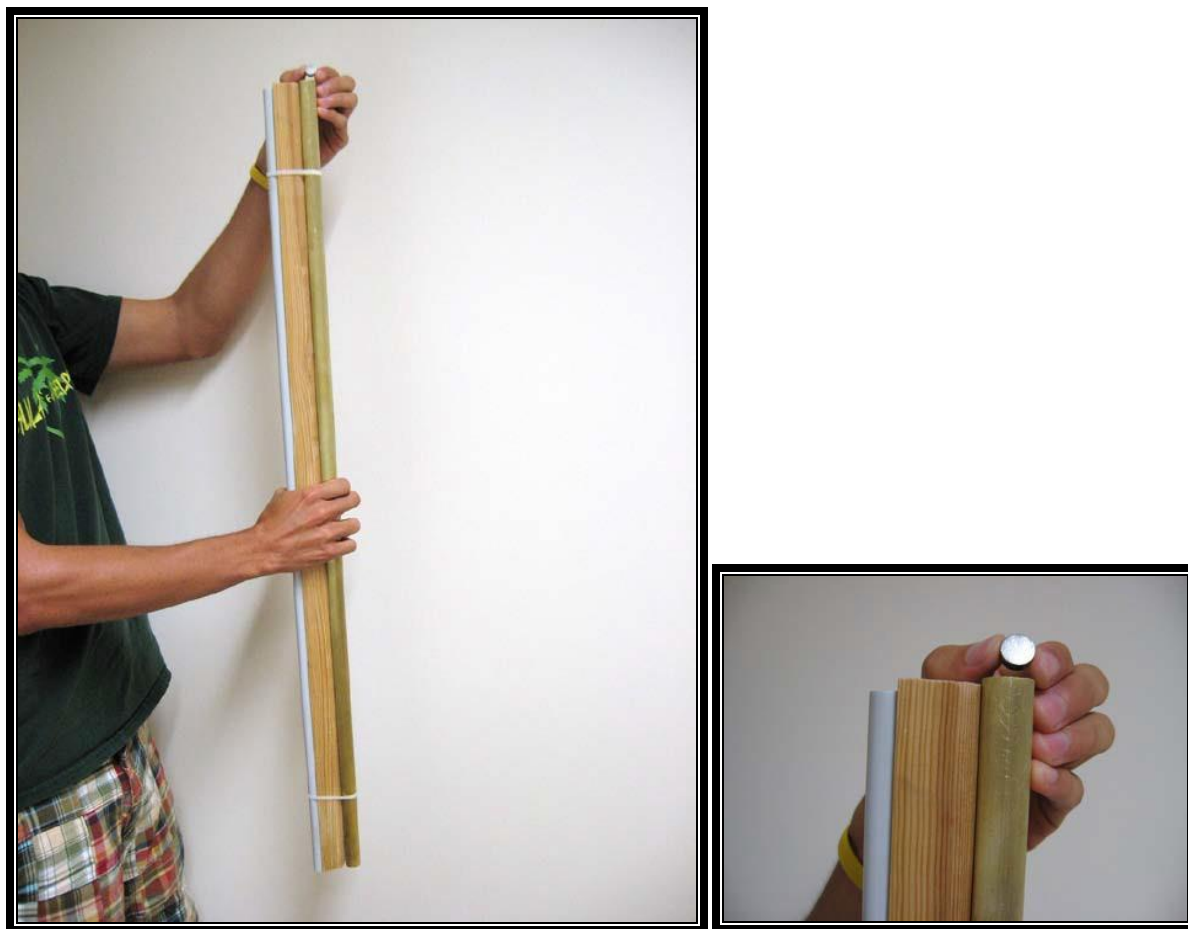
RESOURCE INFORMATION ON EDDY CURRENT BRAKE FROM WIKIPEDIA -

https://en.wikipedia.org/wiki/Eddy_current_brake

This demonstration was made available for classroom use by the Physics Festival group headed by Tatiana Erukhimova. This demonstration was developed by the DEEP students involved in the Festival, funded by DEEP and built by our Physics machine shop and Electronic Shop.

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E7-03 MAGNET FALLING IN TUBE (LENZ'S LAW) [DSC# 5K20.25]



Apparatus:

Brass rod and plastic tube apparatus
Neodymium magnet

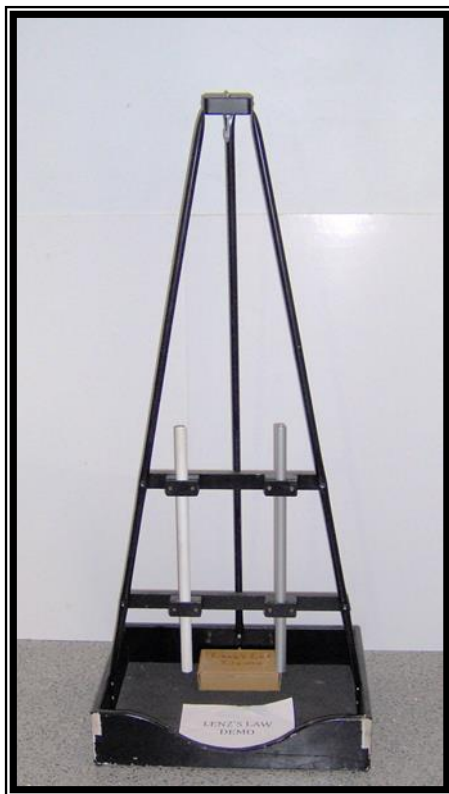
Notes: Hold the tubes in a vertical orientation. Allow the magnet to drop in the plastic tube and show how quickly it goes through the tube. Now, drop the magnet in the brass tube.

RESOURCE INFORMATION ON LENZ'S LAW FROM WIKIPEDIA -

https://en.wikipedia.org/wiki/Lenz%27s_law

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E7-12 LARGE EDDY CURRENT TUBES (LENZ'S LAW) (DSC# 5K20.25)



Apparatus:

Two long tubes (aluminum and plastic)
Metal bar and magnet

Notes: Hold the tubes in a vertical orientation. Allow the magnet to drop in the plastic tube and show how quickly it goes through the tube. Now, drop the magnet in the aluminum tube. Also show how the metal bar drops in the two tubes.

RESOURCE INFORMATION ON LENZ'S LAW FROM YOUTUBE -
<https://www.youtube.com/watch?v=sPLawCXvKmg>

https://www.youtube.com/watch?v=otu-KV3iH_I

This demonstration was made available for classroom use by the Physics Festival group headed by Tatiana Erukhimova. This demonstration was developed by the DEEP students involved in the Festival, funded by DEEP and built by our Physics machine shop and Electronic Shop.

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E7-04 MAGNETIC FORCE ON METAL RINGS (LENZ'S LAW) [DSC# 5K20.26]



Apparatus:

2 metal rings on a Lucite rod attached to a rod and base
Bar magnet

Purpose: Demonstrate Lenz's law

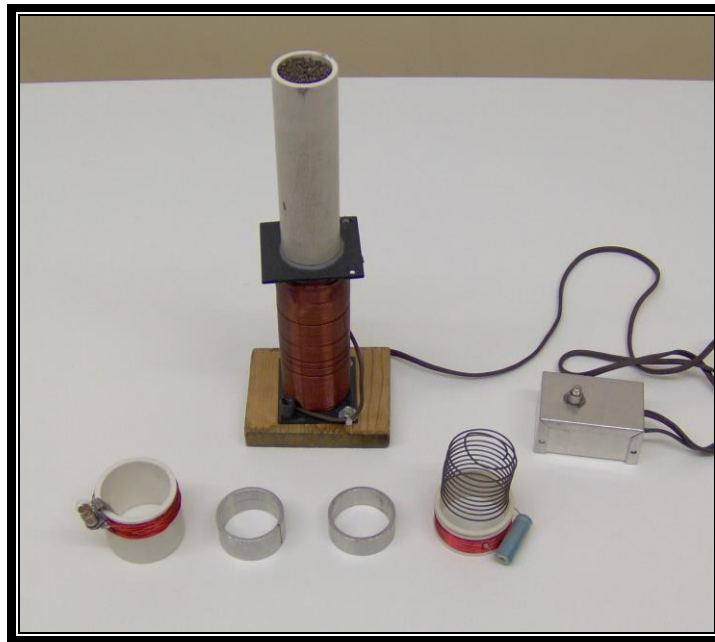
One ring is split and the other is solid. Oscillate the bar magnet in and out of the ring and try to cause them to oscillate. The split ring will not move, as there is no current circulating through it. The solid ring becomes an electromagnet whose field opposes a change in the field due to the moving magnet.

RESOURCE INFORMATION IN YAHOO ON ALUMINUM RINGS AND MAGNETIC FIELD..

<https://answers.yahoo.com/question/index?qid=20110717115703AAeG2et>

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E7-05 JUMPING RINGS [DSC# 5K20.30]



Apparatus:

- Small jumping ring apparatus
- 2 rings—one solid and one with a slit in it
- Coil of wire with a light attached
- TAMU “sucking ring”

Purpose: Demonstrate Lenz’s law and Faraday’s law

Notes: Use the push button on the jumping ring to make the rings jump up in the air or to make the bulb light up.

The solenoid is connected to an AC power source, producing a magnetic field that oscillates along its axis. The iron core intensifies the field of the solenoid, making it into a powerful ac electromagnet. By Faraday’s Law (or Lenz’s Law), currents are induced around the wire-bulb device when placed on the axis of the solenoid, thus causing it to light and establishing that there can be such eddy currents. Then, the solid ring becomes an electromagnet, which jumps when placed along the axis of the solenoid; by Lenz’s Law is of the type that does not “like” to be in a time-varying field, and thus “jumps” out. The TAMU “sucking ring” consists of a white PVS cylinder with winding, a capacitor, and a spring (to hold the cylinder on top of the apparatus). On this ring, the capacitor phase dominates.

Second purpose: Demonstrate magnetic induction with a light bulb

Closing the switch produces a current in the primary coil, which is coupled to a secondary coil (on top of a ferromagnetic core). The induced current in the secondary coil lights the light bulb.

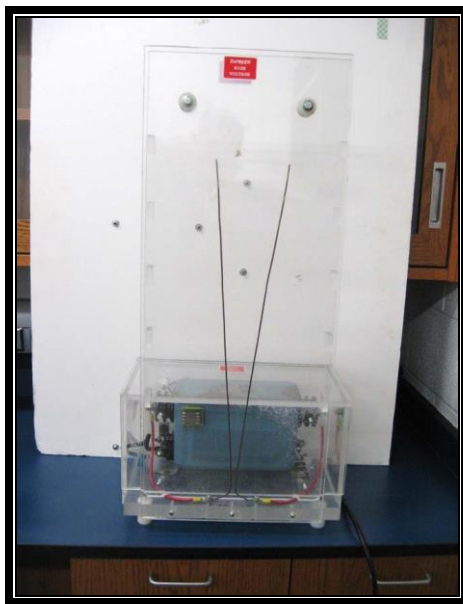
RESOURCE INFORMATION ON JUMPING RINGS FROM ARXIV PAPERS AND EDUCYPEDIA -

<https://arxiv.org/ftp/arxiv/papers/1404/1404.6024.pdf>

<http://educypedia.karadimov.info/library/The%20jumping%20ring%20experiment.pdf>

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E7-06 JACOB'S LADDER [DSC# 5K30.10]



Apparatus: Jacob's ladder apparatus

Notes: Use the on/off switch to apply power to the transformer and the vertical wires.

The Demonstration: An electric spark jumps between two parallel wires. The spark then "climbs" up the ladder.

Quick Physics: The transformer at the bottom creates a potential difference between the wires. The electrons repel each other, so they jump from one wire to try and get as far apart as possible. The spark heats up the surrounding air and hot air rises, so the spark rises with it. When the spark gets to the top of the wires, it dies and a new one starts at the bottom.

The Details:

The Jacob's Ladder is a relatively simple device. The big box on the bottom is called a transformer. A transformer is something that changes the voltage going to a device. You probably have several transformers in your home; for example, the charger on your cell phone is a transformer. Your cell phone converts the 120 Volts that come out of the wall into 9 or 12 Volts. The Jacob's Ladder converts the same 120 Volts to more than 500 Volts!

When the Jacob's Ladder is turned on, electrons are fed into one of the wires. These electrons want to get away from each other, so they jump across to the other wire, which is connected to the ground. When they jump, we see a bright spark in the air. The spark then climbs up the ladder as it heats the air around it. Remember that hot air rises, and in this case takes the spark with it. This spark is very hot, so hot that it can be classified as a plasma (see Plasma Tube). Eventually the spark dissipates and releases all of those electrons into the air. (Info from University of Wisconsin web site)

RESOURCE INFORMATION ON JACOB'S LADDER FROM "HIGH TECH SCIENCE -
http://www.hightechscience.org/high_voltage.htm

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E7-14 JACOB'S LADDER (WITH SWORDS) (DSC# 5D40.10)



Apparatus:

Two swords in plastic box

See previous description of the Jacob's Ladder demo for details.

RESOURCE INFORMATION ON JACOB'S LADDER FROM "HIGH TECH SCIENCE -
http://www.hightechscience.org/high_voltage.htm

This demonstration was made available for classroom use by the Physics Festival group headed by Tatiana Erukhimova. This demonstration was developed by the DEEP students involved in the Festival, funded by DEEP and built by our Physics machine shop and Electronic Shop.

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E7-07 DC MOTOR APPARATUS [DSC# 5K40.10]



Apparatus:

Large motor apparatus
Large DC power supply and leads

Demonstrates magnetic torque $\mathbf{m} \times \mathbf{B}$ and slip-ring connection

Notes: Connect the power supply [red (black) terminals of motor to the red (black) jacks of the power supply]. Slowly increase the output voltage (**MAX 3 AMPS**) of the power supply until the motor coils rotate. One may have to pre-set the alignment of the coils of the motor in order for it to rotate.

Here the dc power makes the fixed solenoids a magnetic core into dc magnets. The rotatable solenoids also get dc power and are dc magnets. However, they are attached to a slip-ring connection, so that when they are attracted to the fixed magnets and overshoot, instead of oscillating their polarity changes, and they continue to overshoot. The slip-ring was invented by Ampere, more noted for his theoretical work on electromagnetism.

RESOURCE INFORMATION ON ELECTRIC MOTORS AND GENERATORS IN WIKIPEDIA -
https://en.wikibooks.org/wiki/Electric_Motors_And_Generators

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E7-08 AC GENERATOR [DSC# 5K40.40]



Apparatus:

Large generator apparatus
Galvanometer and leads

Demonstrates Faraday's Law with motion provided by demonstrator.

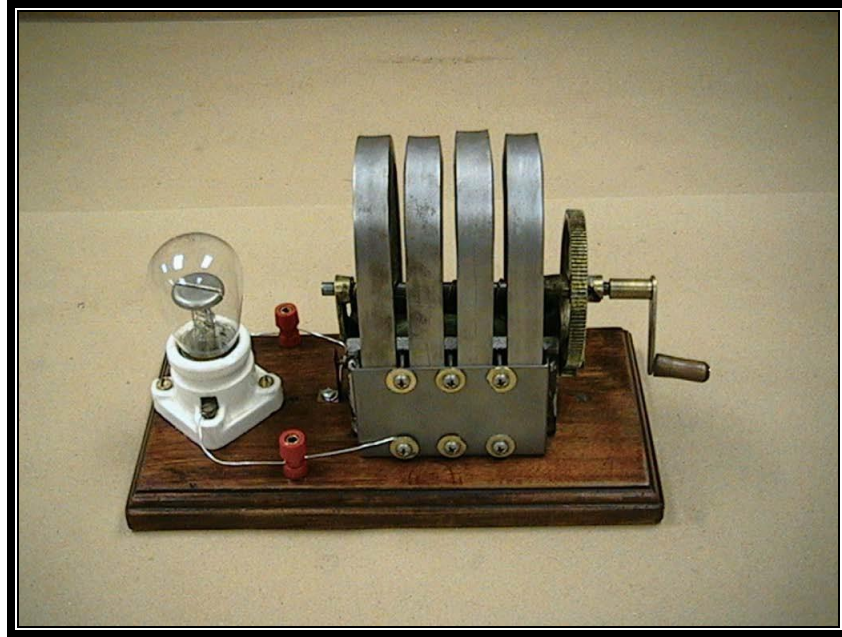
Notes: Connect the generator to the galvanometer. Rotate the spindle of the generator to show that it generates a current as shown on the galvanometer.

The magnetic cores of the solenoids retain a small amount of magnetism in the absence of a current, so that the rings repel and thus the movable rings turn. Because of the slip-ring device, they continue to turn, which leads to a voltage across the fixed rings.

RESOURCE INFORMATION ON ELECTRIC MOTORS AND GENERATORS IN WIKIPEDIA -
https://en.wikibooks.org/wiki/Electric_Motors_And_Generators

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E7-09 HAND CRANK GENERATOR [DSC# 5K40.80]



Apparatus:

“Crank generator”

Demonstrates Faraday’s Law

Notes: The crank generator consists of permanent magnets with an armature that rotates as the handle is turned. The turning of the handle on the generator produces current through the neon bulb. The generator should not be turned quickly, or the handle will break.

Above the armature are 4 horse shoe magnets that provide a magnetic field. Turning the crank handle turns an armature with conducting wires connected to the lightbulb.

RESOURCE INFORMATION ON FARADAY’S LAW OF INDUCTION

https://en.wikipedia.org/wiki/Faraday%27s_law_of_induction

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E7-11 ELECTROMAGNETIC ALTERNATOR BIKE (DSC# 5K40.80)



Apparatus:

Bike with light bulbs and coils on wheels

In this demonstration the bicycle drive wheel is composed of two plastic disks. One of these disks is stationary and contains a series of circular "pick up" coils located along the perimeter of the disk. The output of these pick coils is routed to the light bulbs located in the seat area. The second disk is free to move when the bicycle pedals are engaged and contains a series of circular permanent magnets that pass over the stationary coils when the wheel is turned, thereby generating an EMF through the time changing flux through the pick up coils.

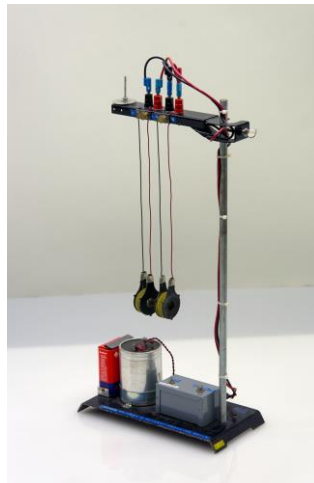
RESOURCE INFORMATION ON ELECTRIC GENERATORS FROM WIKIPEDIA -

https://en.wikipedia.org/wiki/Electric_generator

This demonstration was made available for classroom use by the Physics Festival group headed by Tatiana Erukhimova. This demonstration was developed by the DEEP students involved in the Festival, funded by DEEP and built by our Physics machine shop and Electronic Shop.

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E7-10 FORCE BETWEEN TWO CURRENT-CARRYING COILS



Apparatus:

Two coils hanging on a stand
Battery source

Demonstrates that current carrying coils produce magnetic fields and interact like bar magnets

Two coils are aligned with their currents moving in the same direction, so their magnetic fields will be North to South. They will attract each other when the current is started. Reversing one of the currents will make the coils repel.

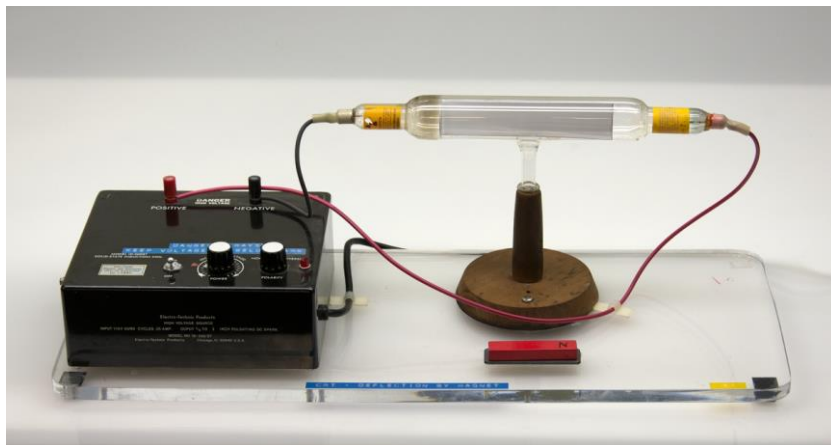
[Picture from University of Maryland Physics Demonstration site]

(Under construction – due to be completed Sept 1, 2016)

RESOURCE INFORMATION ON FORCE BETWEEN CURRENT CARRYING COIL IN YOU TUBE -
https://www.youtube.com/watch?v=FLWgm_j0XZc

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E7-15 CATHODE RAY TUBE - DEFLECTION BY A MAGNET



Apparatus:

Cathode ray tube
Bar magnet
Power supply

Demonstrates the magnetic force on an electron beam

The cathode ray tube produces an electron beam, which can be seen as it hits a phosphorescent surface inside the tube. Holding a bar magnet parallel to the tube it causes a horizontal magnetic field inside the tube that causes the electron beam to deflect. The vector nature of this force can be observed by reversing the magnet.

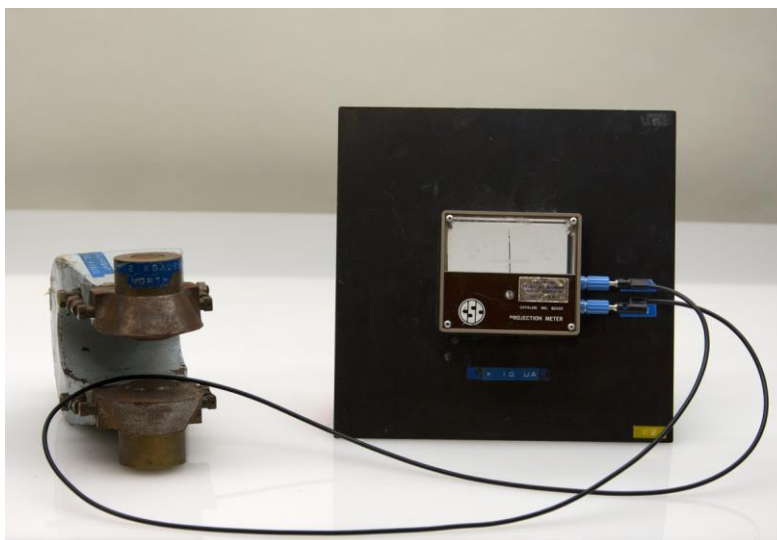
[Picture from University of Maryland Physics Demonstration site]

(Under construction – due to be completed Sept 1, 2016)

RESOURCE INFORMATION ON MAGNETIC DEFLECTION CROOKES TUBE IN YOUTUBE -
<https://www.youtube.com/watch?v=7krccKBgvP0>

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E7-16 INDUCTION IN A SINGLE WIRE



Apparatus:

Galvanometer
Strong permanent magnet
Single wire

Demonstrates magnetic induction

A single wire is connected to a galvanometer. Passing the wire quickly through the poles of the permanent magnet induces an electric current that can be observed on the galvanometer.

[Picture from University of Maryland Physics Demonstration site]

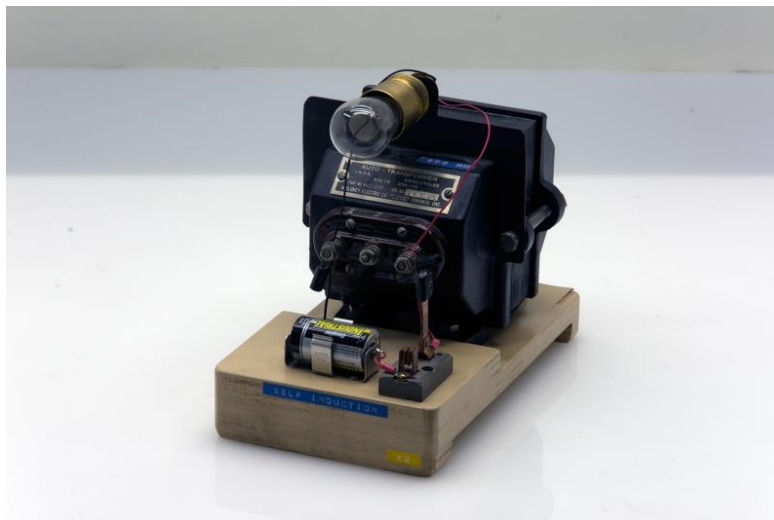
(Under construction – due to be completed Sept 1, 2016)

RESOURCE INFORMATION ON INDUCED CURRENT IN A WIRE FROM KHAN ACADEMY -

<https://www.khanacademy.org/science/physics/magnetic-forces-and-magnetic-fields/magnetic-field-current-carrying-wire/v/magnetism-12-induced-current-in-a-wire>

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E7-17 SELF-INDUCTION



Apparatus:

Large coil
Battery (1.5V)
Neon light bulb

Demonstrates self-induction

Closing the switch connects the large coil to a 1.5V battery causing the current to flow. When the switch is turned off, the collapsing field creates a back EMF sufficient to light a neon bulb (90V).

[Picture from University of Maryland Physics Demonstration site]

(Under construction – due to be completed Sept 1, 2016)

RESOURCE INFORMATION ON YOU TUBE OF A SELF INDUCTANCE LAMP -

<https://www.youtube.com/watch?v=pKKsco9EgBQ>

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E7-18 EDDY CURRENTS ON A COKE CAN IN A MAGNETIC FIELD



Apparatus:

Soda can suspended on nylon filament
Horseshoe magnet

Demonstrates Eddy currents and Lenz's law

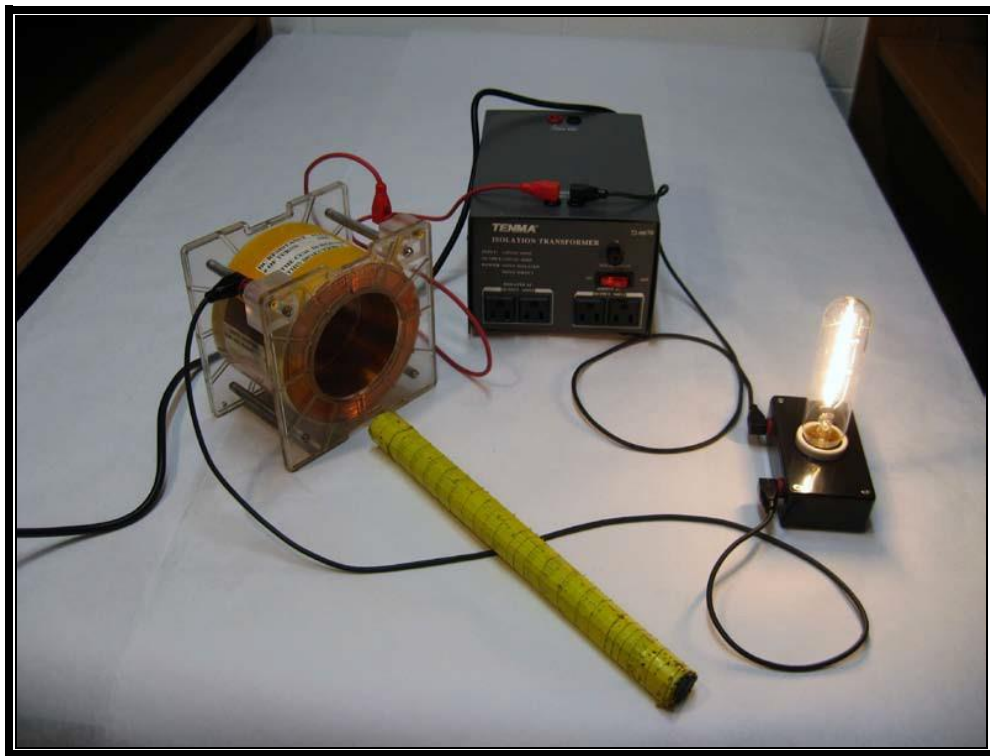
A soda can is suspended by a nylon filament over a horseshoe magnet that can rotate on a plastic disc. When the magnet is rotated, the force on the can due to Lenz's law causes the can to rotate in the same direction as the magnet.

RESOURCE INFORMATION ON EDDY CURRENTS FROM WIKIPEDIA -

https://en.wikipedia.org/wiki/Eddy_current

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E8-01 AC VS DC VOLTAGE ON AN INDUCTIVE COIL [DSC# 5L10.10]



Apparatus:

- 1 large coil
- Light bulb on base
- Iron rods wrapped in yellow tape
- AC/DC voltage output circuit box and leads

Demonstrates Inductance

Notes: Connect the circuit box (DC output) in series with the large coil and light bulb. Insert the iron rod bundle into the center of the coil and note that there is no change in the brightness of the bulb. Now reconnect the circuit to the AC output of the circuit box and again insert the iron rods into the coil. What happens now?

With DC power there are no time-varying fields and no induced currents to be affected by the iron rod bundle (which is a powerful soft magnet), so the circuit impedance equals the circuit resistance. With AC power there is an AC field along the solenoid axis that magnetizes the iron rod bundle and leads to an increase in inductance. Thus the overall impedance increases, which decreases the current and the brightness of the lightbulb.

RESOURCE INFORMATION ON “ASK AN ENGINEER” AS TO THE DIFFERENCE BETWEEN AC AND DC.
<http://engineering.mit.edu/ask/what%E2%80%99s-difference-between-ac-and-dc>

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