Electricity and Magnetism

For the complete bibliography with references as well as an explanation of the classification scheme go to:

Demonstration Bibliography

The **demonstration name** listed in the bibliography is either the name listed on the reference or, if none is given, a simple descriptive name. In cases where there are several common names for a demonstration, the committee has chosen a preferred name.

The **description** is very brief. It is not intended to be a summary of the reference. One sentence is, in general, sufficient to describe the unique characteristics, if any, of an item. Each source has a unique numbering format. These unique formats are used identify references in the Bibliography.

The formats for the **reference** column and links to the sources are listed below:

Reference	Source
M-1	Sutton
Ma-1	Freier & Anderson
M-1d	Hilton
8-2.8	Meiners
M-108	Dick & Rae
1A 12.01	University of Minnesota Handbook
AJP 52(1),85	American Journal of Physics
TPT 15(5),300	The Physics Teacher
Disc 01-01	The Video Encyclopedia of Physics Demonstrations
PIRA 200	Physics Instructional Resource Association
PIRA 500	PIRA 500
PIRA 1000	PIRA 1000

Each demonstration is listed in only one location, even if it is commonly used to illustrate several concepts.

9/7/23

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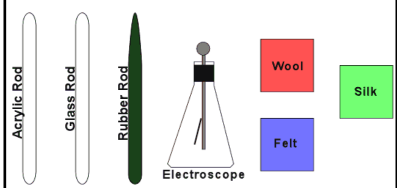
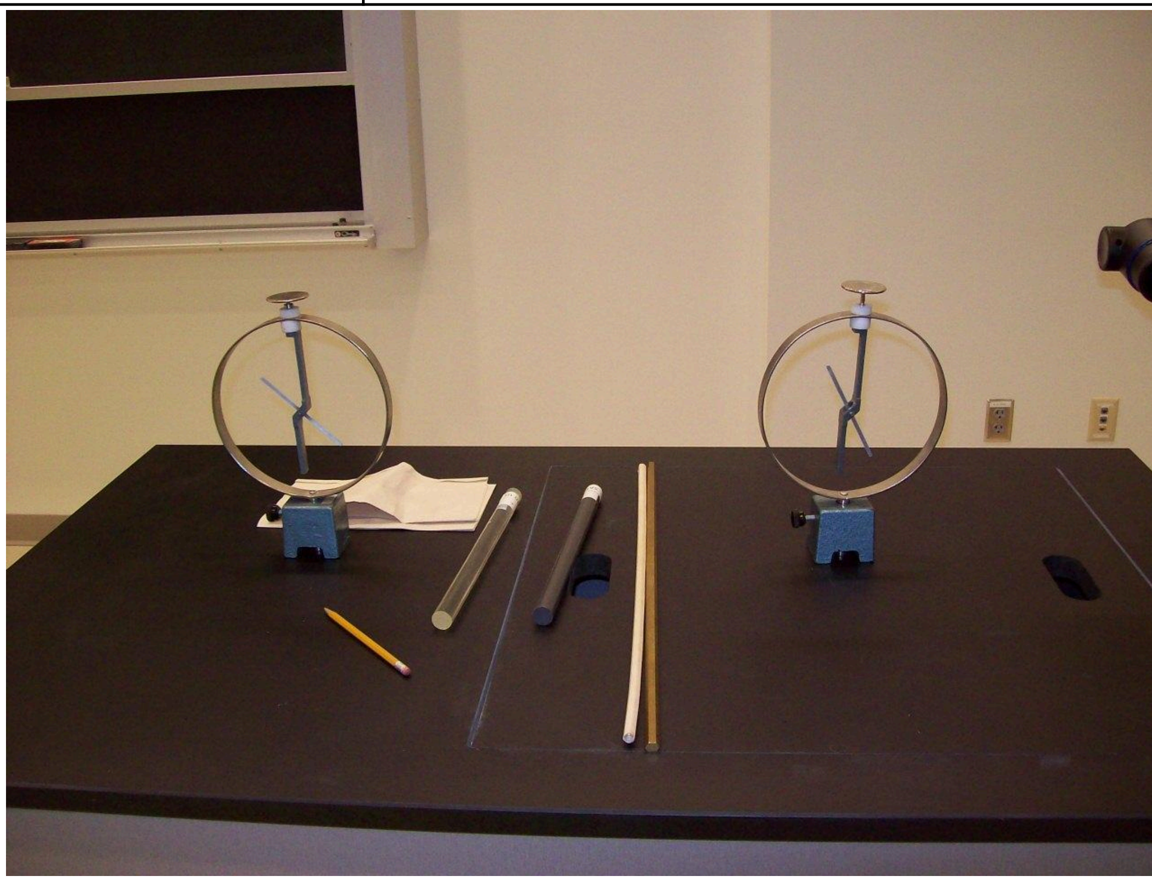
Producing Static Charge

Rods and Fur



Rub a paper towel on the PVC (gray) rod to produce negative charge on the rod.
Rub a paper towel on the polycarbonate (clear) rod to produce positive charge on the rod. Conductors and insulators can be demonstrated using the two electroscopes and the hexagonal shaped plastic and brass rods.



Location: Gc1, Gc2

Electricity and Magnetism	5A10.20	ELECTROSTATICS
Producing Static Charge		

Electrophorus

	Rub the plastic sole plates with a paper towel. Then place the metal discs on the plates. Ground the back side of a disc with a finger then lift the disc by the insulating handle. If you used the polycarbonate plate, you will have a negatively charged disc; if you used the PVC plate you will have a positively charged disc. The discs can have a potential of about 50,000 volts and have a capacitance of about 9 pF.

Location: Gc1

Electricity and Magnetism	5A10.35	ELECTROSTATICS

Producing Static Charge

Equal and Opposite Charges

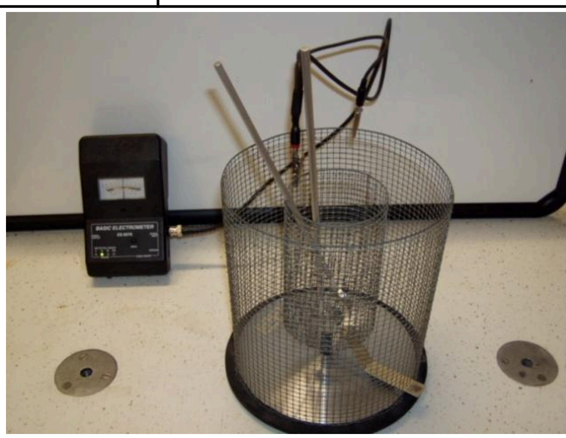
Using a PVC or polycarbonate rod, two electroscopes are equally charged. Then use the brass rod on the insulating foam cradle and try to transfer charge from one to the other. Now repeat the experiment this time charging the two electroscopes equally and oppositely by using both the polycarbonate and PVC rods. As the charge is transferred, both electroscopes will go to no deflection. Note that you may need to "rub" charge onto the electroscopes initially to get them to have equal deflections.

Location: Gc1, Gc2, Gc3

Electricity and Magnetism	5A10.36	ELECTROSTATICS
Producing Static Charge		

Equality of Charge

	First version: After zeroing the electrometer, rub the two discs (vinyl and leather) together inside the Faraday cage; the electrometer will still be reading zero. Remove one and note the electrometer's reading; then return it and remove the other. Be careful not to touch the cage with either disc. Second version: Carefully ground both pots. Rub the two garments (polyester fleece and wool) together inside one pot being careful not to touch the pot with your arm (hold just one garment; a swirling motion works well). Then put the garment you were holding into the second pot. Use a charged rod to show the pots are oppositely charged and the discharge electrode to show they are equally and oppositely charged.

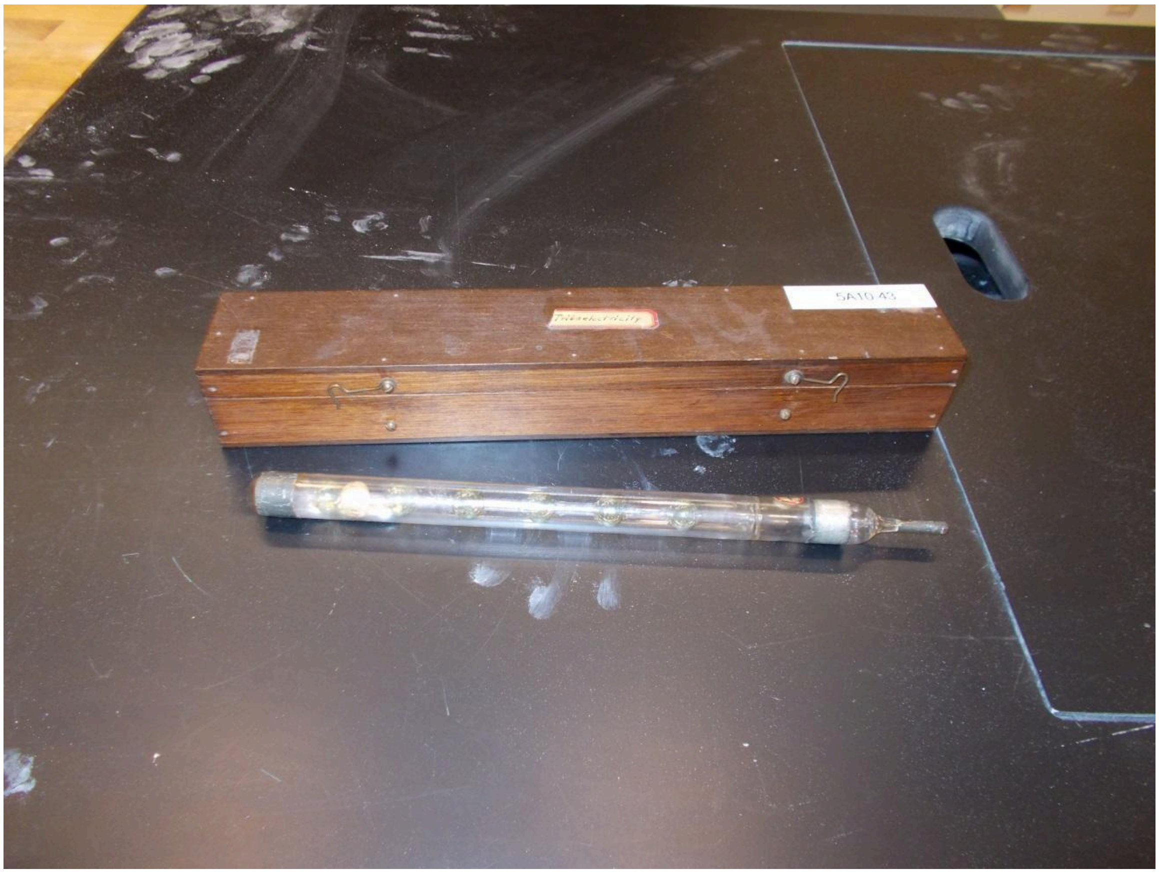


Location: Gc2, Gc4, Gc6, Gc7

Electricity and Magnetism	5A10.43	ELECTROSTATICS
Producing Static Charge		

Mercury Tube

	A mercury tube that lights when shaken. As the mercury flows against the glass, a charge separation is created resulting in a glow discharge. The mercury gets positively charged and the glass negatively. This must be done in a darkened room; the computer monitor should be turned off.

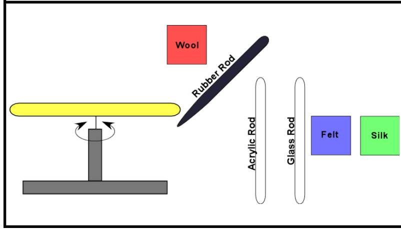


Location: Gc1

Electricity and Magnetism	5A20.10	ELECTROSTATICS

Coulomb's Law

Rods and Pivot



Rub both ends of a rod and center it on the pivot. Rub the PVC rod (negative charge) with a paper towel or the polycarbonate rod (positive charge) with a paper towel.
Rub one end of a second rod and hold its charged end near the end of the rod on the pivot.

Location: Gc1, Gc2

Electricity and Magnetism	5A20.23	ELECTROSTATICS

Coulomb's Law

Electric Potential

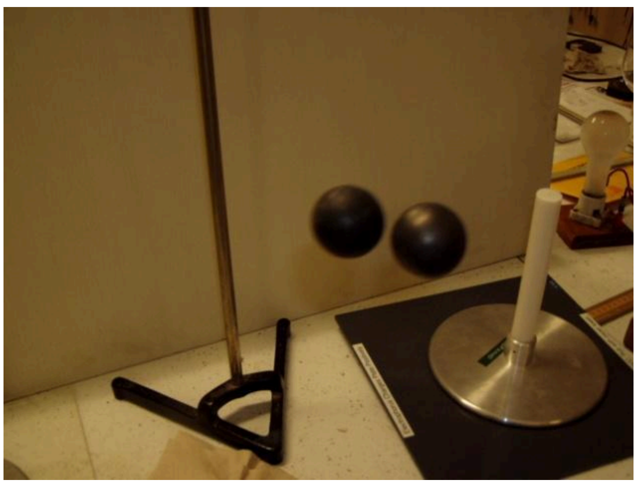
	A small piece of aluminum leaf is dropped onto a charged electrophorus plate. The leaf is at firstly strongly attracted to the plate, then touches it and is repelled. It can be made to levitate well above the plate by the repulsive force. Also shown is the "Fun-Fly-Stick" levitating a mylar "butterfly."

Location: Gc3

Electricity and Magnetism	5A20.25	ELECTROSTATICS
Coulomb's Law		

Ping Pong Ball Electroscope

	Repulsion of two coated ping pong balls. This demonstration should be done on a low humidity day otherwise it will not work well. Use the electrophorus plates for charging. Two foil balls (these are made of aluminum foil and are considerably less massive than ping pong balls) work much better.

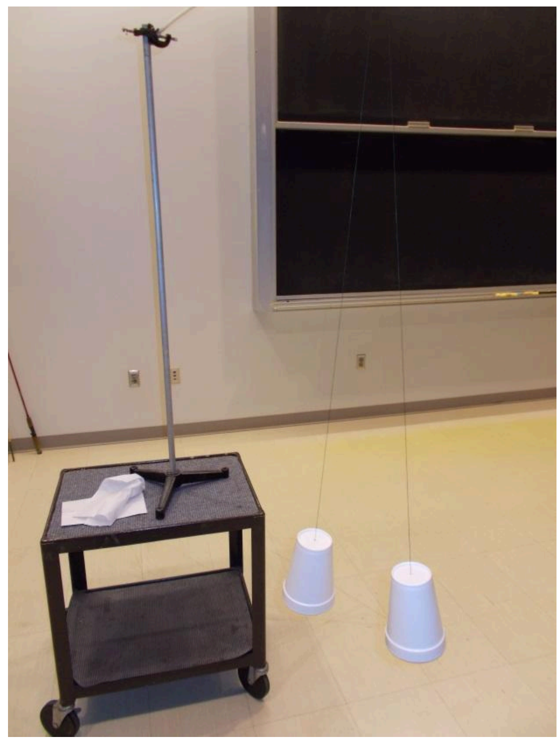



Location: Gc3

Electricity and Magnetism	5A20.30	ELECTROSTATICS
Coulomb's Law		

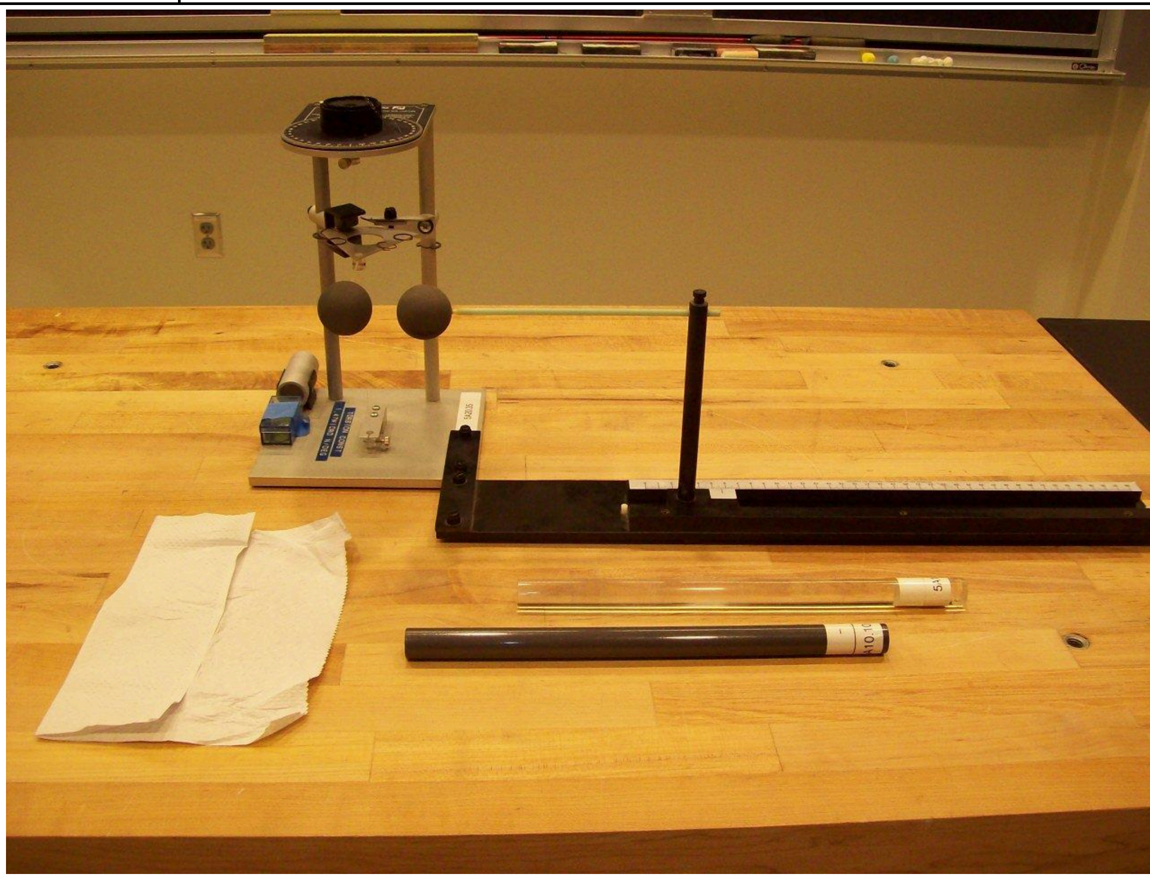
Balloon Electroscope

	Hang a couple of balloons and charge them by rubbing them against your hair or shirt. Also shown, a Styrofoam cup version (rub with paper towel to charge).



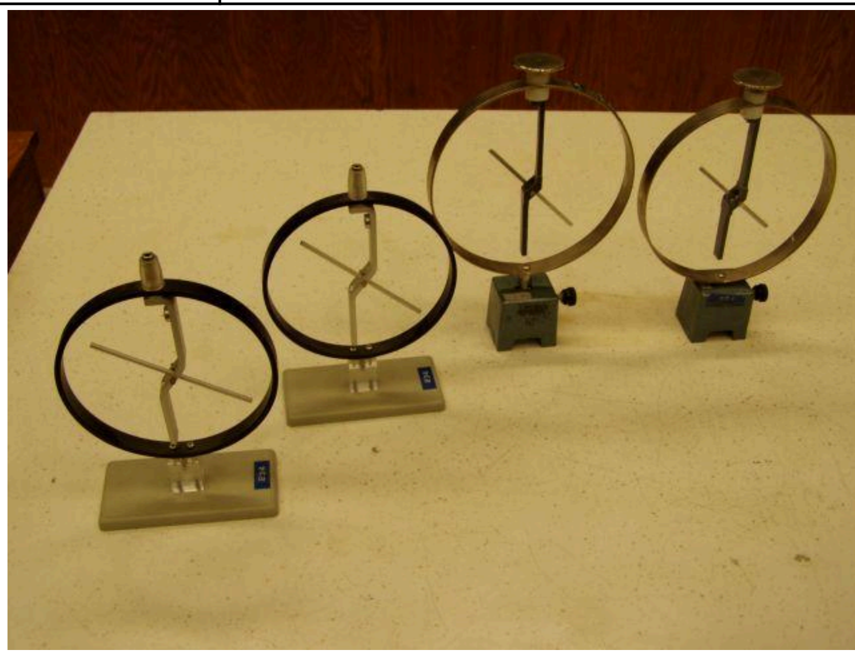
Location: Gc3

Electricity and Magnetism	5A20.35	ELECTROSTATICS
Coulomb's Law		
Coulomb's Law Balance		
	A Torsion balance is used to measure the force between charged, conductor coated ping pong balls. The balls can be charged either with a charged rod or power supply (5000 volts or so). The torsion constant is printed on the apparatus.	



Location: Gc3

Electricity and Magnetism	5A22.10	ELECTROSTATICS
	Electrostatic Meters	
	Braun Electroscope	
	A well balanced needle measures voltage to a few KV. The capacitance is around a dozen pf with the charging plate attached.	



Location: Gc2

Electricity and Magnetism	5A22.25	ELECTROSTATICS
Electrostatic Meters		
Soft Drink Can Electroscope		
	A strip of aluminum foil is hung over the lift tab of a soft drink can which is supported on a Styrofoam cup.	

Location: Gc2

Electricity and Magnetism	5A22.30	ELECTROSTATICS

Electrostatic Meters

Leaf Electroscope

These are sensitive but delicate. Be careful not to overcharge them.

Location: Gc2

Electricity and Magnetism	5A22.70	ELECTROSTATICS
Electrostatic Meters		

Pasco Electrometer

	Use the electrometer to measure charge. The input capacitance of the cage/electrometer combination is about 150 pF. Use the vinyl and leather faced proof planes to show charge conservation.

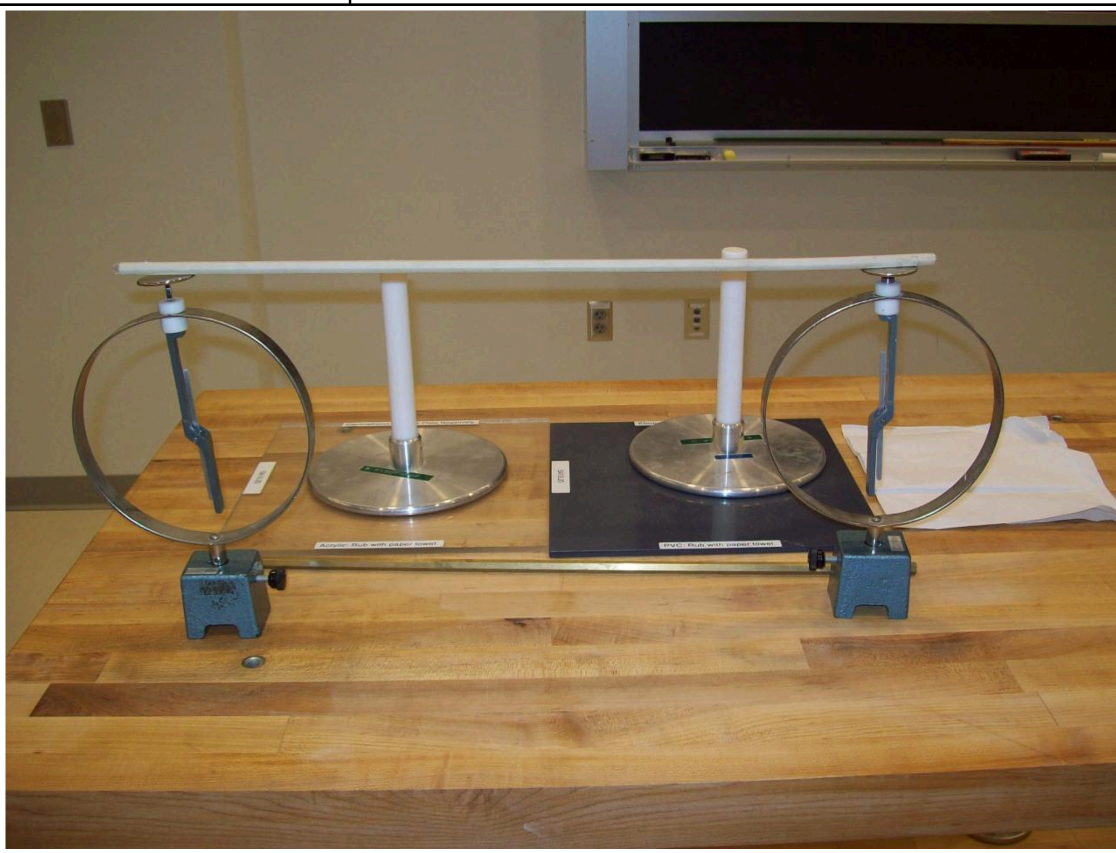
Location: Gc4

Electricity and Magnetism	5A30.15	ELECTROSTATICS

Conductors and Insulators

Conductors and Insulators

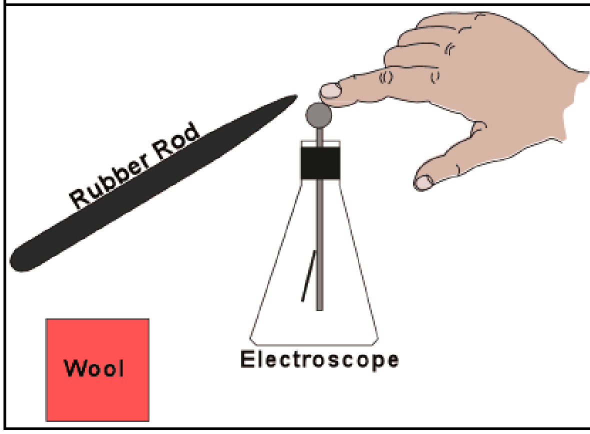
A plastic or brass hexagonal rod is placed on two electroscopes and one electroscope is charged using an electrophorus. Depending on whether the rod is a conductor or an insulator, the other electroscope will show a deflection.



Location: Gc1, Gc2

Induced Charge

Charging by Induction

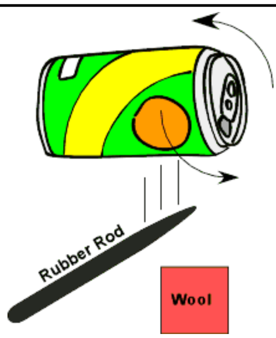


Charging by induction with an electroscope for a charge indicator.

Location: Gc1, Gc2

Electricity and Magnetism	5A40.20	ELECTROSTATICS
	Induced Charge	

Charge Propelled Cylinder



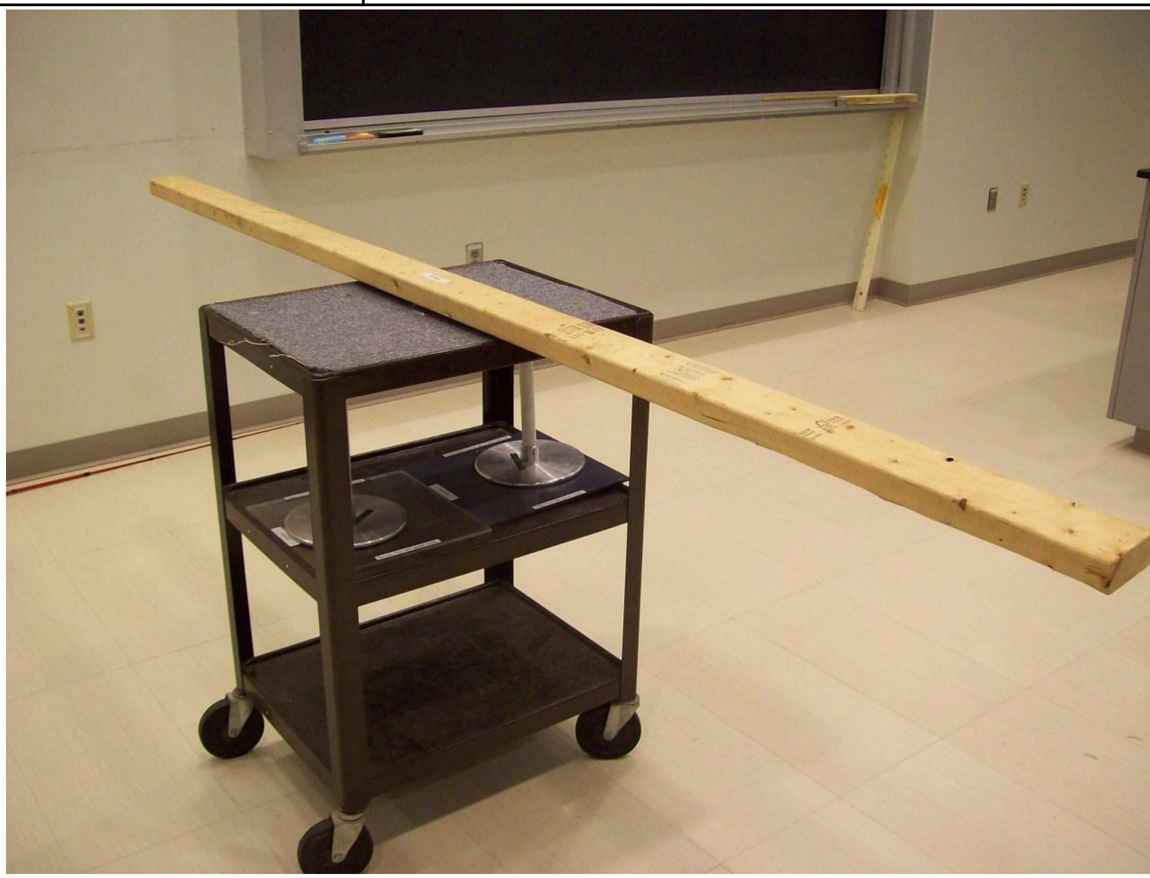
Set an empty soda can on the table so the open end faces the students. Pull the can forward with induced charge. Switch to the oppositely charged rod and repeat. This can be done with either the charged rods or the "Fun-Fly-Stick."

Location: Gc1

Electricity and Magnetism	5A40.30	ELECTROSTATICS
Induced Charge		

Two by Four

	Balance a two by four on a watch glass and attract it with a charged electrophorus plate.

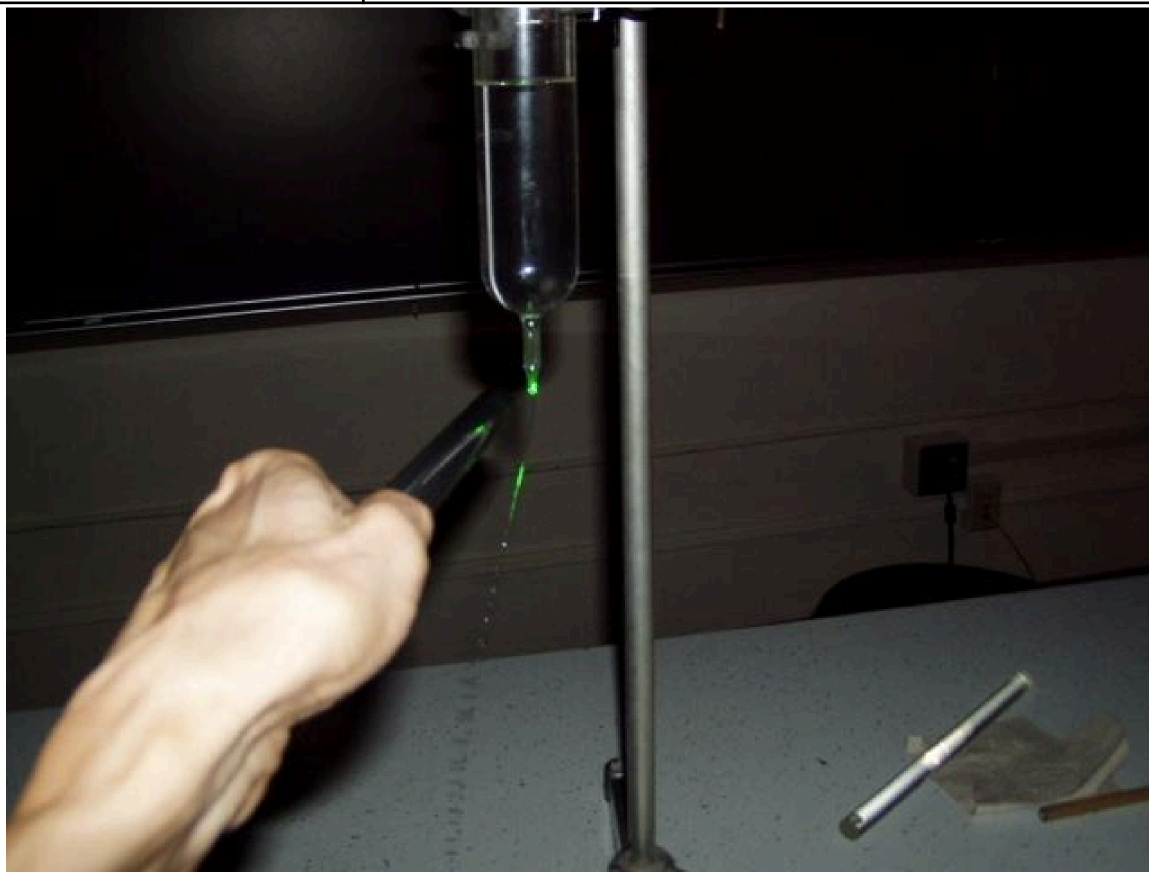


Location: GcT

Electricity and Magnetism	5A40.40	ELECTROSTATICS
Induced Charge		

Deflection of Water Stream

	A charged rod deflects a stream of water. The laser is used to improve visibility.

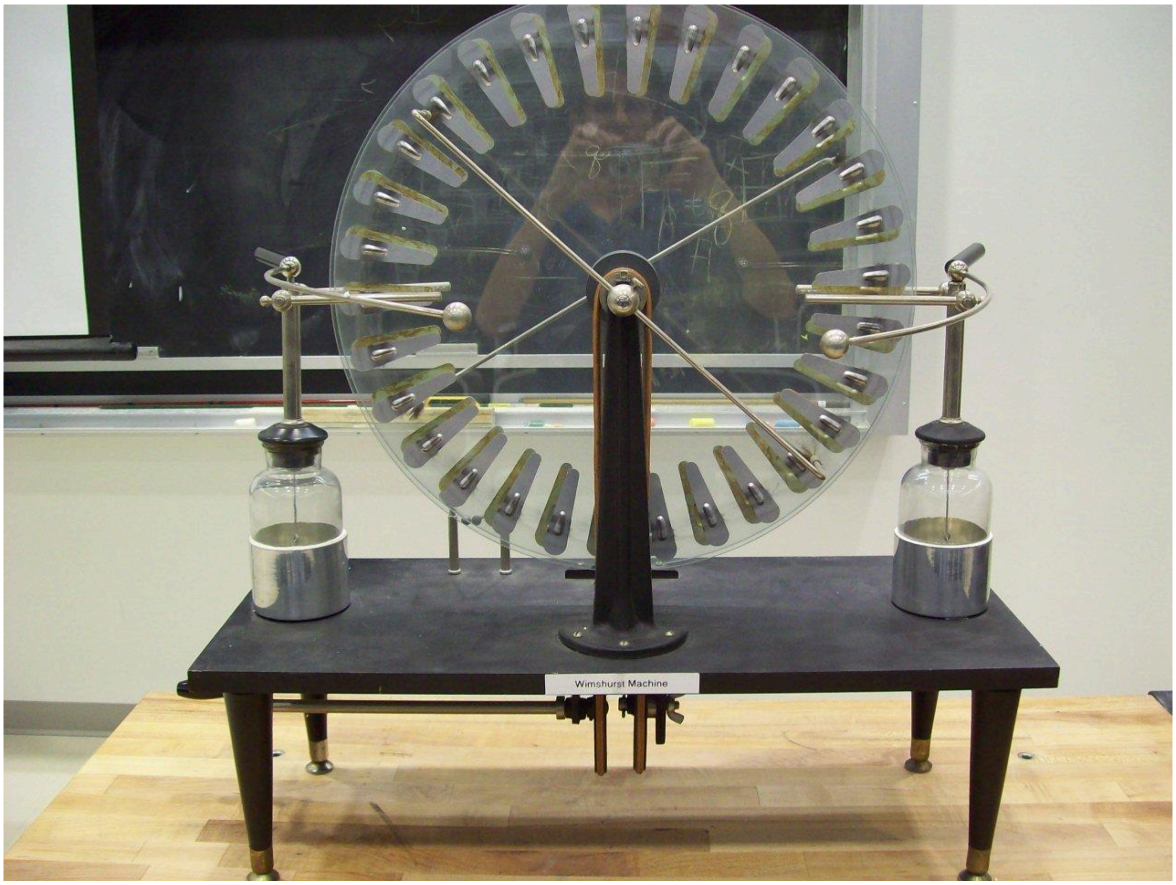


Location: Gc1

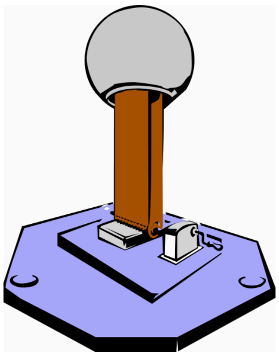
Electricity and Magnetism	5A40.70	ELECTROSTATICS
Induced Charge		
Kelvin Water Dropper		
	Potential difference is created by induction caused by two streams of water falling through two inducting rings connected by an "X" arrangement to opposite collectors. The generator uses the potential difference to drive a set of Franklin's Bells.	

Location: Gd1

Electricity and Magnetism	5A50.10	ELECTROSTATICS
	Electrostatic Machines	
	Wimshurst Machine	
	Crank a Wimshurst Machine.	



Location: Gd2

<table>
<tr><td>Electricity and Magnetism</td><td>5A50.30</td><td>ELECTROSTATICS</td></tr>
<tr><td colspan="3">Electrostatic Machines</td></tr>
<tr><td colspan="3"><h1>Van de Graaff Generator</h1></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td></td><td colspan="2">Have student stand on platform and place hand on top of VDG. Do not remove hand from the surface. Turn on the VDG and observe their hair.
Turn off the VDG. Use grounding wire attached to base of generator to discharge the sphere, then allow student to withdraw hand.
Place various equipment items in kit one at a time on top on the VDG and turn it on.</td></tr>
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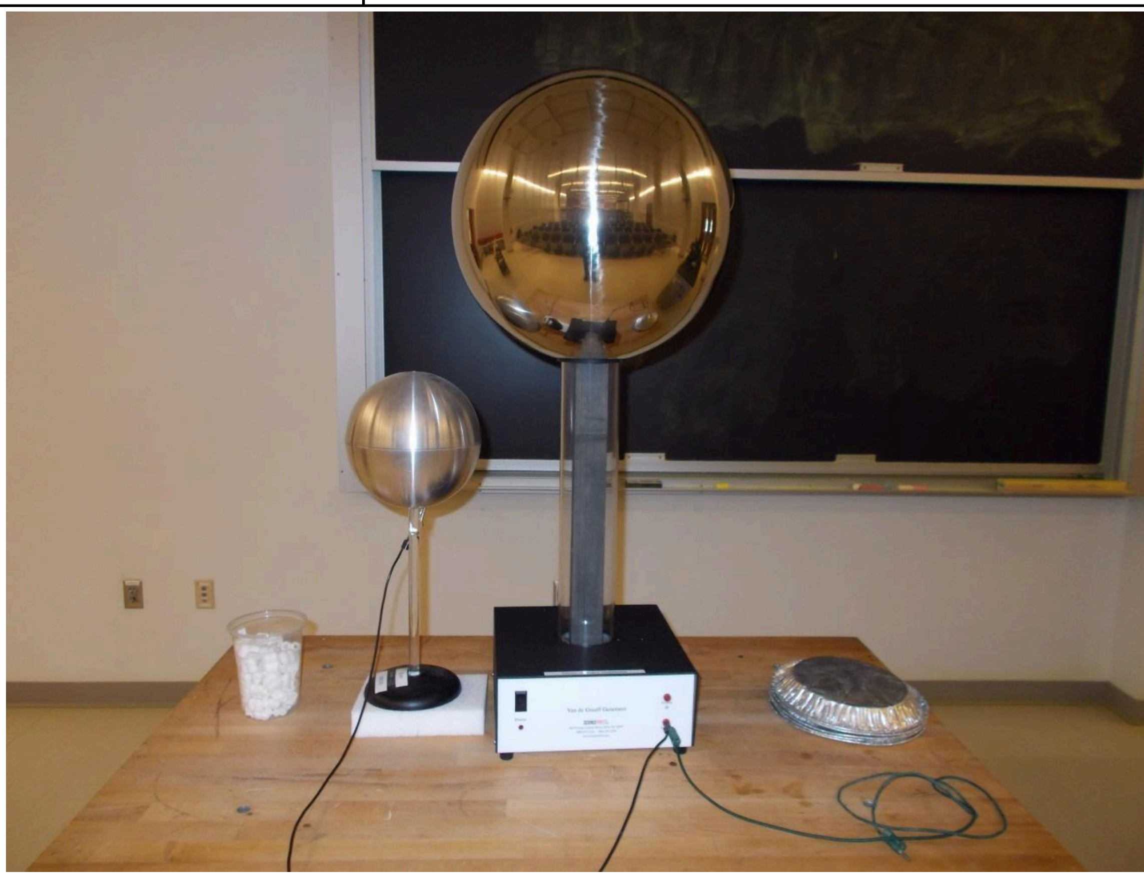


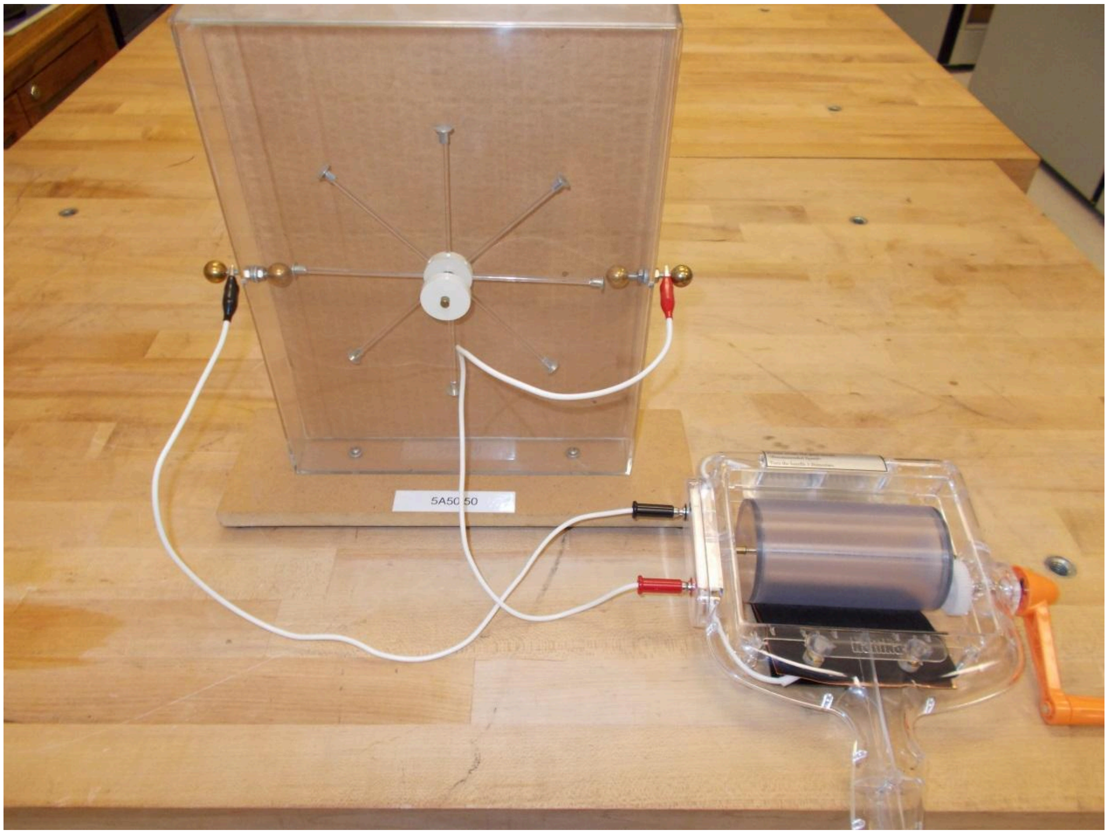
Location: Gc4, Gd3

Electricity and Magnetism	5A50.50	ELECTROSTATICS

Electrostatic Machines

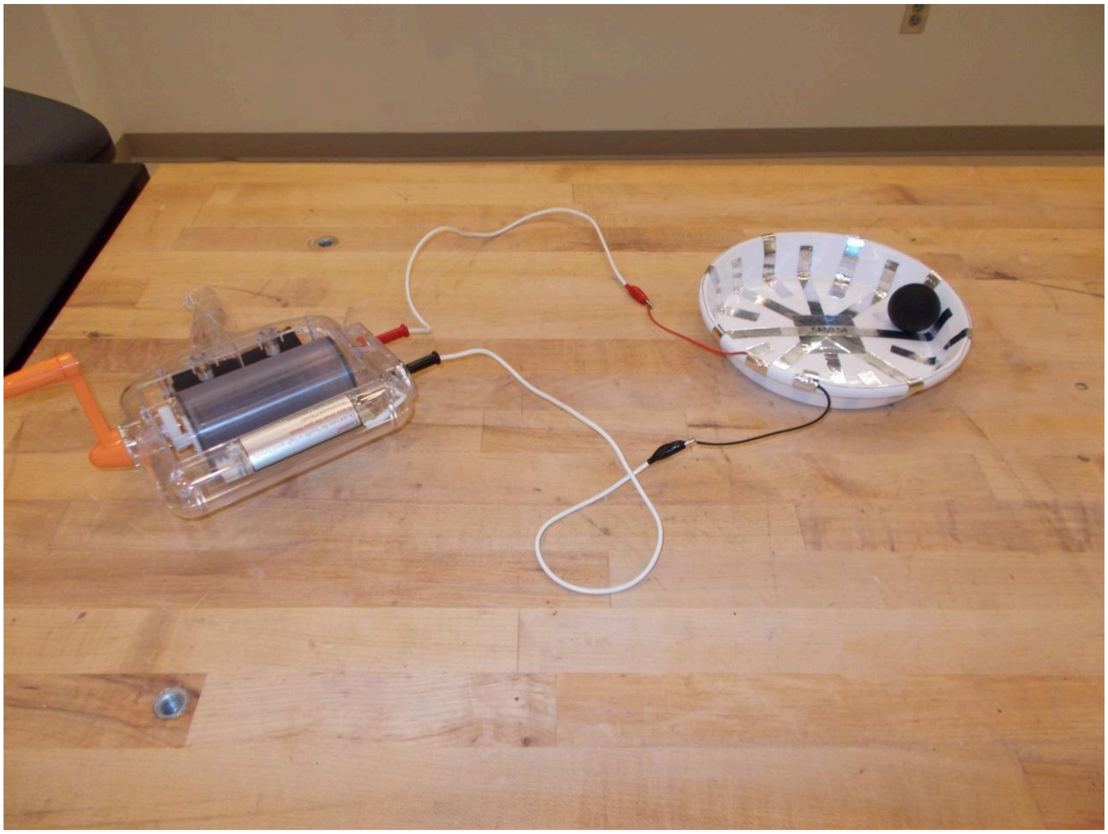
Franklin's Electrostatic Motor

A version of Franklin's first electrostatic motor.



Location: Gc4, Gd2

Electricity and Magnetism	5A50.54	ELECTROSTATICS
	Electrostatic Machines	
	Moore's Electrostatic Motor	
	One of A. D. Moore's electrostatic motors.	

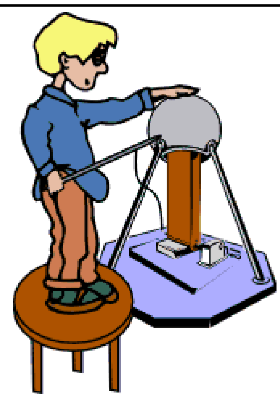


Location: Gc4, Gd2

Electricity and Magnetism	5B10.10	ELECTRIC FIELDS AND POTENTIAL

Electric Field

Hair on End



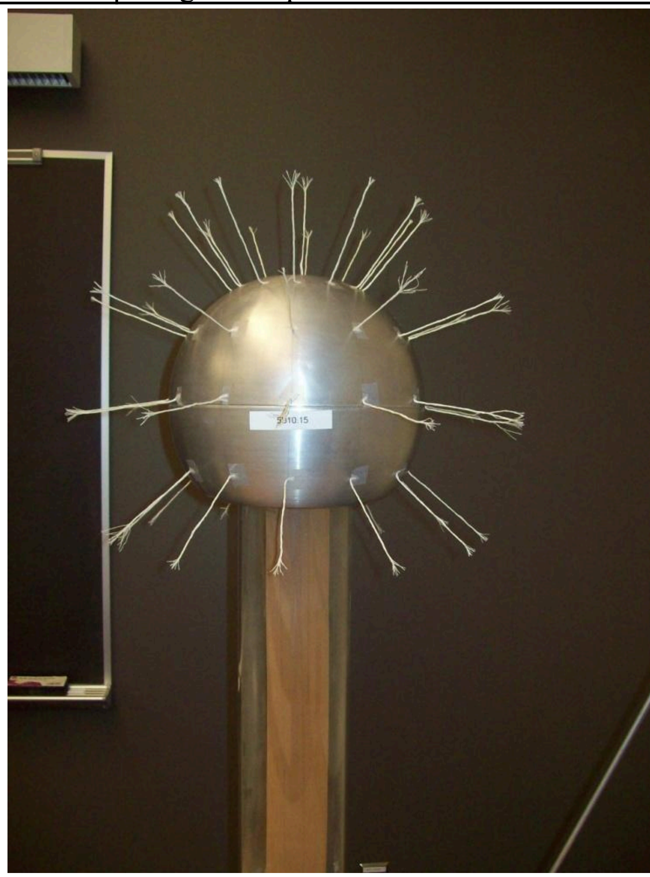
Remove pointed metal items such as keys and microphones. Stand on the insulated stool. Hold the pointed probe against the sphere.
Place your other hand on the sphere before removing the probe. Do not remove your hand and stay away from anything metal. Allow yourself to charge up. Fine, clean, dry hair stands on end the best.
Try pointing at a student or the electrified strings.
To discharge without shocks, hold pointed probe against the sphere, remove other hand and turn off motor.

Location: Gc2, Gd3

Electricity and Magnetism	5B10.15	ELECTRIC FIELDS AND POTENTIAL
Electric Field		

Van De Graaff Streamers

	Strings are taped to a Van de Graaff dome and charged



Location: Gd3

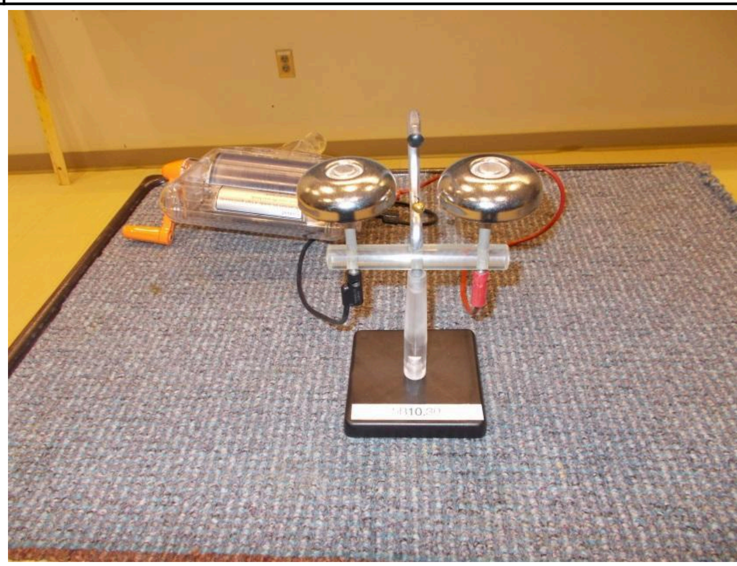
Electricity and Magnetism	5B10.25	ELECTRIC FIELDS AND POTENTIAL
Electric Field		
Styrofoam Peanuts		
	Styrofoam peanuts fly off of the dome of a Van de Graaff. They will not do so if placed in a metal container instead of a plastic one	

Location: Gd3

Electricity and Magnetism	5B10.30	ELECTRIC FIELDS AND POTENTIAL
Electric Field		

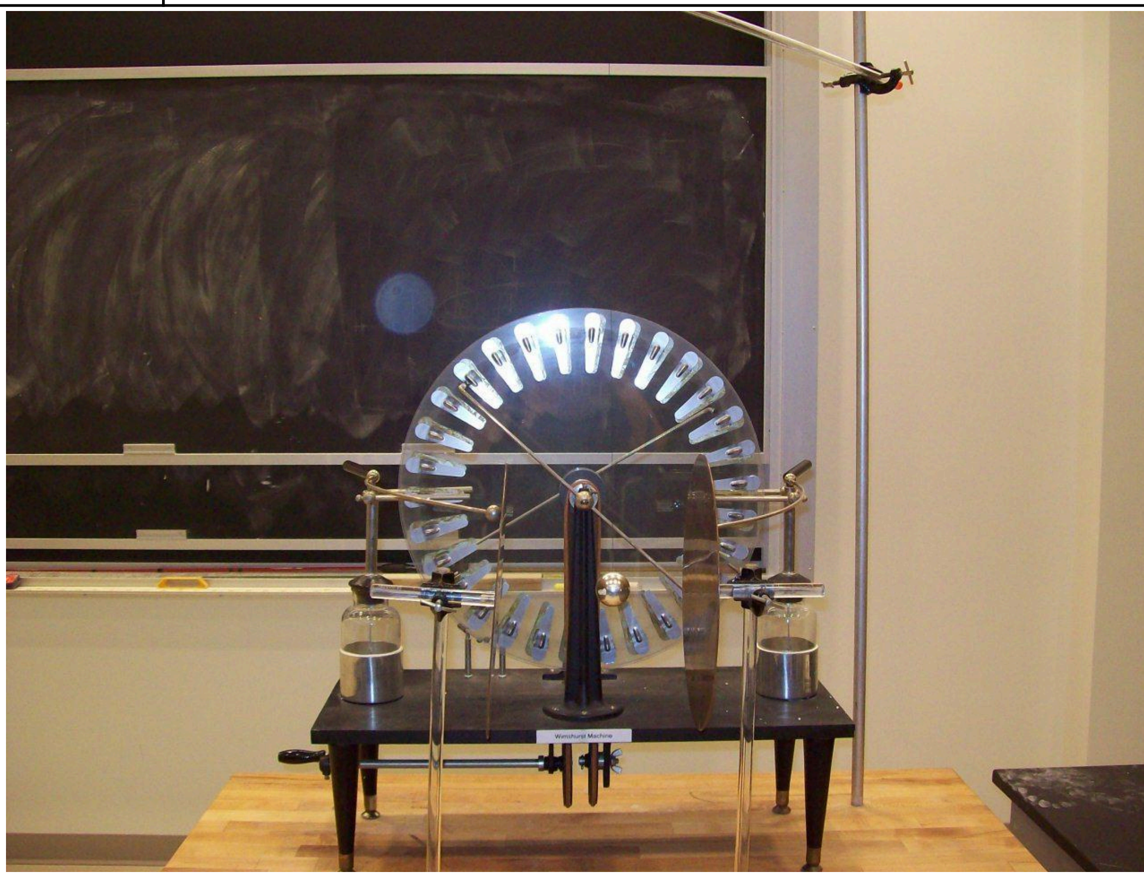
Electric Chimes

	A small metal ball bounces between charged metal chimes. Second version requires you to touch the neg. side to start it. In both cases, give the clapper a little shove to start it.



Location: Gc5

Electricity and Magnetism	5B10.35	ELECTRIC FIELDS AND POTENTIAL
Electric Field		
Electrostatic Ping Pong		
	Parallel plates are connected to a Wimshurst machine and a metalized ping pong ball is hung between them. The machine is cranked (make sure it's cranked in the right direction!). At first the uncharged, but polarized ball does not move, but if it is made to touch one of the plates it will bounce back and forth between them as long as the machine is cranked.	

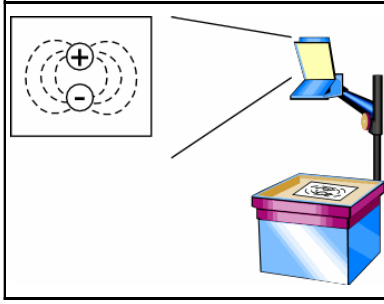


Location: Gc3, Gd2

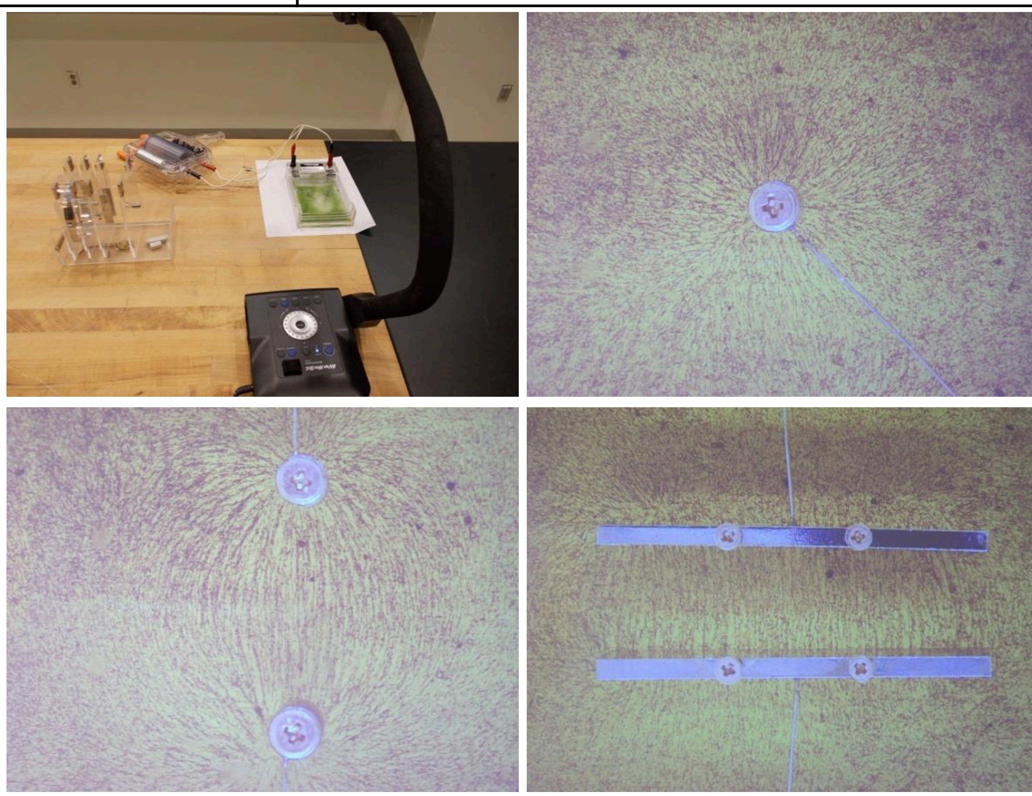
Electricity and Magnetism	5B10.40	ELECTRIC FIELDS AND POTENTIAL

Electric Field

Electric Field Lines



Bits of wood fiber suspended in oil align with an applied electric field. Several pole arrangements are shown. Hold the cell upside down while shaking to randomize the wood fibers so that they are near the top surface. Exhale on the top surface to remove remaining stray charges, place the electrodes of your choice on the cell and turn the crank on the generator only a half turn or so.



Location: Gc6

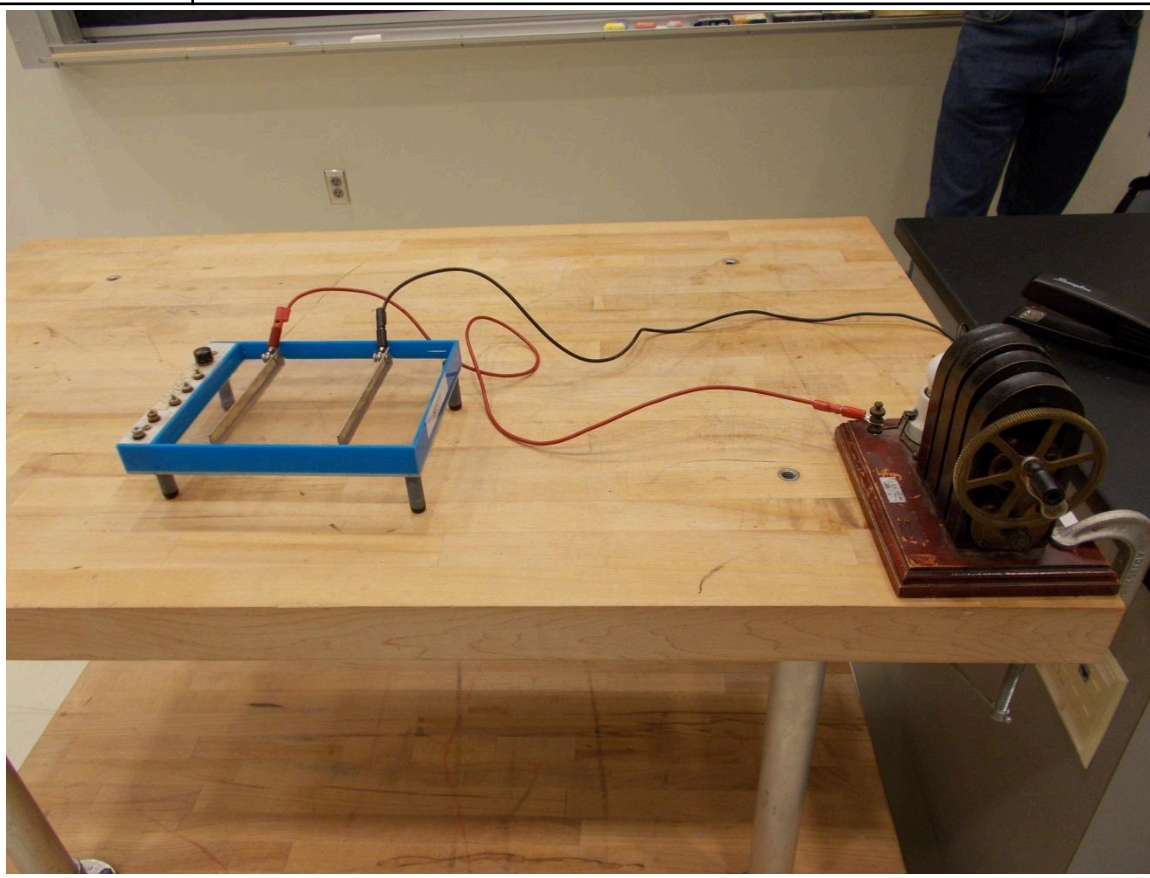
Electricity and Magnetism	5B10.50	ELECTRIC FIELDS AND POTENTIAL
Electric Field		
Electrostatic “Compass”		
	A paper arrow mounted on a yoke is used to map the electric field. It lines up with the electric field because of the induced dipole moment.	

Location: Gc6

Electricity and Magnetism	5B10.51	ELECTRIC FIELDS AND POTENTIAL
	Electric Field	

Plotting Electric Field Lines

	Use the hand crank generator to create an electric field between the electrodes. Then use two fingers to sense the direction of the field and the difference in potential as you increase the distance between fingers.

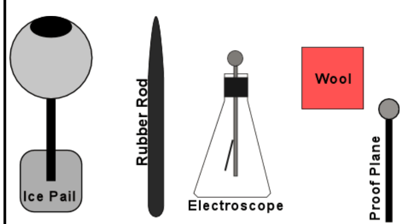


Location: Gc6

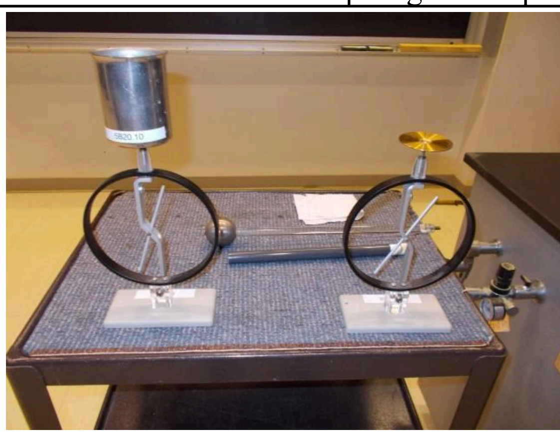
Electricity and Magnetism	5B20.10, 5B20.15	ELECTRIC FIELDS AND POTENTIAL

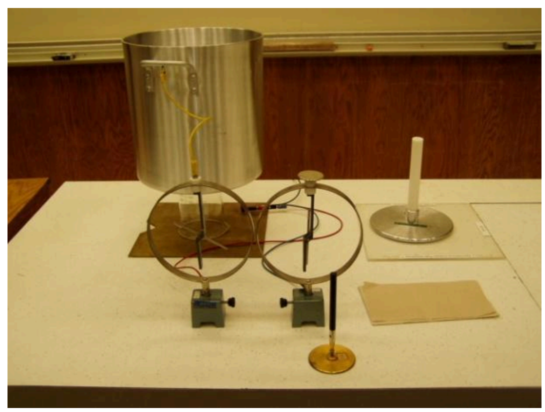
Gauss' Law

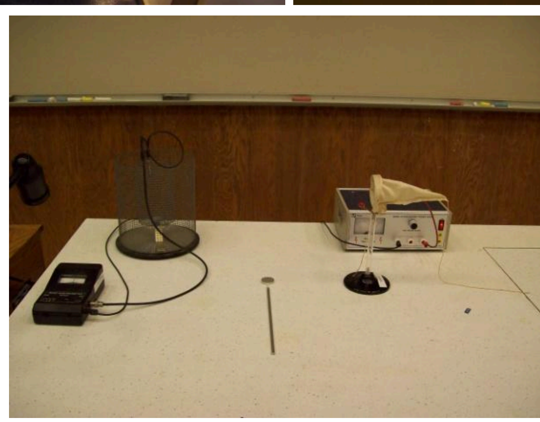
Faraday's Ice Pail



Charge the pail with the electrophorus (5A10.20). Touch the proof plane to the outside of the sphere and then to the second electroscope (5A22.10). The electroscope charges, indicating there is a charge on the outside of the sphere. You may need to do this several times to get a good deflection. Repeat the same test on the inside of the pail. The electroscope does not charge. Three versions are shown. The "butterfly net" is charged with a 6000V power supply and sampled inside and out with a proof plane and an electrometer (5A22.70); turn it inside out with the strings and repeat. Also see 5B10.25

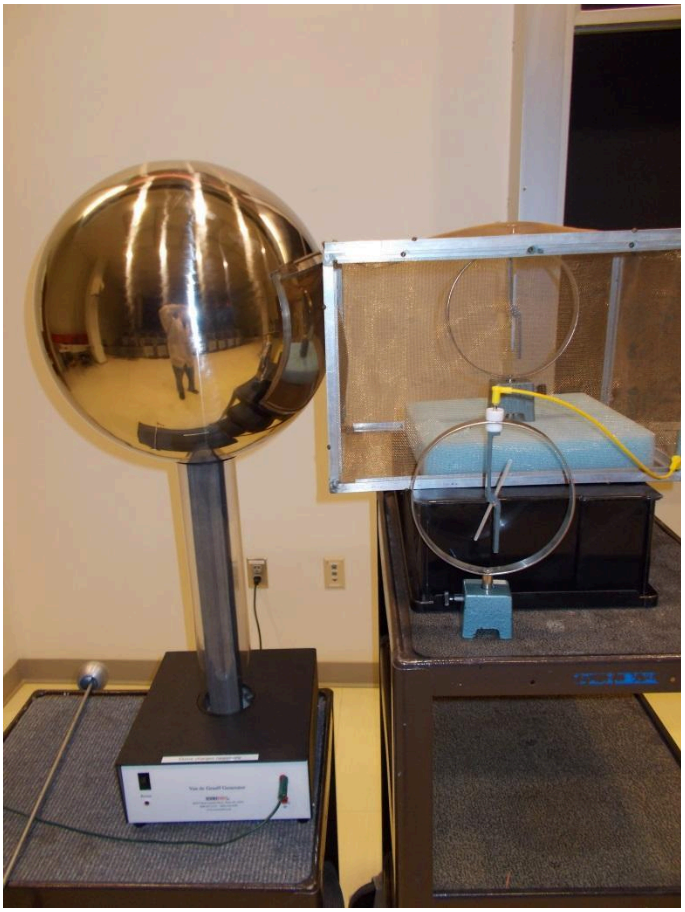






Location: Gc4

Electricity and Magnetism	5B20.30	ELECTRIC FIELDS AND POTENTIAL
Gauss' Law		
# Electroscope in a Cage		
	An electroscope is placed inside a cage with its electrode touching the wire mesh. Another electroscope is placed outside the cage with its electrode also touching the wire mesh. A Van de Graaff generator then charges up the cage and the deflections of the two electroscopes are noted.	

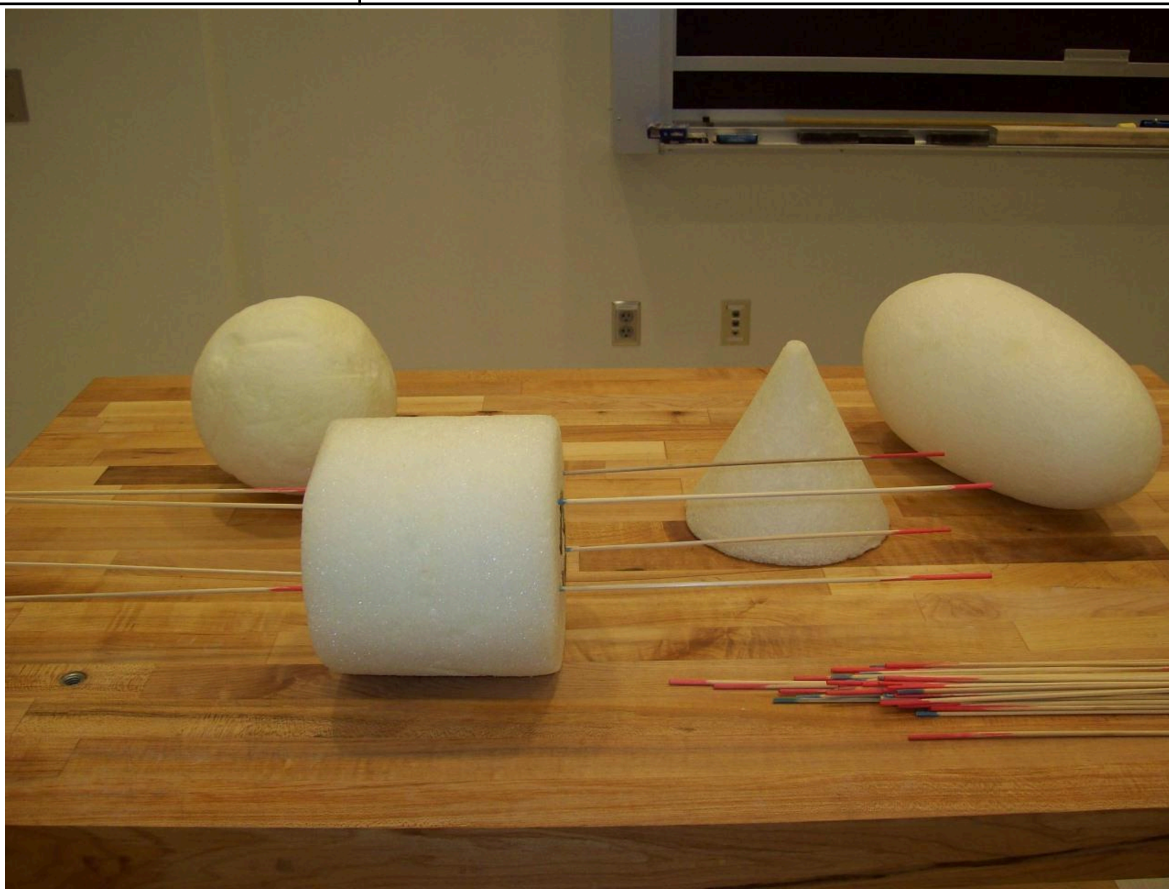


Location: Gc2, Gd3, Ha1

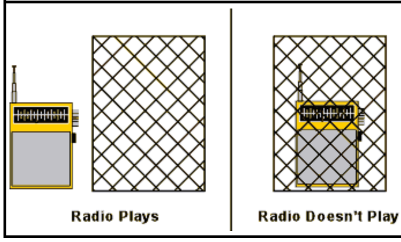
Electricity and Magnetism	5B20.20	ELECTRIC FIELDS AND POTENTIAL
Gauss' Law		

Flux Models

	Styrofoam shapes and wooden skewers are used to illustrate flux.



Location: Ha1

Electricity and Magnetism	5B20.35	ELECTRIC FIELDS AND POTENTIAL
Gauss' Law		
Radio in a Cage		
	Tune the radio to a station (reception varies with which classroom you're in). When the radio is placed in the music stops.	

Location: Ha1

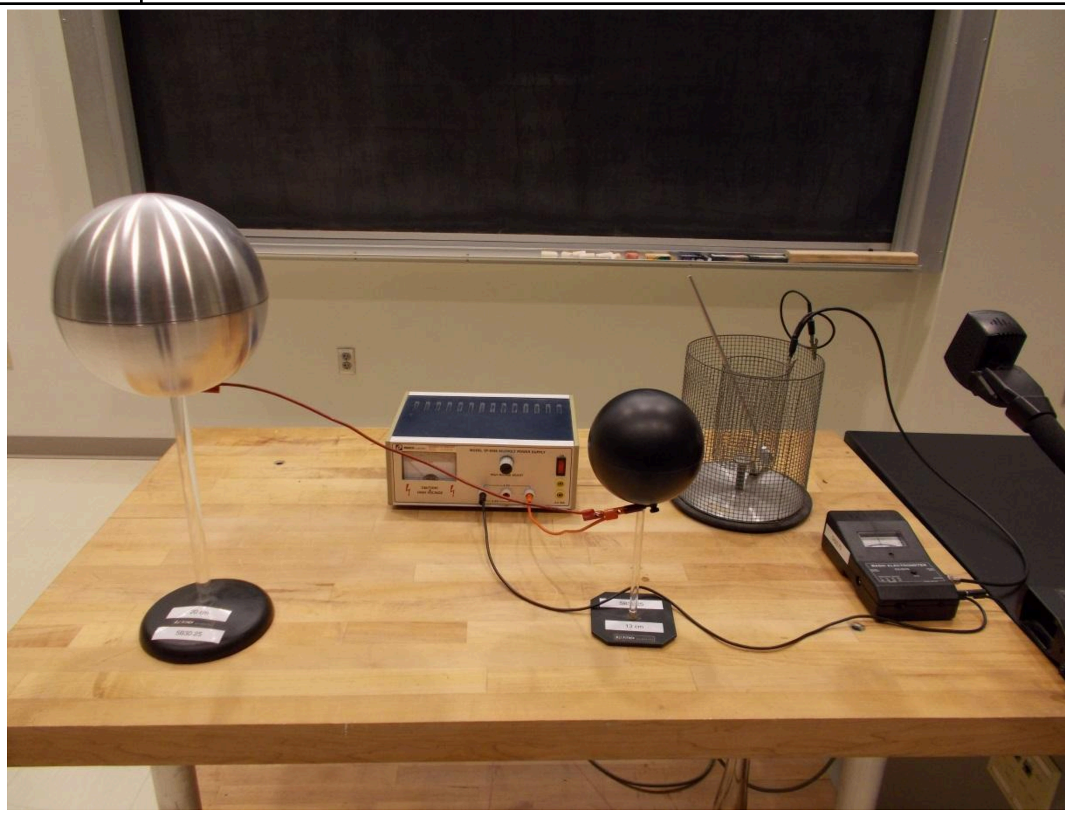
Electricity and Magnetism	5B30.20	ELECTRIC FIELDS AND POTENTIAL
Electrostatic Potential		
Surface Charge Density		
	Use a proof plane to sample the surface charge density of an object with varying curvature. The truncated cone shaped conductor can also be used to show there is no charge on the inside. The objects are raised to a potential of 6000 V and the electrometer is set on the 30 V scale.	

Location: Gc4, Gd1

Electricity and Magnetism	5B30.25	ELECTRIC FIELDS AND POTENTIAL
Electrostatic Potential		

Charge on Spheres

	Two conducting spheres of different diameters (20 cm and 13 cm) are connected together and raised to a potential of 6000 V. The surfaces are then sampled with a proof plane using the electrometer (set at 30 V) to measure the surface charge density.

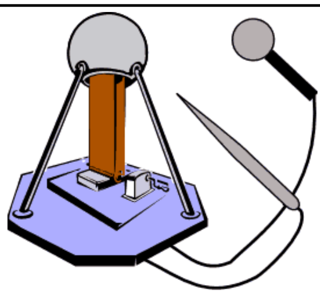


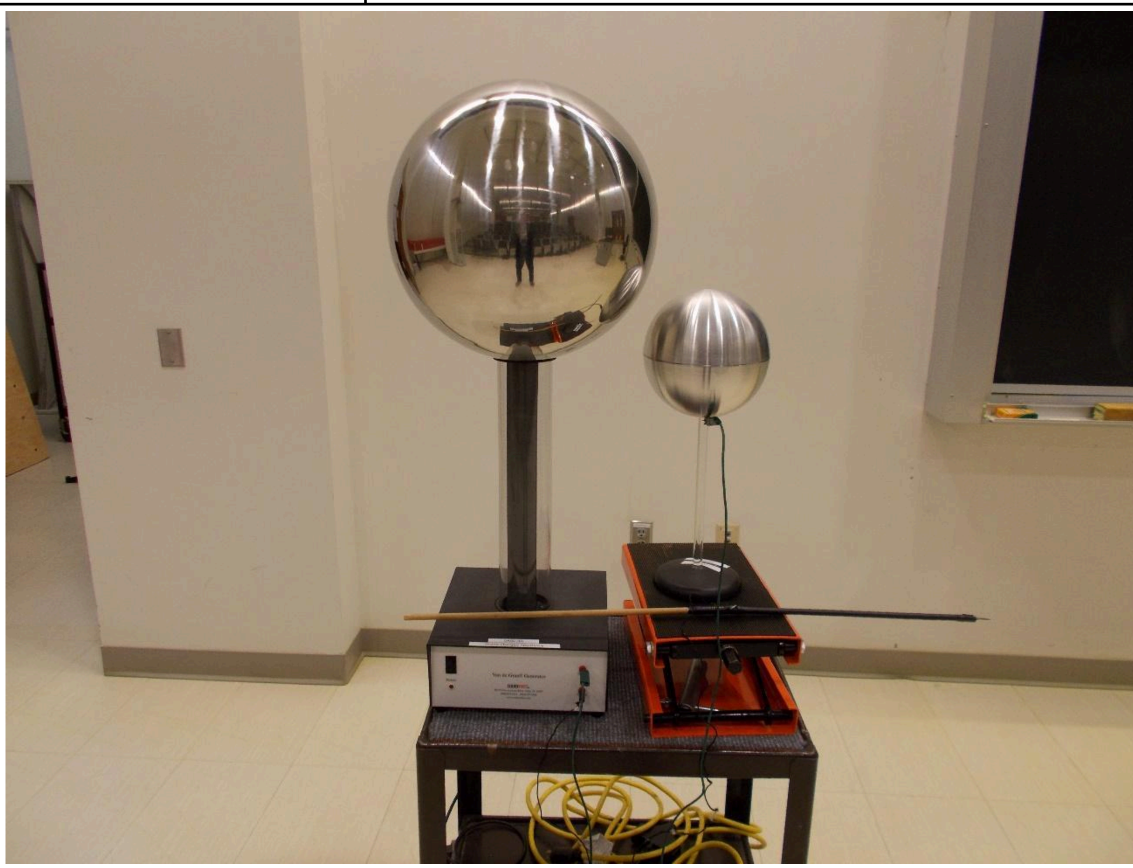
Location: Gc4, Gc7

Electricity and Magnetism	5B30.35	ELECTRIC FIELDS AND POTENTIAL

Electrostatic Potential

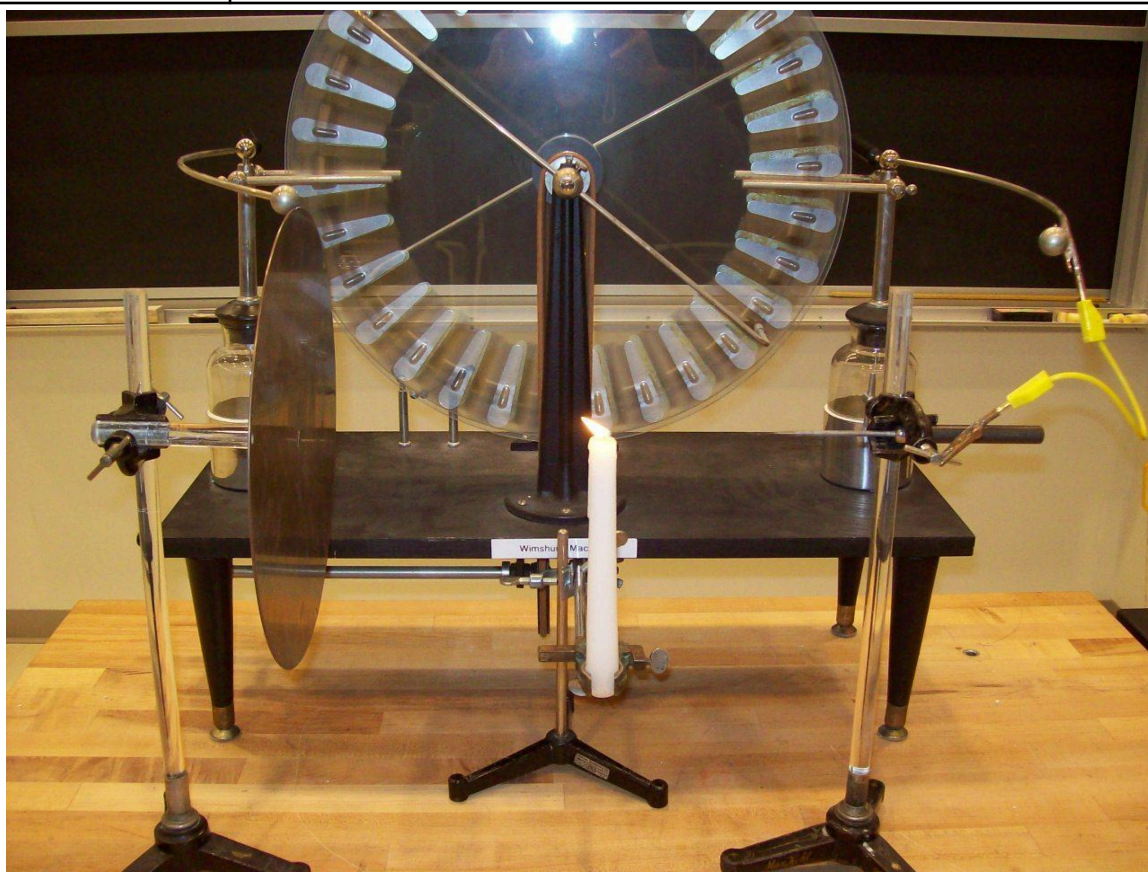
Point and Ball with Van de Graaff

	Hold a ball close to a VDG and then bring a point close.



Location: Gd3

Electricity and Magnetism	5B30.40	ELECTRIC FIELDS AND POTENTIAL
Electrostatic Potential		
# Electric Wind		
	A candle between pointed and plane electrodes attached to a Wimshurst machine will have its flame "blown" when the machine is cranked.	



Location: Gd2, Ia3, Gb1

Electricity and Magnetism	5B30.50	ELECTRIC FIELDS AND POTENTIAL
Electrostatic Potential		
Pinwheel		
	A pinwheel spins when placed on the Van de Graaff machine.	

Location: Gc5

Electricity and Magnetism	5C10.10	CAPACITANCE

Capacitors

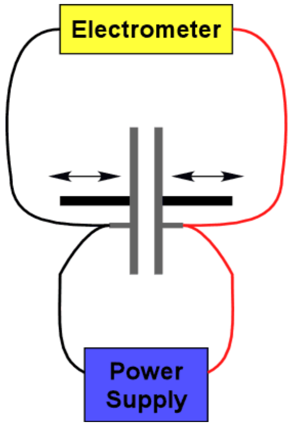
Sample Capacitors

	An assortment of various capacitors.

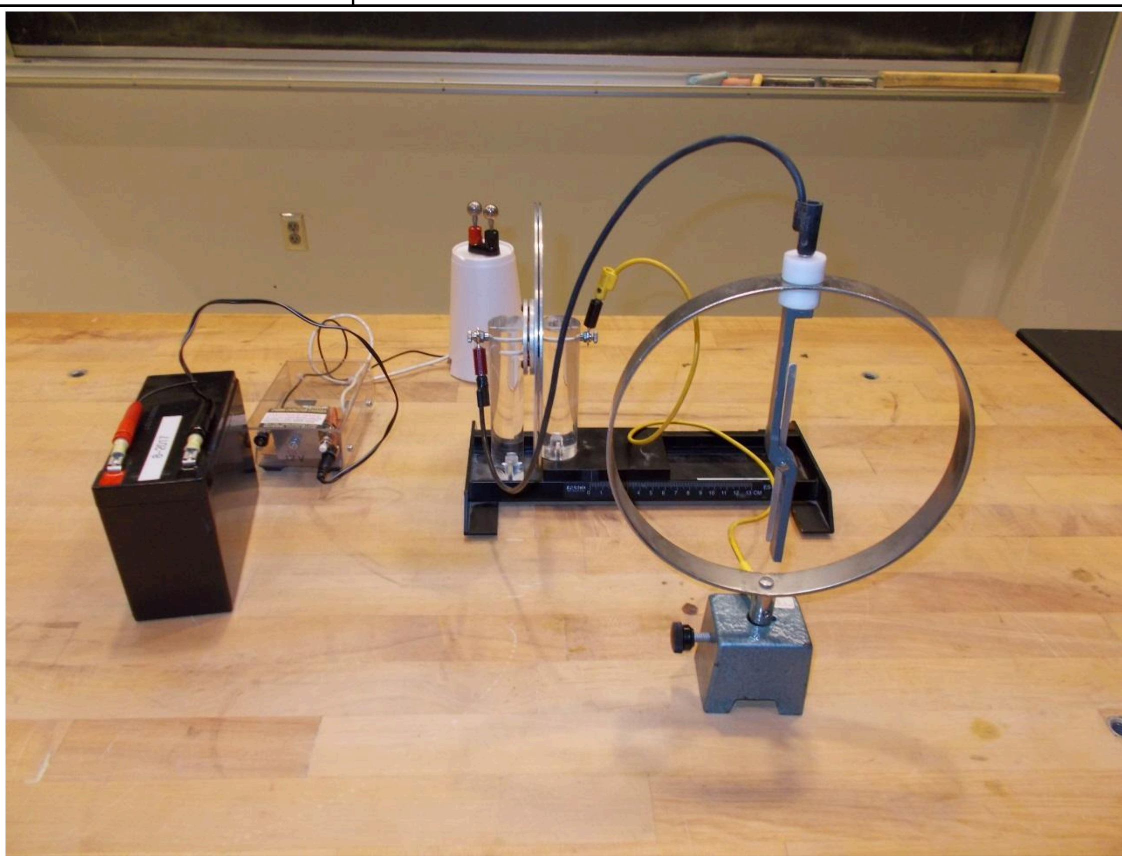
Location: Ha2

Electricity and Magnetism	5C10.20	CAPACITANCE
	Capacitors	

Parallel Plate Capacitor



Change the spacing of a charged parallel plate capacitor while it is attached to an electroscope. Charge the capacitor with the capacitor charger (touch the electrodes to the plates and hold down the white button, keeping the button depressed as remove the electrodes) with the plates at their closest possible position. The capacitor charger charges the capacitor to about 1500V.

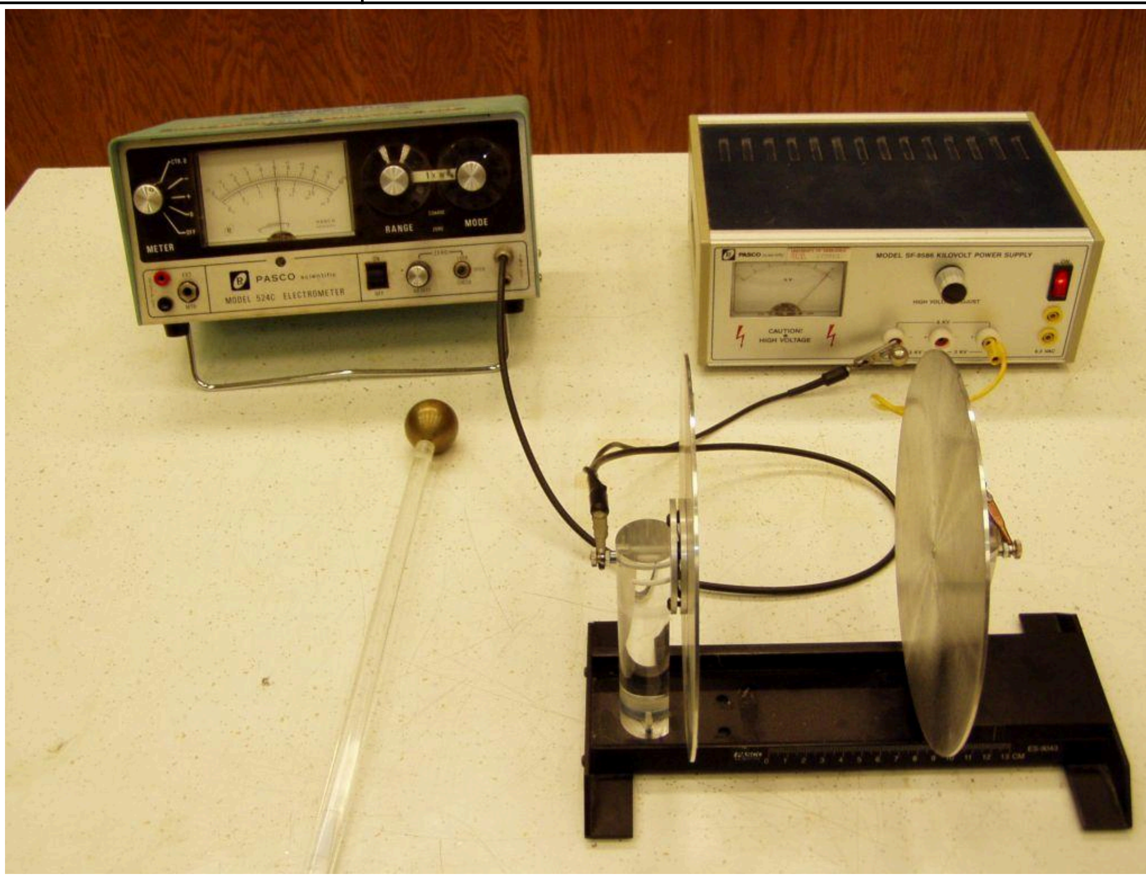


Location: Gc2, Ha2, Ha4

Electricity and Magnetism	5C10.50	CAPACITANCE
Capacitors		

Inducing Current with a Capacitor

	A nanoammeter is connected to a capacitor in series with a kilovolt power supply. As a metal ball is bounced back and forth between the plates, an induced current is seen always with the same polarity.

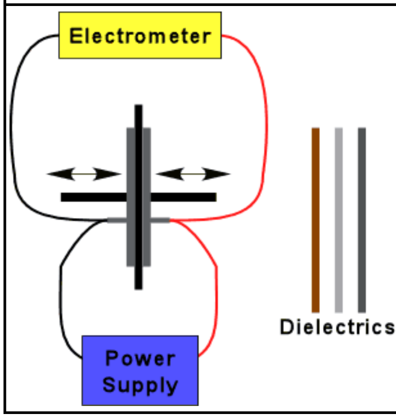


Location: Gc4, Ha2

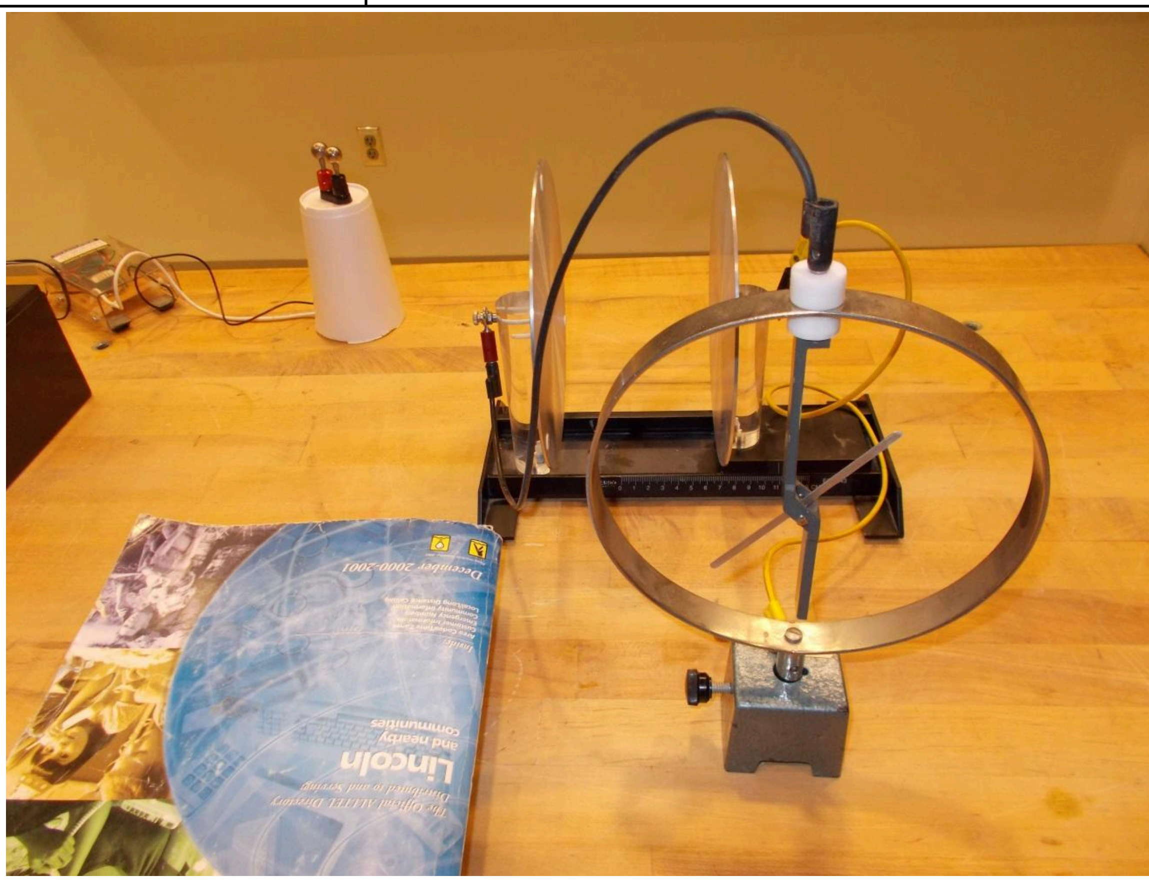
Electricity and Magnetism	5C20.10	CAPACITANCE

Dielectrics

Capacitor with Dielectrics



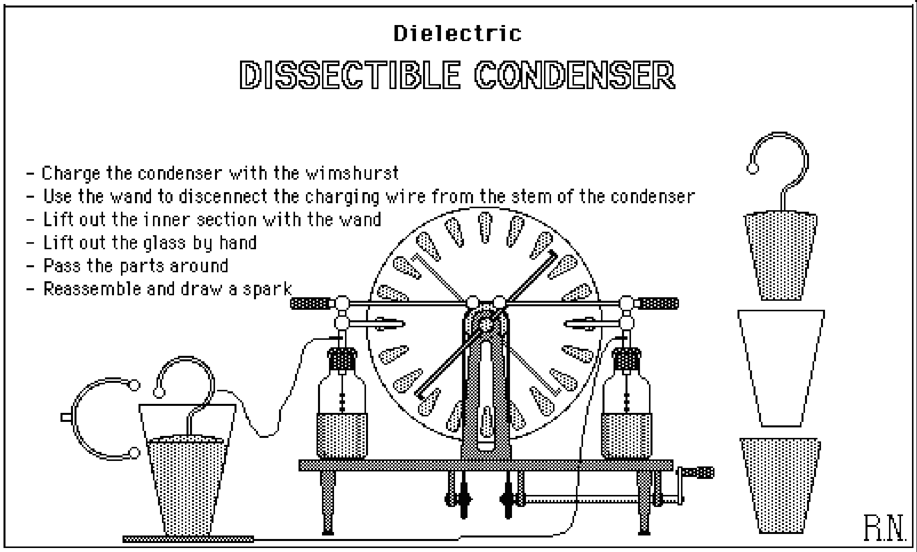
Use the capacitor charger to charge the plates as in 5C10.20 and remove the charger keeping the white button depressed. Slide the dielectric (phone book) between the plates and observe how the electroscope changes.

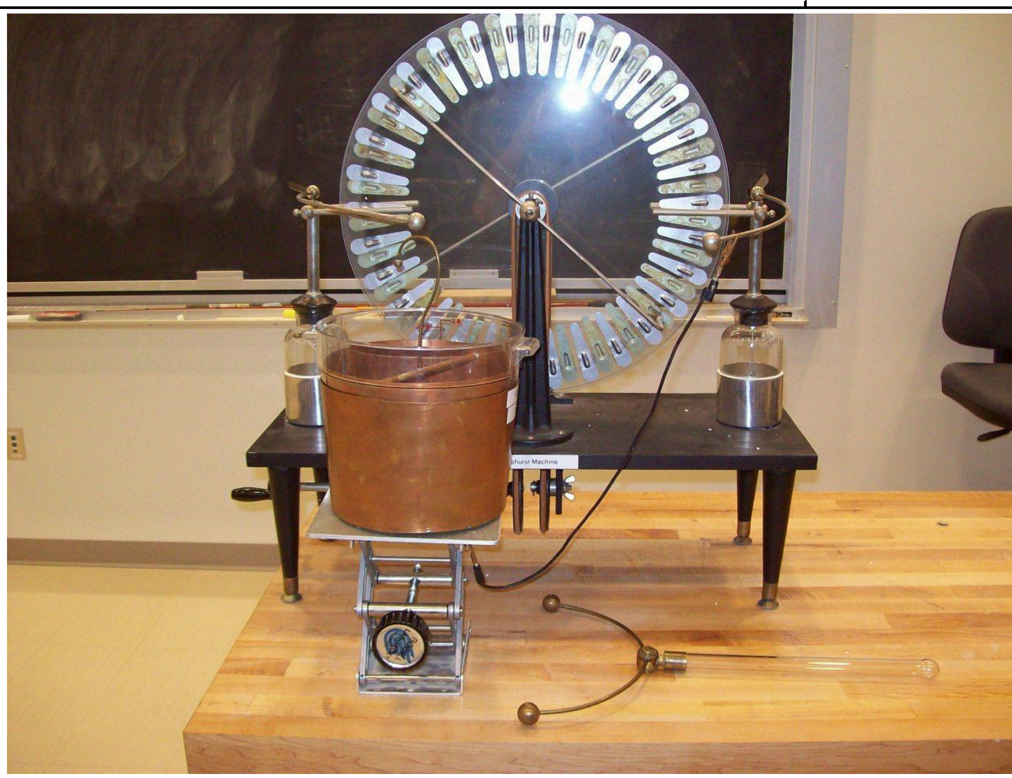


Location: Gc2, Ha2, Ha4

Electricity and Magnetism	5C20.30	CAPACITANCE
Dielectrics		

Dissectible Condenser

	Charge the condenser with the Wimshurst (be sure to crank the Wimshurst in the right direction!). Show a spark from the stored energy. Charge it up again. Use the wand to lift out the inner section. Lift out the dielectric by hand. Pass the parts around. Reassemble and draw a spark. The capacitance is about 1 nF.

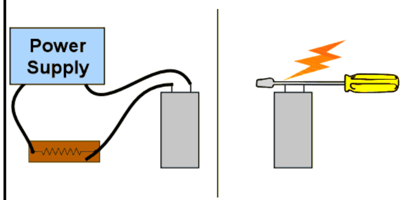


Location: Gd2, Ha3

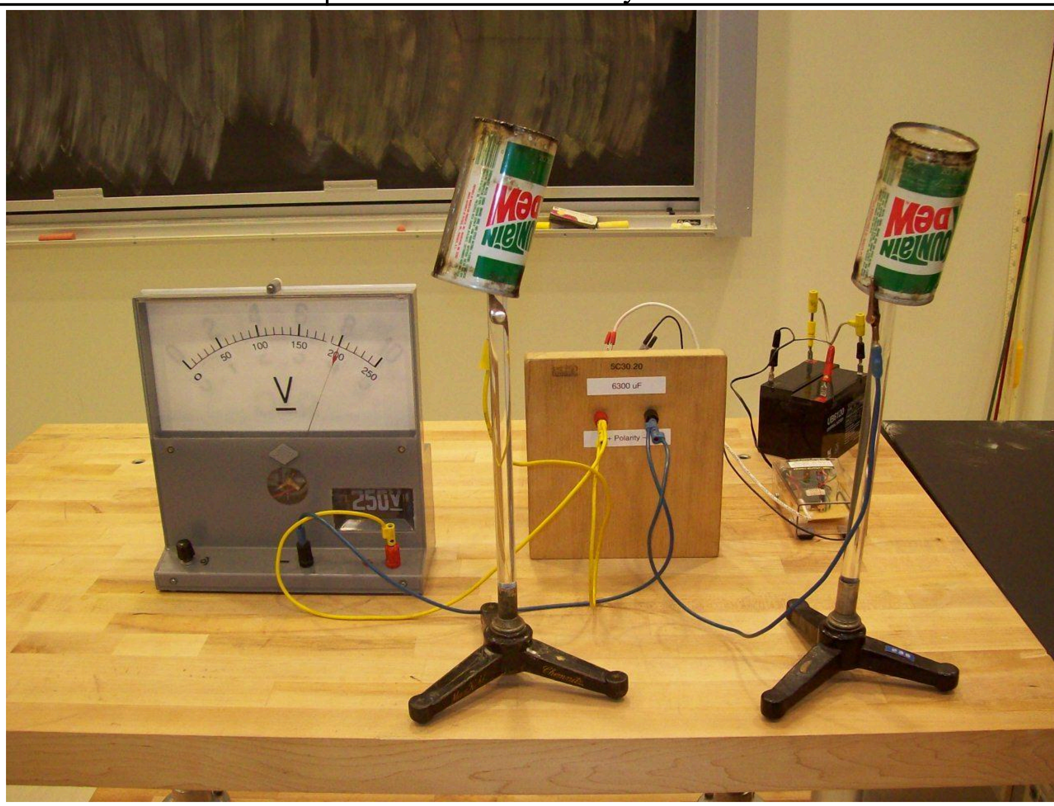
Electricity and Magnetism	5C30.20	CAPACITANCE

Energy Stored in a Capacitor

Short a Capacitor



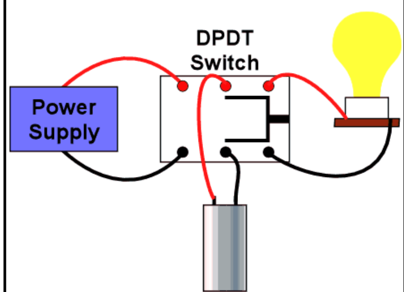
Press the white button until the 6300 microfarad capacitor is charged to 200 volts. Carefully remove the charging leads, if you wish to. Short the capacitor by touching one pop can to the other. WARNING: at this voltage, this capacitor stores 126 Joules which is a deadly shock hazard.



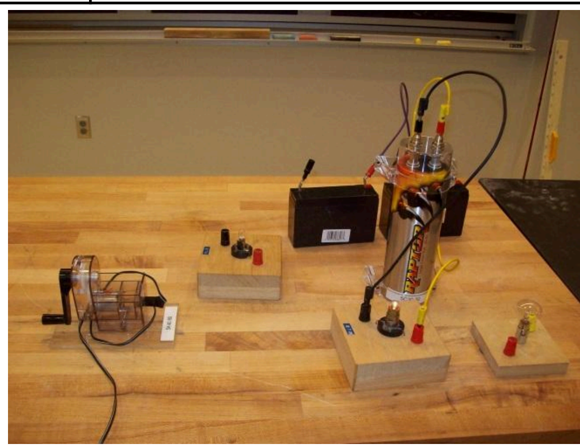
Location: Ha4

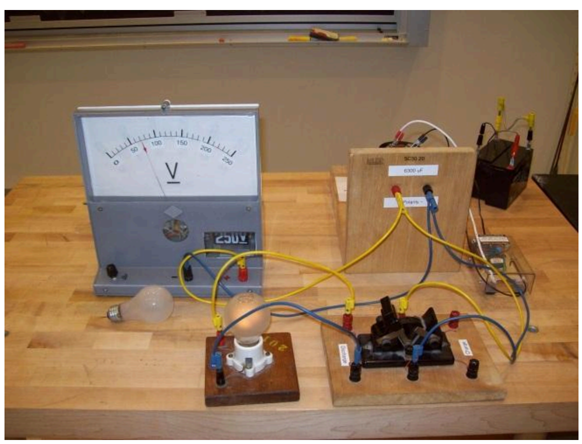
Electricity and Magnetism	5C30.30	CAPACITANCE
	Energy Stored in a Capacitor	

Light the Bulb



Version one: Connect the battery to the one farad capacitor to charge it. Remove the battery. To discharge the capacitor, connect to the light bulb only (the various bulbs have different resistances). You can also charge and discharge the capacitor using the motor/generator if you use the smaller bulb
Version two: Charge the 6300 microfarad capacitor to 125 volts and then discharge it through either a 25 or 75 watt bulb. The 25 watt bulb will glow for a few seconds.



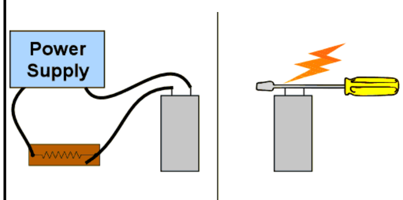


Location: Ha4, Ha7

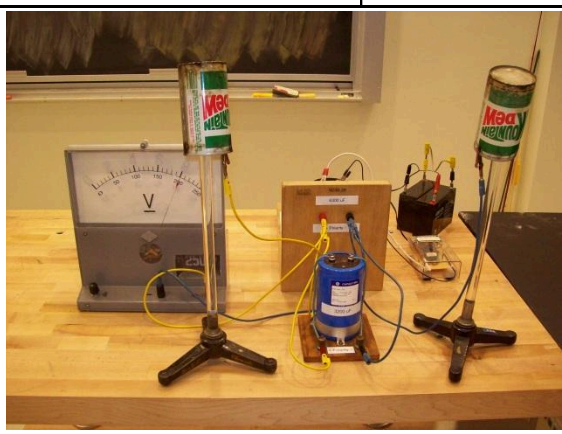
Electricity and Magnetism	5C30.42	CAPACITANCE

Energy Stored in a Capacitor

Series/Parallel Capacitors



Press the white button until the 6300 microfarad capacitor is charged to 200 volts. Short the capacitor by touching one pop can to the other. Place the 3200 microfarad capacitor in series or parallel with the 6300 microfarad capacitor, and repeat the experiment noting the difference in the spark between the pop cans. WARNING: at this voltage, the parallel combination stores 190 Joules which is a deadly shock hazard. Be sure both capacitors are completely discharged before manipulating them. You may carefully remove the charging leads between discharges, but be sure to observe the correct polarity when you reconnect them.



Location: Ha4

Electricity and Magnetism	5D10.10	RESISTANCE
	Resistance Characteristics	
	Resistor Assortment	
	Show various resistors.	

Location: Ha5

Electricity and Magnetism	5D10.20	RESISTANCE
Resistance Characteristics		

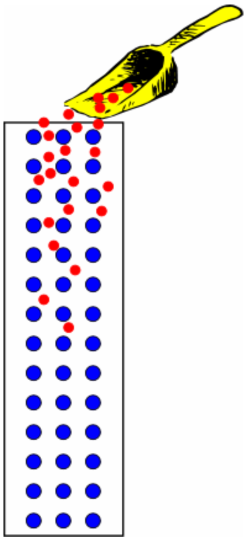
Characteristic Resistances

Wires of various diameters and materials can be mounted in a slide wire arrangement. The voltage across the wire and the current through the wire is measured. Set the power supply in the constant current mode.

Location: Ha5

Electricity and Magnetism	5D10.40	RESISTANCE
Resistance Characteristics		

Resistance Model

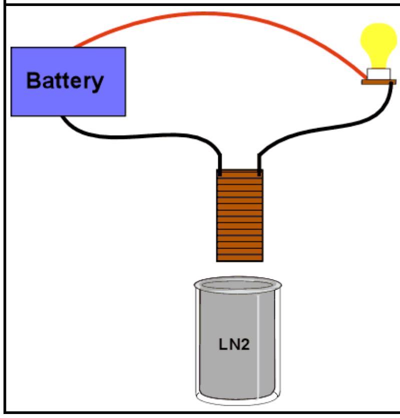
	Ball bearings are rolled down an inclined bed of nail to simulate current flow in a wire. Use 3/8 inch balls.

Location: By the door

Electricity and Magnetism	5D20.10	RESISTANCE

Resistivity and Temperature

Wire Coil in LN2



Set up as shown. Place the coil into the LN2. Watch the light bulb get brighter as the coil cools.

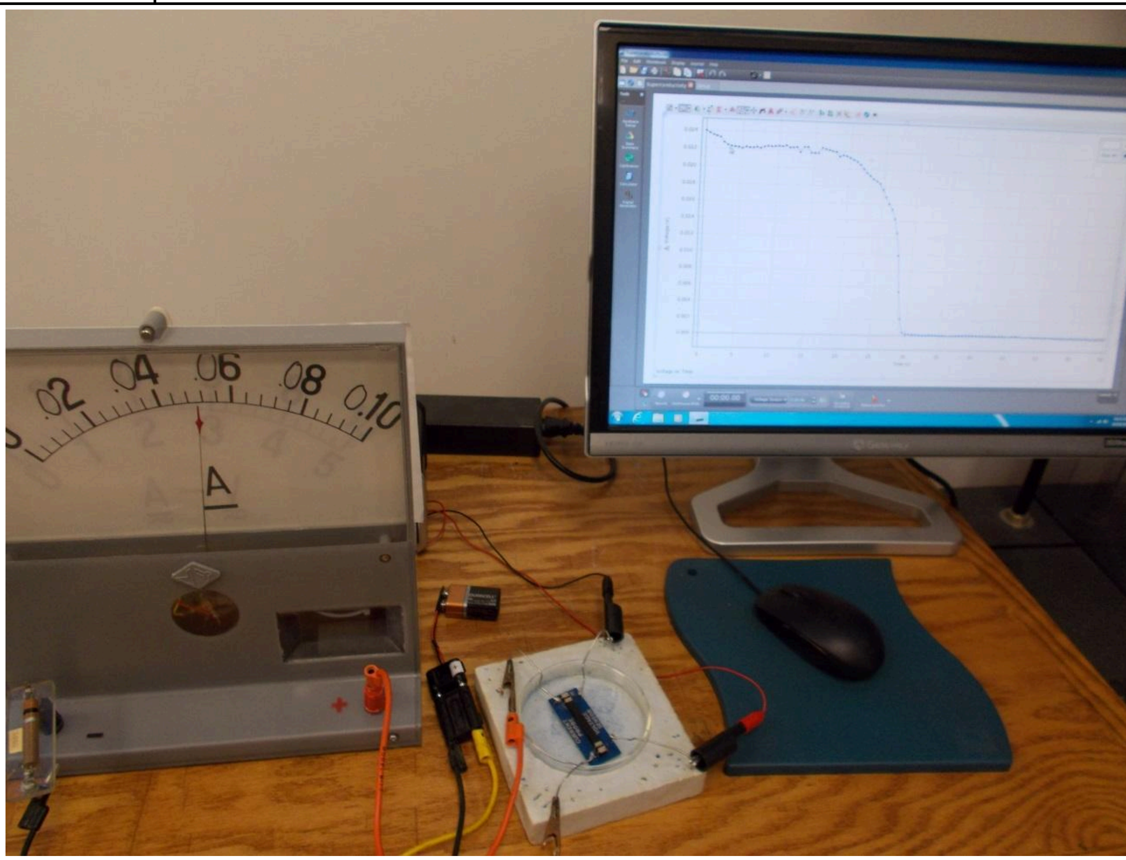
Location: Hb3, Ga2

Electricity and Magnetism	5D20.14	RESISTANCE

Resistivity and Temperature

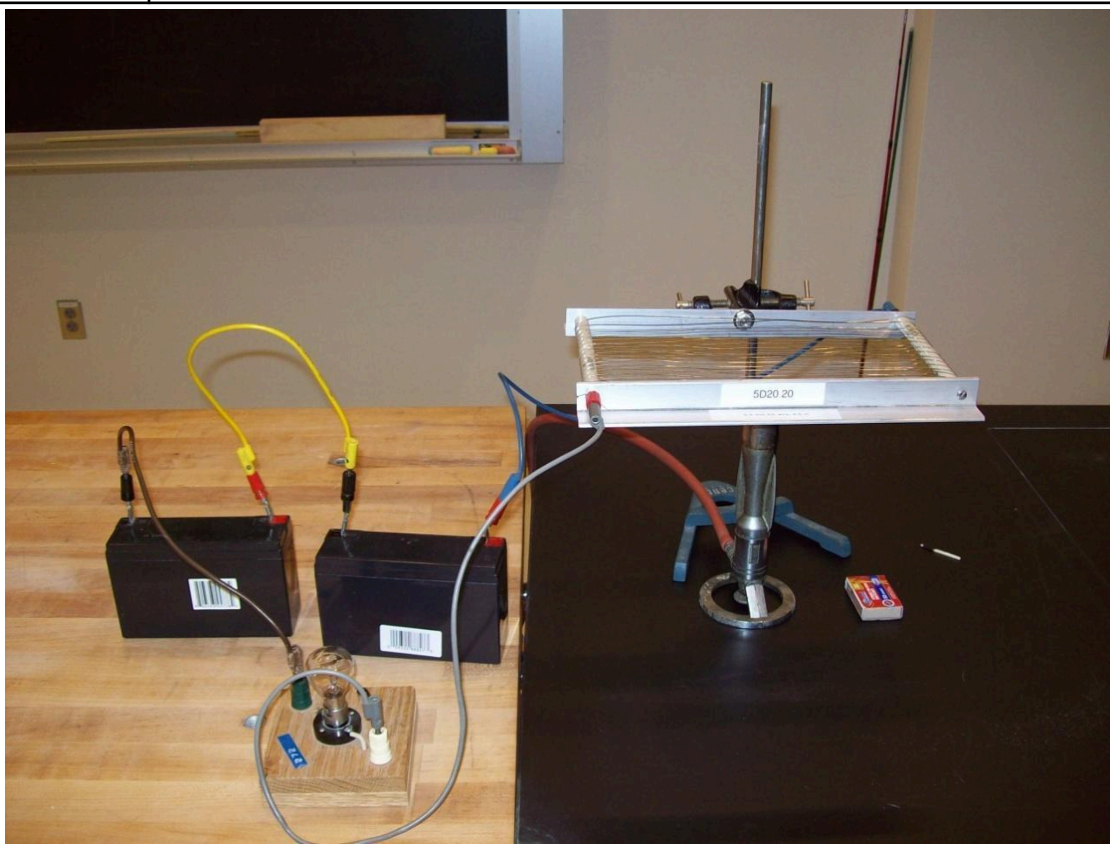
Superconducting Wire

A current (about 100 mA) is made to flow through a bar of superconducting material. A voltmeter is connected across it and the voltage is monitored as the sample is cooled below the transition point. Use Capstone file Superconductivity.cap



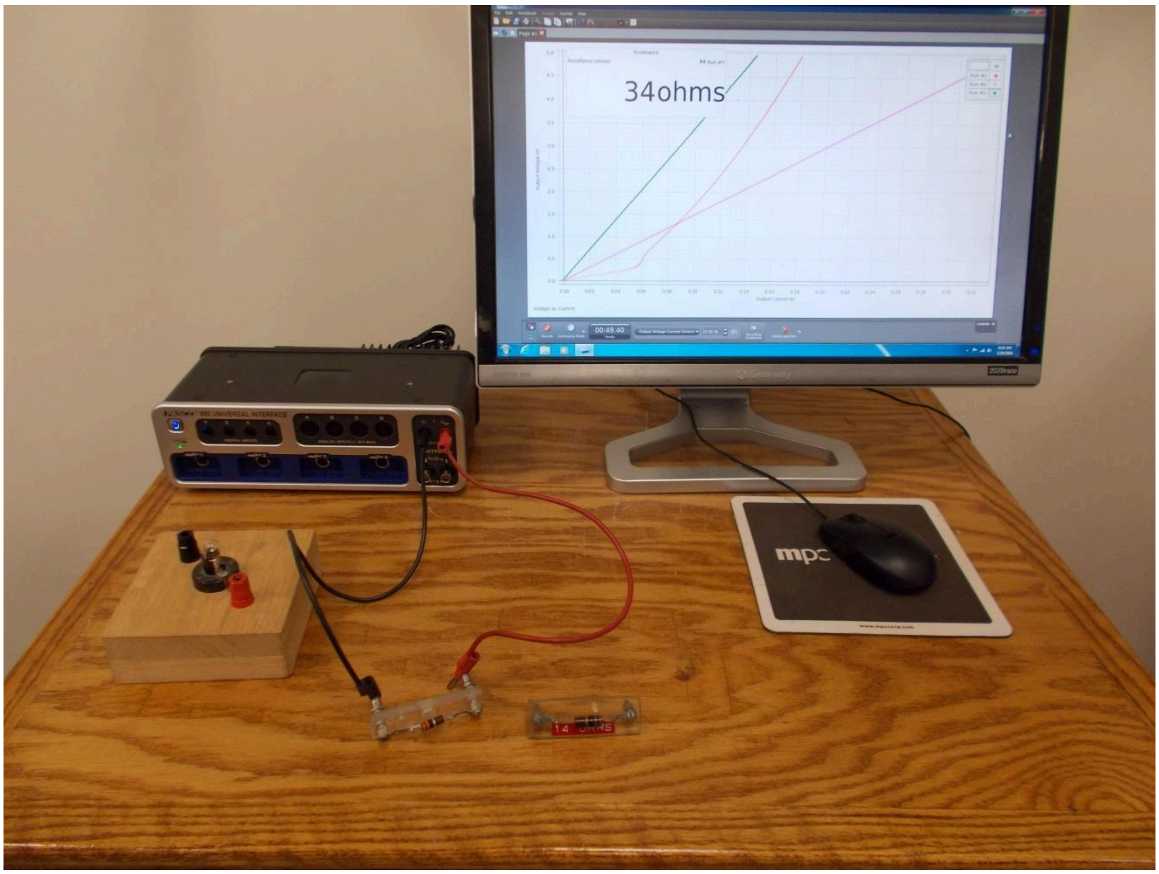
Location: Ha5

Electricity and Magnetism	5D20.20	RESISTANCE
Resistivity and Temperature		
Heated Wire		
	A flat coil of 0.5 mm diameter stainless steel wire 8.5 m long is placed in series with a light bulb and a 12 volt battery. The bulb glows. Now heat the wire with a flame from a Bunsen burner and the bulb dims.	



Location: Ha5

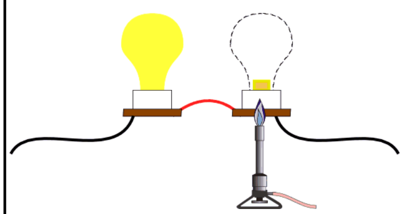
Electricity and Magnetism	5D20.31	RESISTANCE
Resistivity and Temperature		
Resistance of Light Bulbs		
	Use Capstone to measure the voltage current relation of several resistors and a light bulb. (5D20.31 is the V – I curve of a light bulb)	

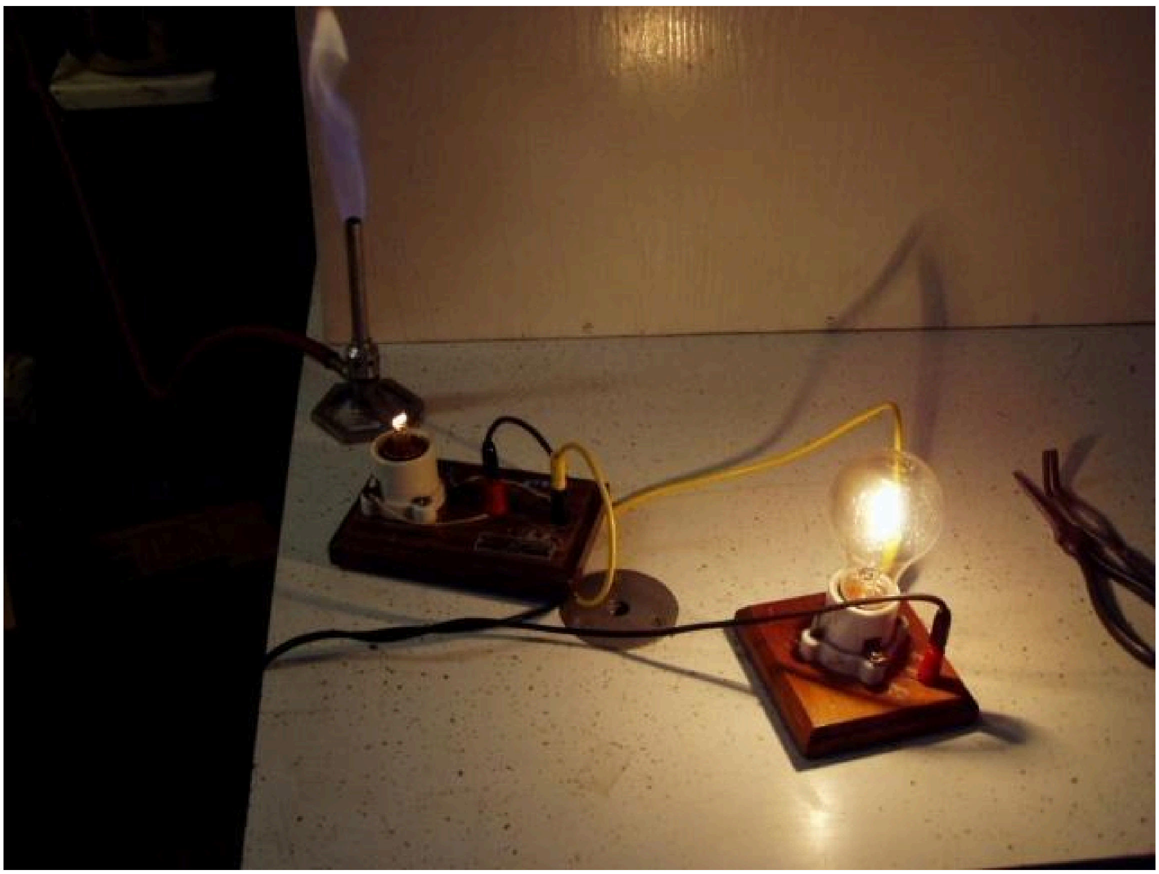


Location: Science Workshop Cabinet, Ha7, Hb2

Electricity and Magnetism	5D20.60	RESISTANCE
Resistivity and Temperature		

Conduction in Glass

	A light bulb is smashed with a mallet and the filament is cut off. Then, the glass stem is heated with a burner. The broken bulb in the photo is a 25 W, 230 V bulb. The unbroken bulb is a 100 W, 120 V bulb. The series combination of the two is connected to the AC line. Once the glass is heated enough to conduct, ohmic heating is enough to sustain the high temperature and the burner is no longer needed.

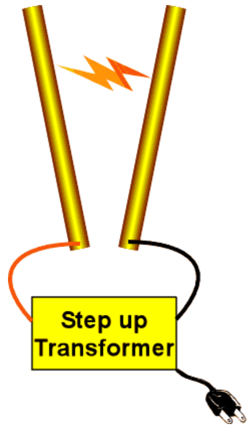


Location: Ha5

Electricity and Magnetism	5D40.10	RESISTANCE

Conduction in Gases

Jacob's Ladder



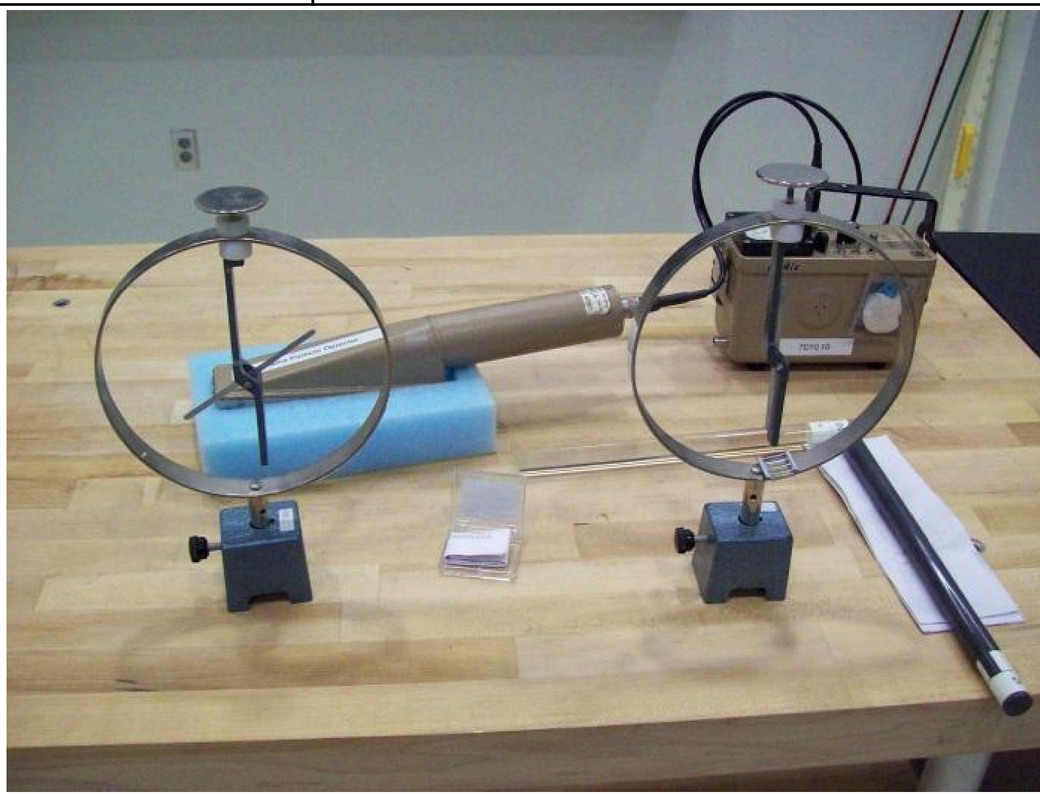
This is a step up transformer. CAUTION: LETHAL VOLTAGE. The Step up transformer is connected to a Variac to adjust the high voltage.
Turn on the power and the discharge will travel up the wires.
The distance between the wires is the critical adjustment. The wires should not be moving.
Unplug after use so that students don't inadvertently play with it.

Location: HcT, Ia1

Electricity and Magnetism	5D40.30	RESISTANCE
Conduction in Gases		

Discharge an Electroscope

	Charge the electroscope either positively or negatively by induction. Then place the Po-210 source (0.5 mCi when new) in the electroscope and watch the electroscope discharge in a couple of seconds. Use safety protocols when handling the source.



Location: Kb6, Gc2

Electricity and Magnetism	5D40.43	RESISTANCE
Conduction in Gases		

Thermionic Emission Model

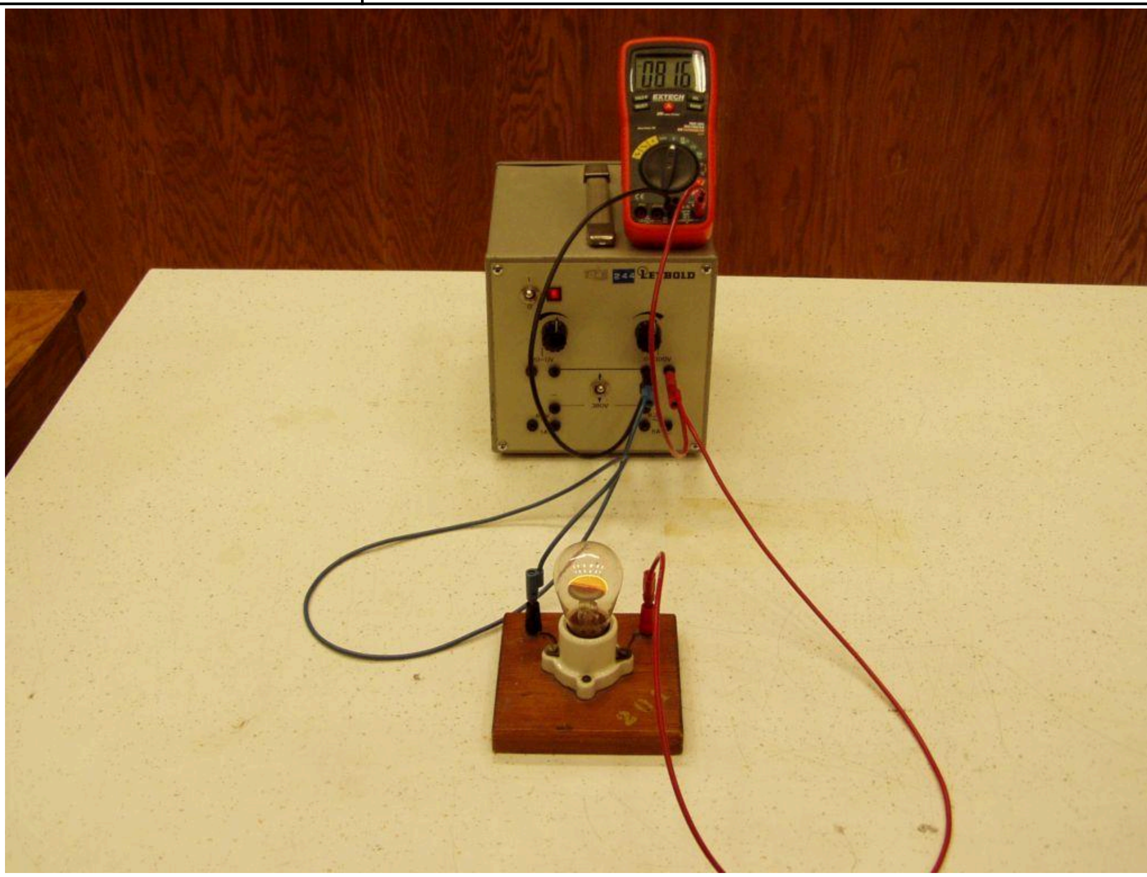
	The Air Cushion table is set up with a lattice and some bound "electrons" (magnetic pucks bound by the lattice of fixed magnets). As energy is added by opening the impulse valve, every now and then an "electron" escapes. Air Cushion Table manual 2.4.8

Location: Ga5

Electricity and Magnetism	5D40.50	RESISTANCE
Conduction in Gases		

Neon Bulb

	A neon lamp lights at about 80 V and shuts off at about 60V. When a DC potential difference only one side lights because of the cathode fall.



Location: Ha6

Electricity and Magnetism	5E20.10	ELECTROMOTIVE FORCE AND CURRENT
Electrolysis		

Electrolysis of Water

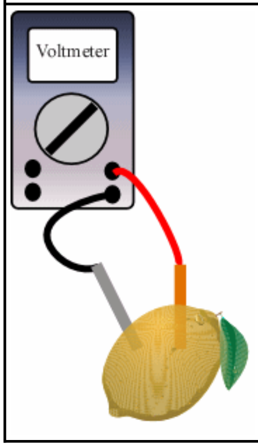
	DC current passed through slightly acidic water evolves hydrogen and oxygen at the electrodes.

Location: Ha6

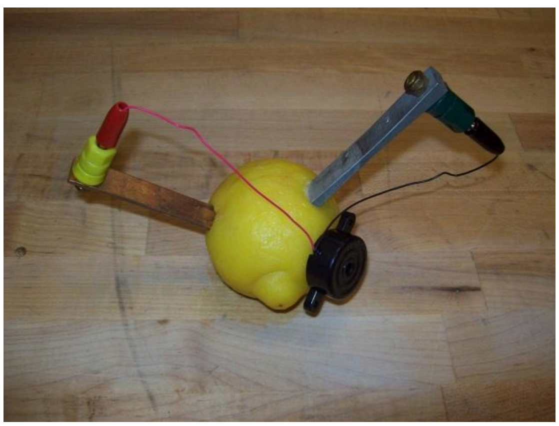
Electricity and Magnetism	5E40.25	ELECTROMOTIVE FORCE AND CURRENT

Cells and Batteries

Lemon Battery



Magnesium and copper electrodes in a lemon are connected to a piezoelectric buzzer or an LED. The lemons need to be bought so give advanced notice if you want to use them. The copper electrode is positive and the magnesium is negative. The LED will be brighter with two lemon batteries in series.

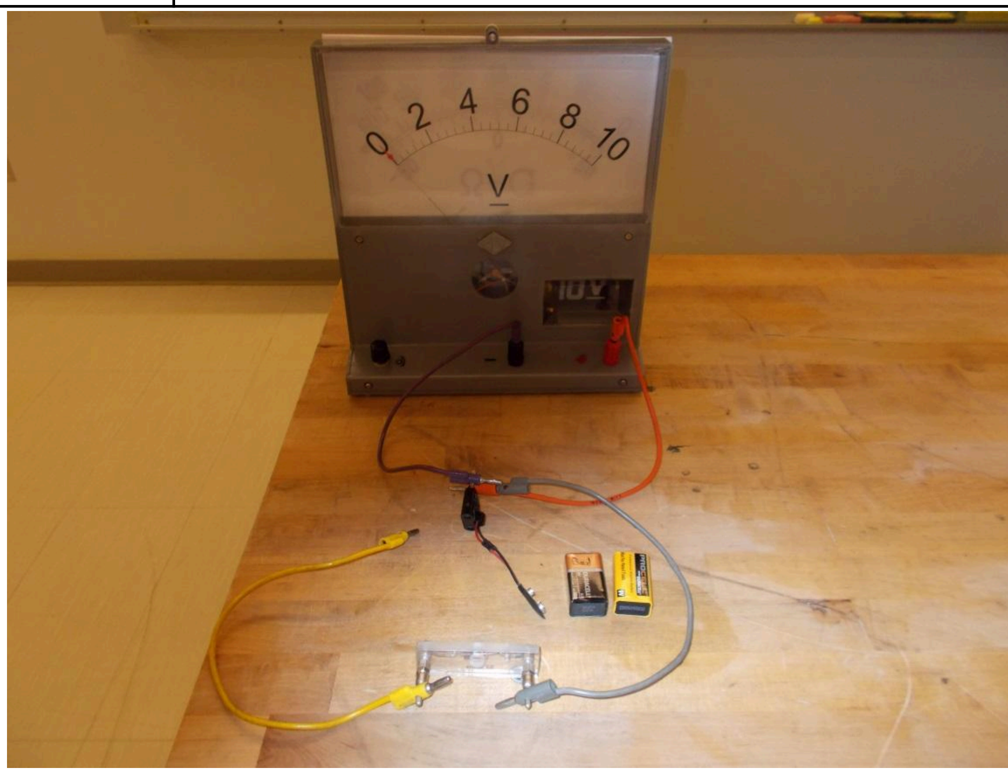


Location: Ha6

Electricity and Magnetism	5E40.75	ELECTROMOTIVE FORCE AND CURRENT
Cells and Batteries		

Internal Resistance of Batteries

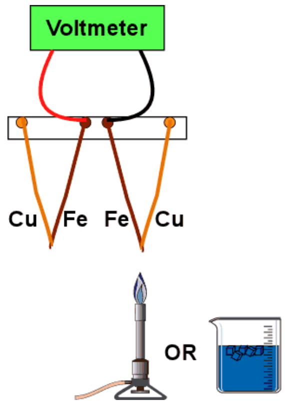
	The EMF of a good battery is measured and then a load is placed across it. Repeat the experiment using a weak battery. Prepare the good and weak batteries by appropriately charging them. The load is a 33 ohm coil of resistor.



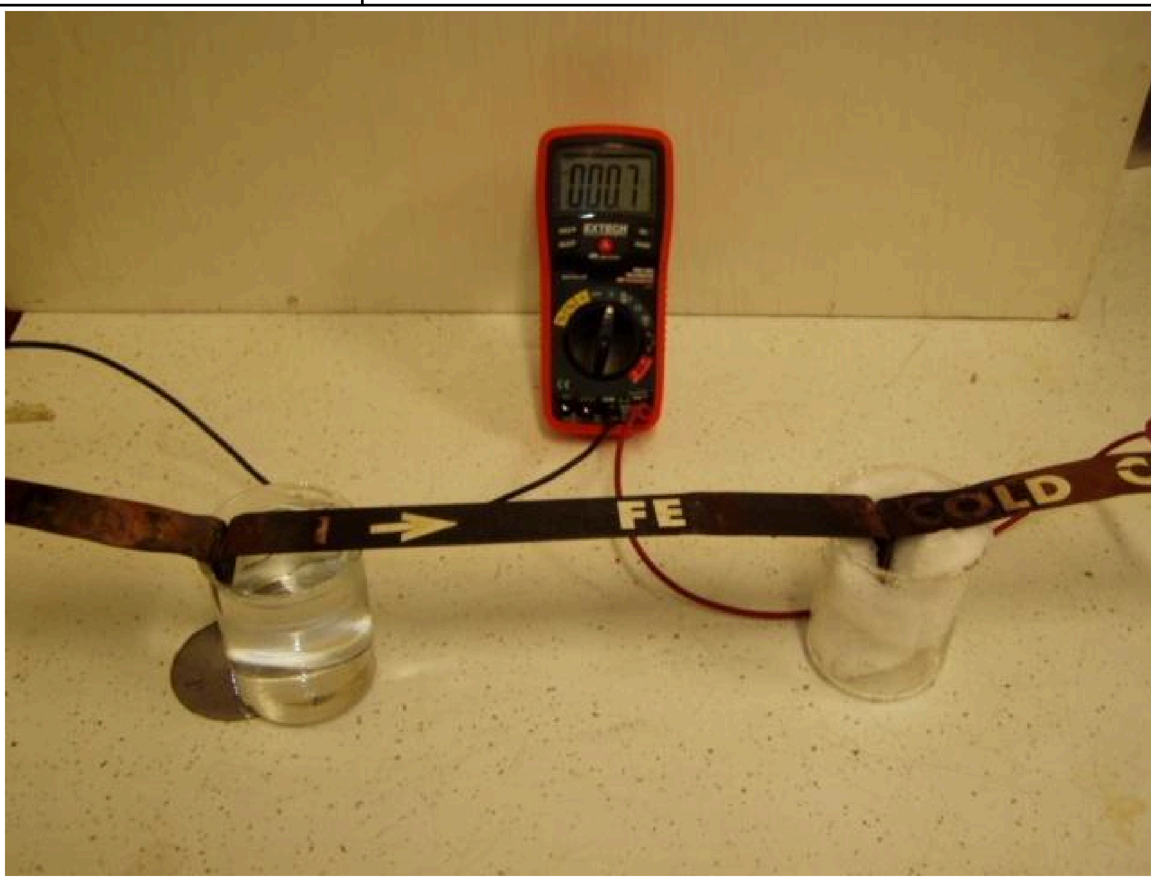
Location: Ha6

Thermoelectricity

Thermocouple



A voltmeter is connected to the iron wires of two copper-iron wire junctions hanging from a stand. Light the Bunsen burner and heat one of the junctions, watching the voltmeter. You can also immerse a junction in ice.
The Photograph shows the use of hot and cold (snow) water.

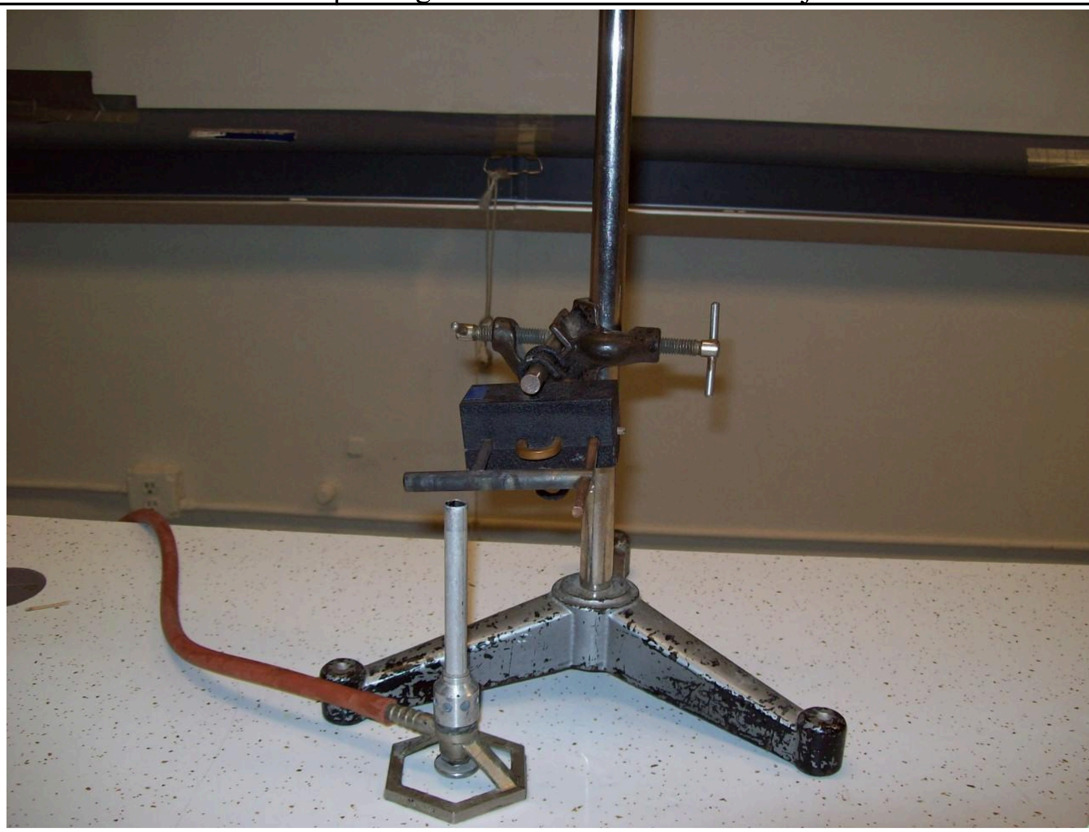


Location: Ha6

Electricity and Magnetism	5E50.30	EMF AND CURRENT
	Thermoelectricity	

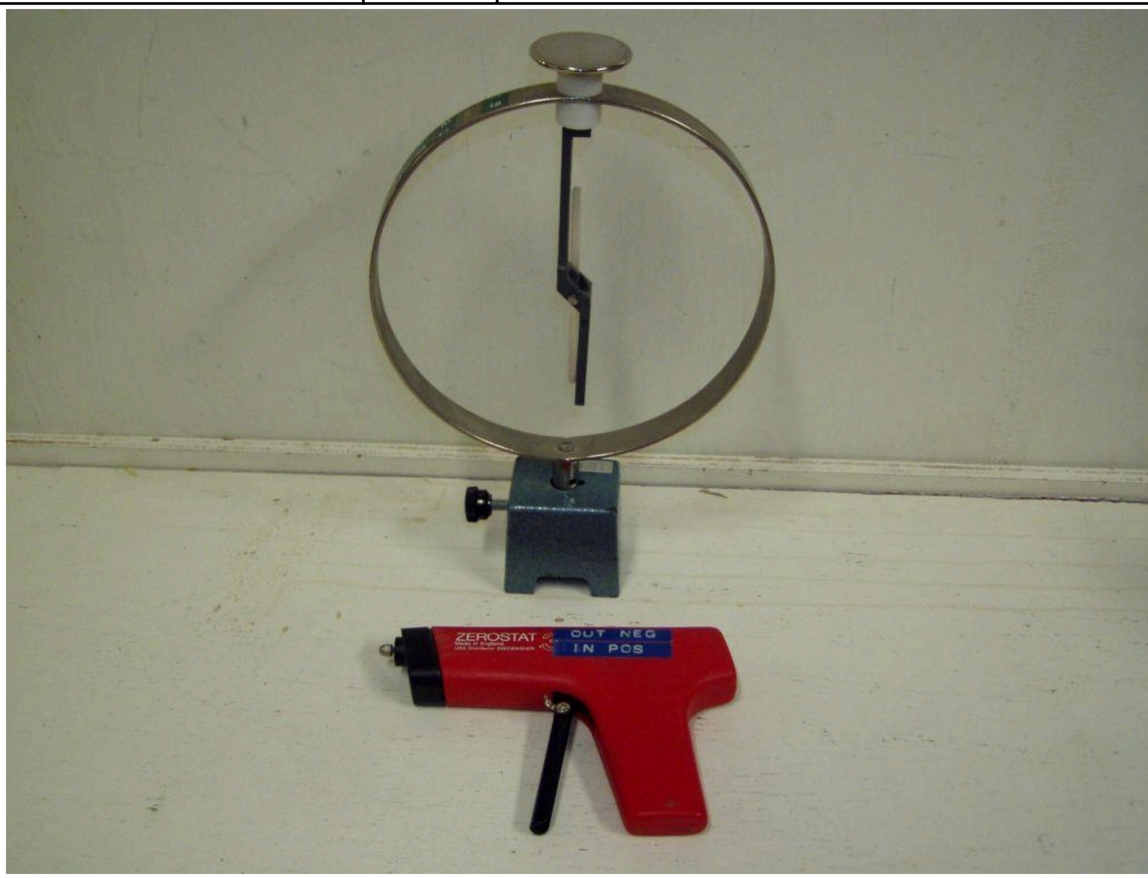
Thermoelectric Magnet

	Enough current to power one turn electromagnet is produced by heating one side of a thermoelectric junction.



Location: Ha6

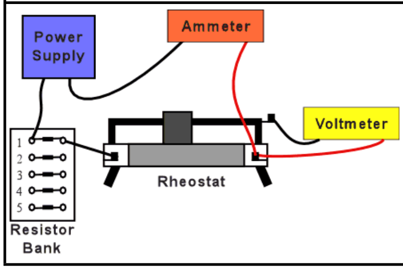
Electricity and Magnetism	5E60.20	EMF AND CURRENT
Piezoelectricity		
# Piezoelectric Sparker		
	Attach the commercial piezoelectric gun to a Braun electroscope.	



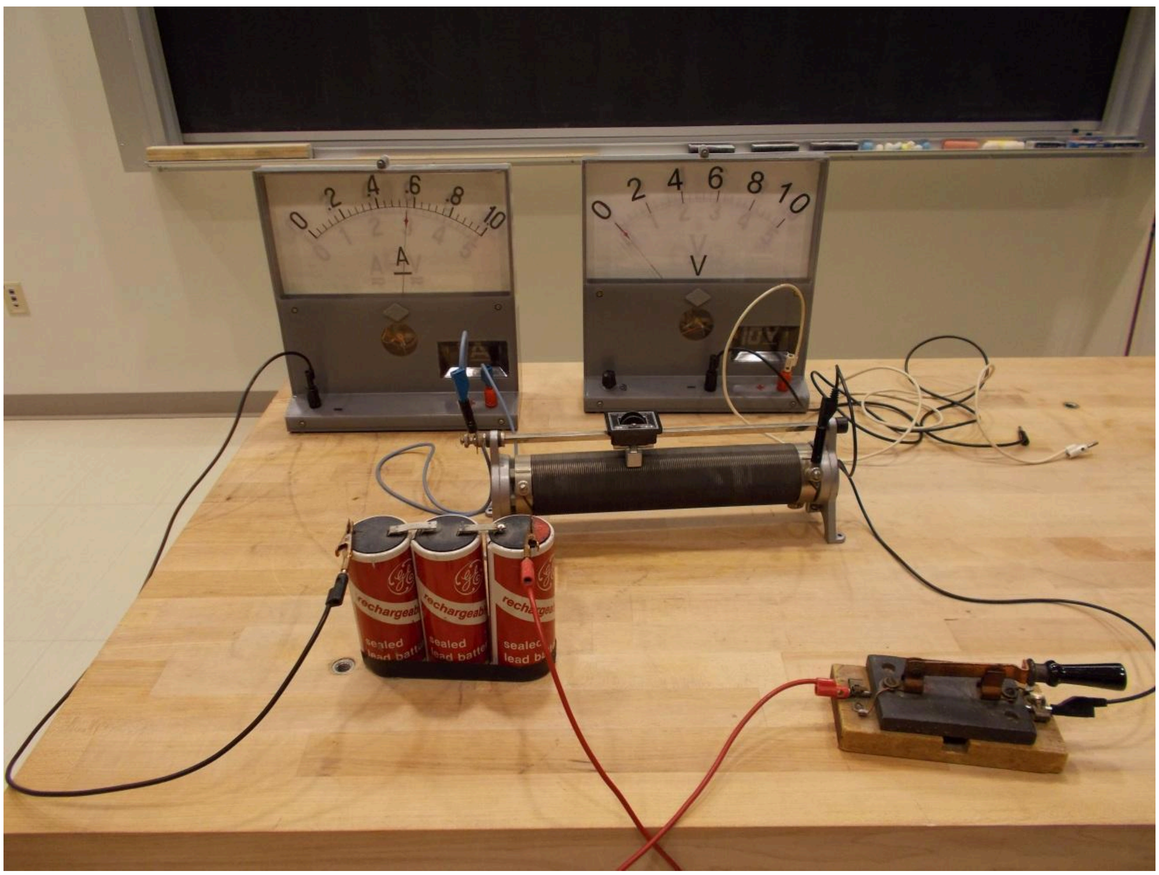
Location: Gc2, Gc4

Ohm's Law

Ohm's Law



Large meters measure the current and the voltage in a simple circuit of a battery and resistor. Change the number of batteries in the circuit OR change the resistance and observe that the meters change proportionally.

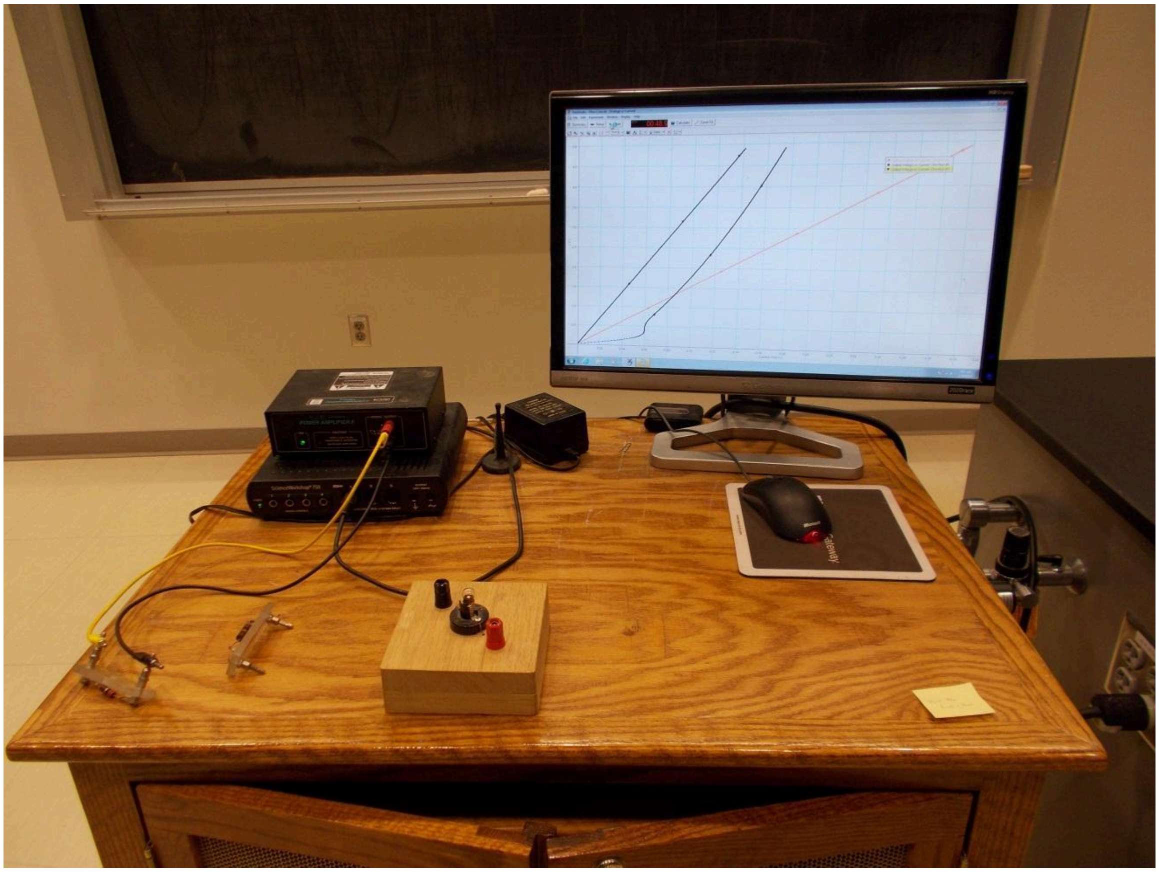


Location: Ha7

Electricity and Magnetism	5F10.10a, 5D20.31	DC CIRCUITS
Ohm's Law		

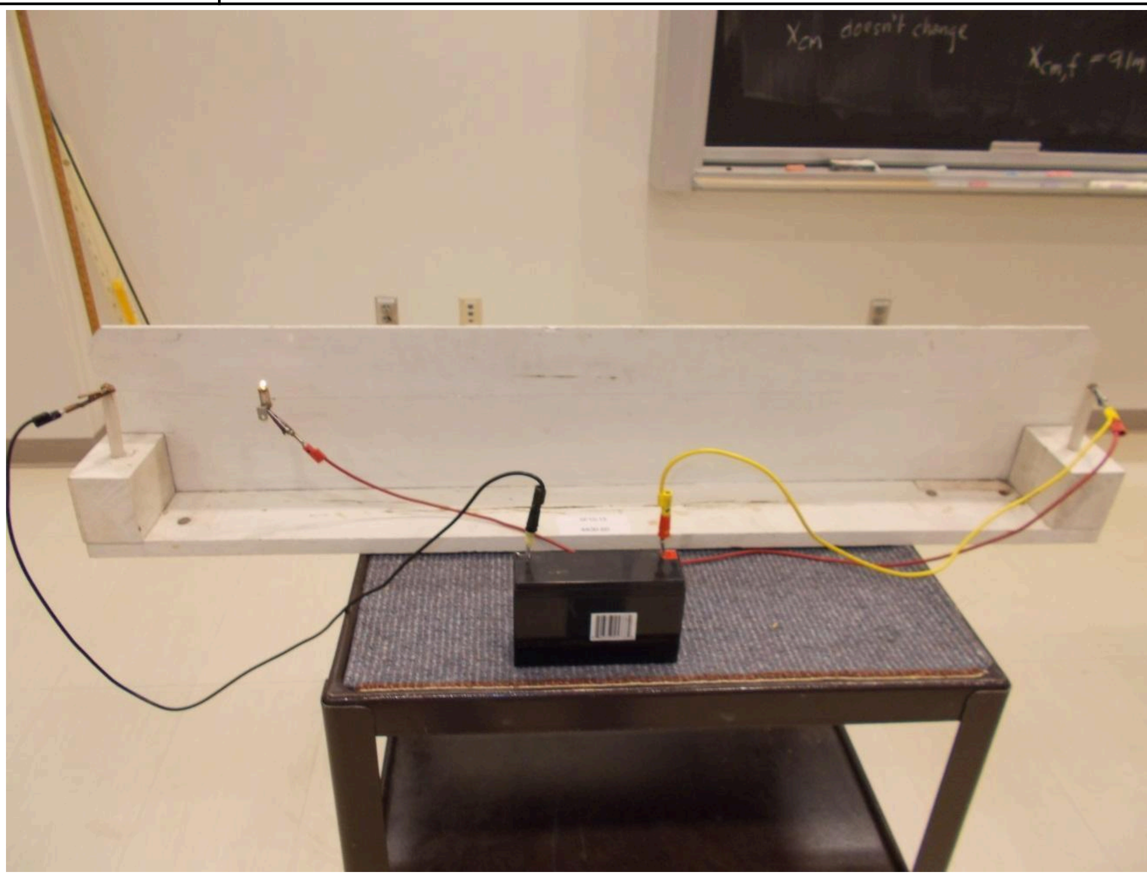
Ohm's Law

	Use Science Workshop to measure the voltage current relation of several resistors and a light bulb. (5D20.31 is the V – I curve of a light bulb)



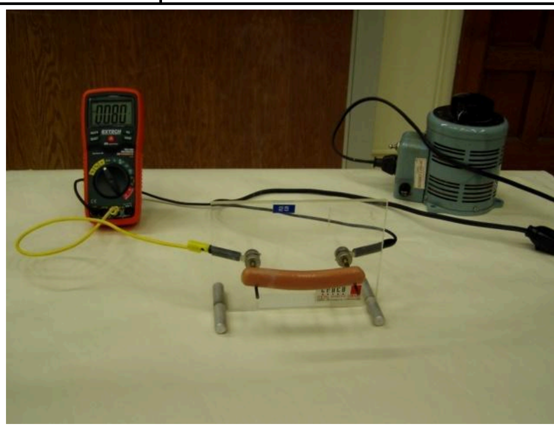
Location: Science Workshop Cabinet, Ha7, Hb2

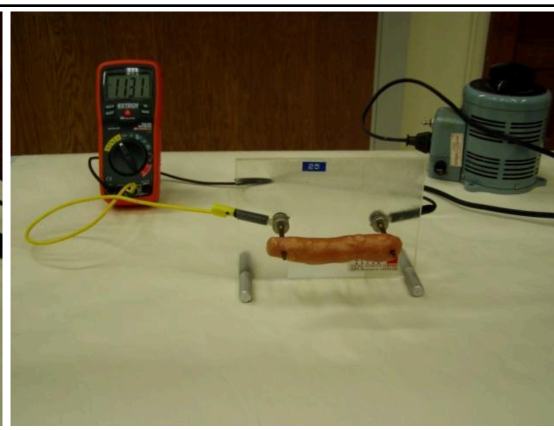
Electricity and Magnetism	5F10.15	DC CIRCUITS
Ohm's Law		
IR Drop in a Wire		
	A battery is connected across a long nichrome wire and a flashlight bulb connected to a traveling lead at one end is used to show the IR drop along the wire.	



Location: Fc4, Hb2, Hb3

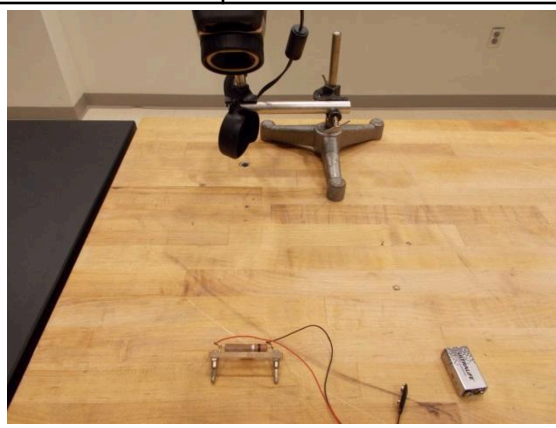
Electricity and Magnetism	5F15.20	DC CIRCUITS
Ohm's Law		
Hot Dog Cooker		
	Apply 110V to spikes and first rest the hot dog on top of them. Because the contact resistance is high, not much happens except a little surface charring. Now impale the hot dog on the spikes and repeat. The current will go up to about an ampere and the hot dog will cook.	

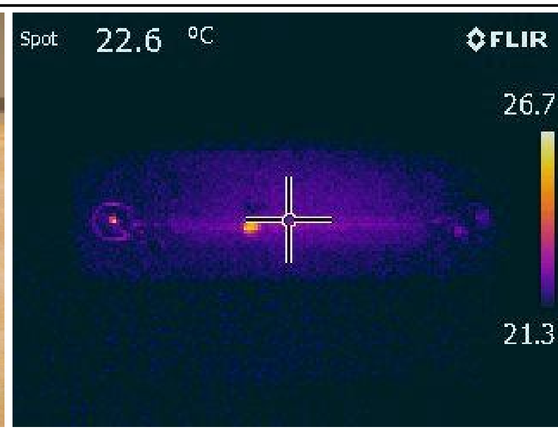


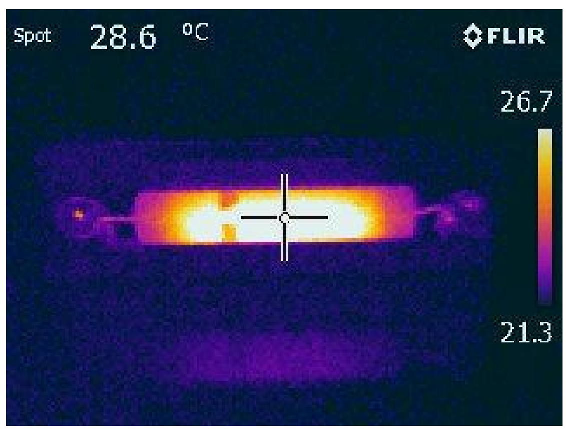


Location: Ha7

Electricity and Magnetism	5F15.16	DC CIRCUITS
Ohm's Law		
Heating with Current		
	Connect a 100 ohm resistor to a nine volt battery and watch it heat up using the FLIR camera (manual temperature scale works best).	





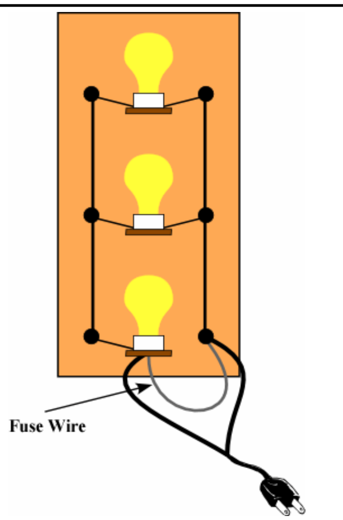


Location: Ha7, FLIR cabinet

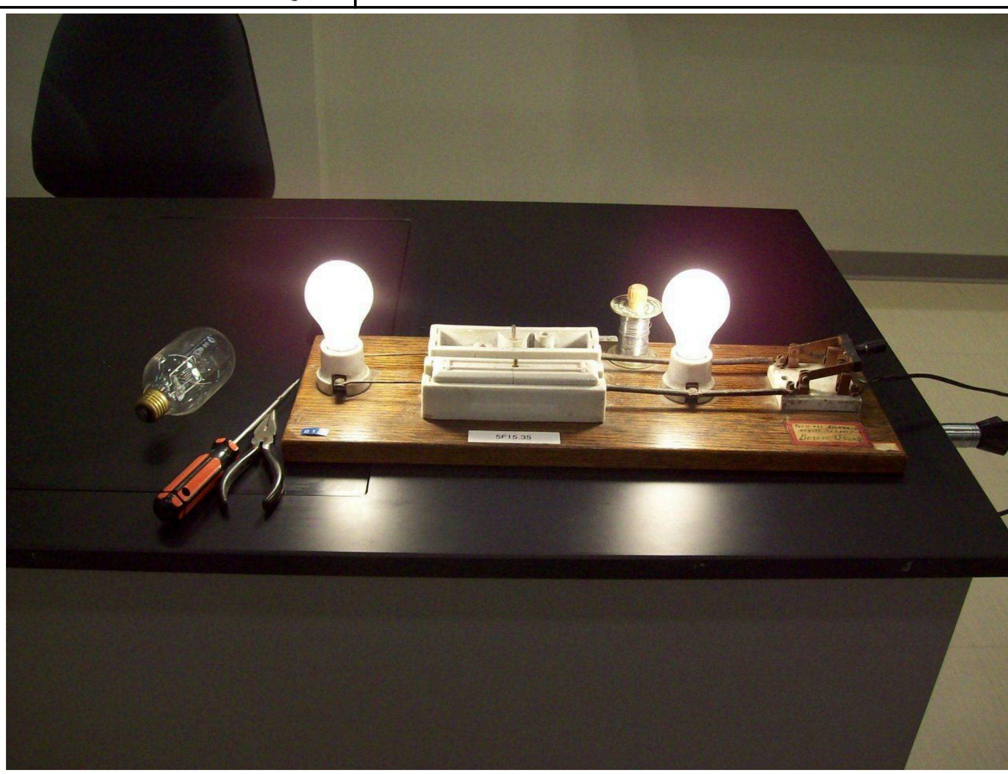
Electricity and Magnetism	5F15.35	DC CIRCUITS

Power and Energy

Fuse with Increasing Load



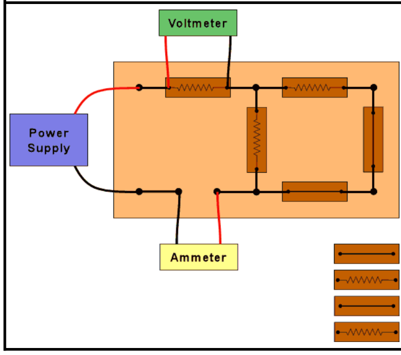
A fuse wire will eventually fail when the load on the circuit is increased.



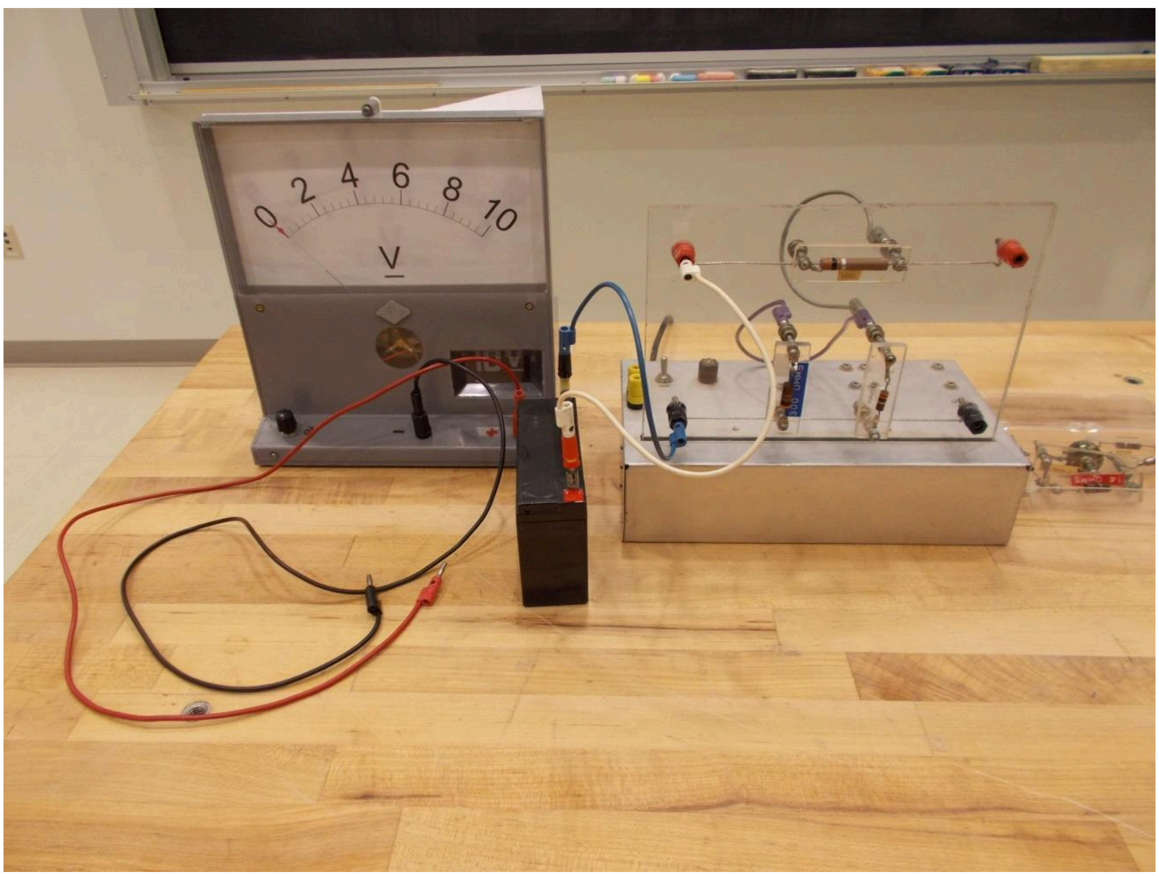
Location: Hb1

Circuit Analysis

Kirchhoff's Voltage Law



Measure the voltage at different places in the circuit and show that the sum is zero. There are many possible combinations of components.

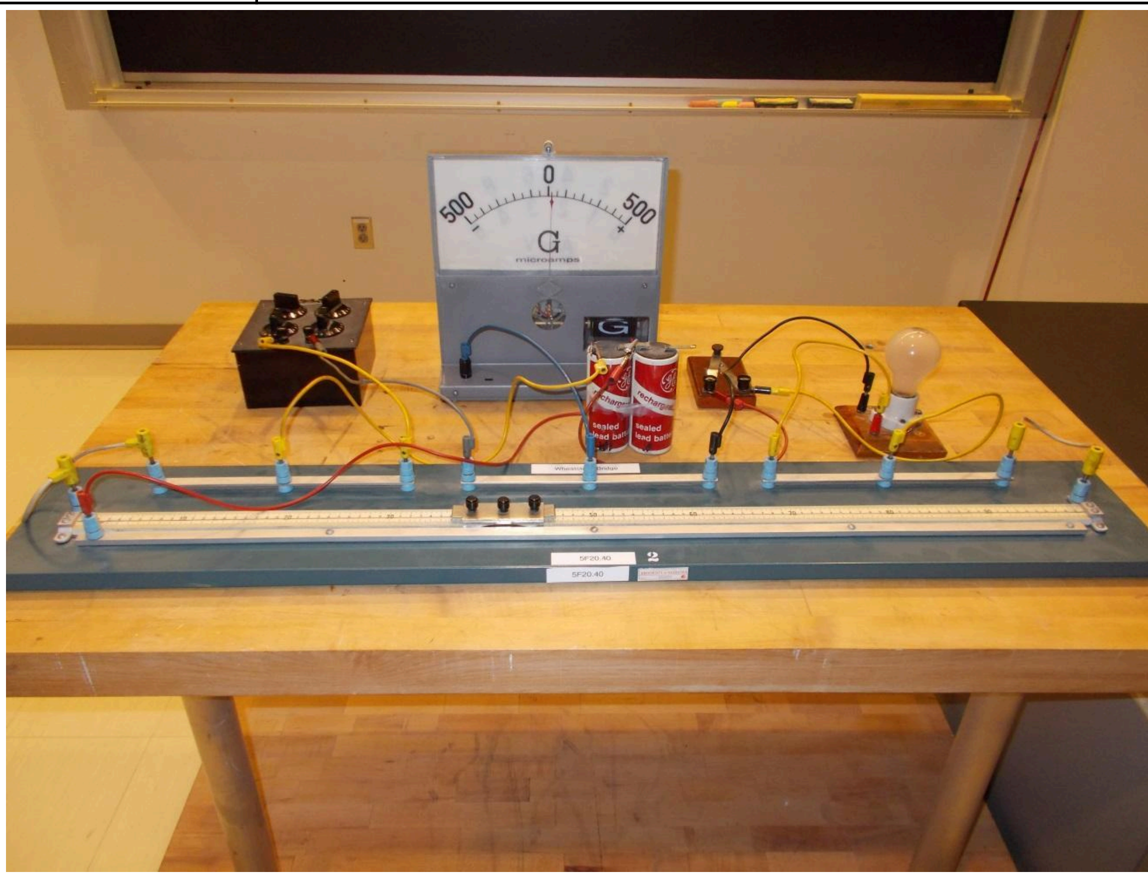


Location: Hb2, Hb3

Electricity and Magnetism	5F20.40	DC CIRCUITS
Circuit Analysis		

Wheatstone Bridge

	The slide wire Wheatstone Bridge. Use a 2 V battery. The "unknown" resistor is a 75 W light bulb (about 16 ohms)

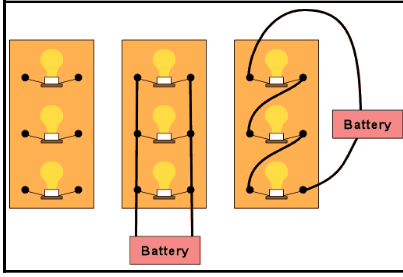


Location: Ha5, Ha6, Hb3, HbT

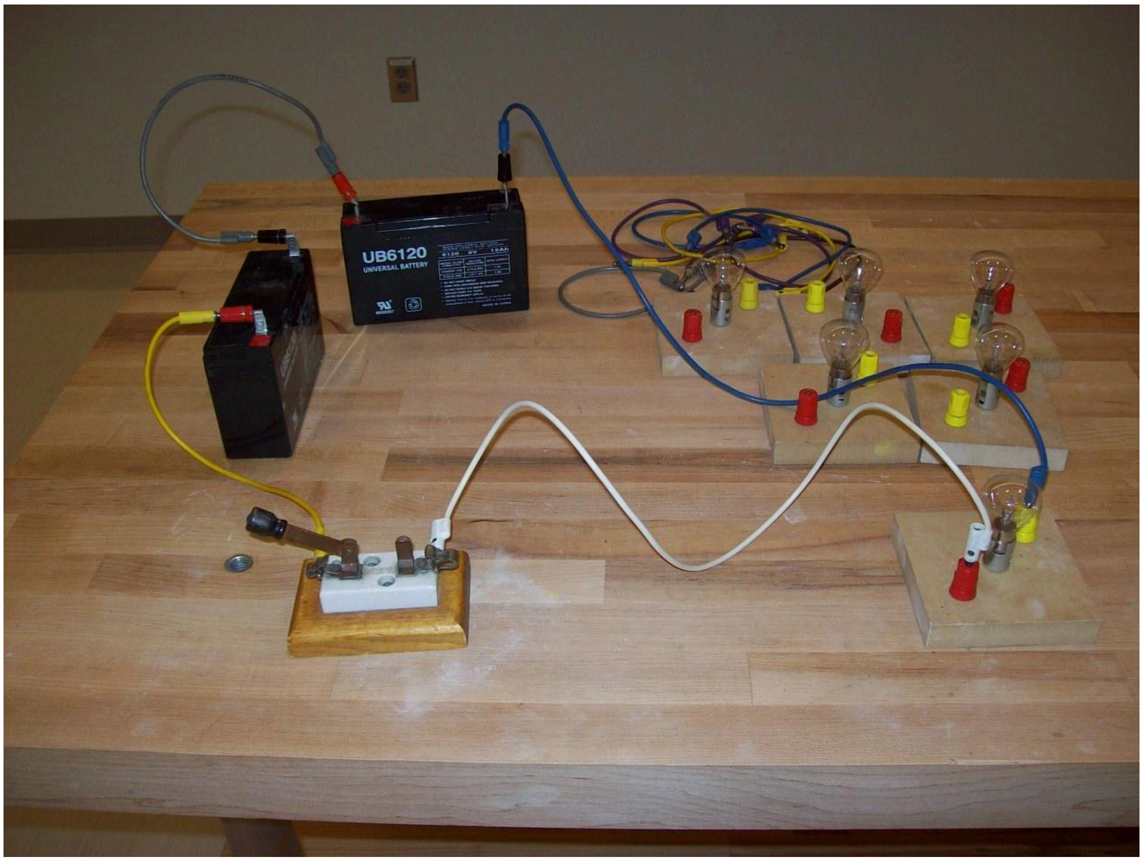
Electricity and Magnetism	5F20.50	DC CIRCUITS

Circuit Analysis

Series and Parallel Circuits



If the combined series and parallel boards are confusing, try the separate boards.

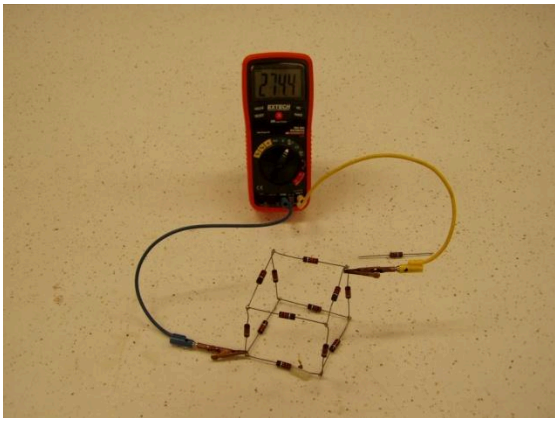
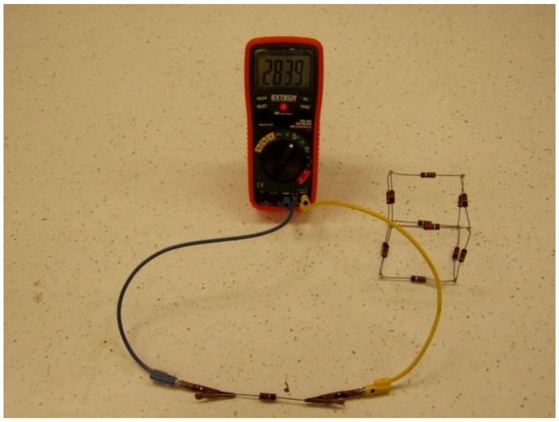


Location: Ha7, Hb3

Electricity and Magnetism	5F20.60	DC CIRCUITS
Circuit Analysis		

Equivalent Resistance

	The resistance between opposite corners of a cube made of 330 ohm resistors is compared to the resistance of a single 270 ohm resistor.

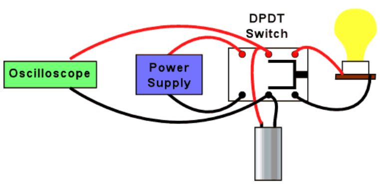



Location: Ha7

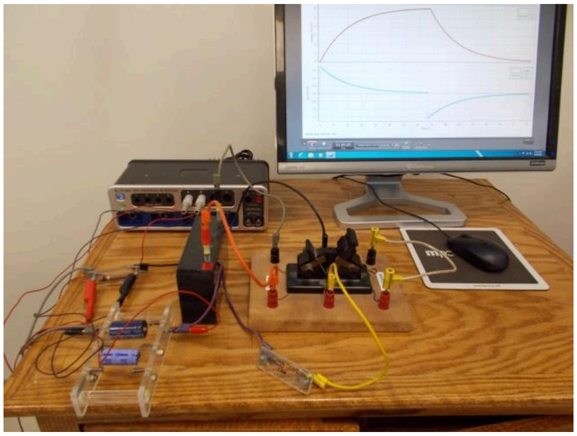
Electricity and Magnetism	5F30.10	DC CIRCUITS

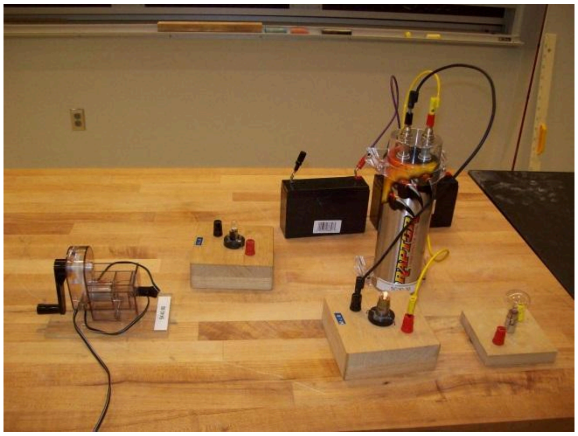
RC Circuits

Capacitor and Light Bulb



A one Farad capacitor, a light bulb, and a 6 V dc supply in series show a long time constant where the bulb dims as the capacitor charges. Also shown in the photograph, is a Capstone version. It uses the file "RC Circuit.cap". The capacitor is 2200 microfarad and the resistance is a 3400 ohm resistor. A 100 ohm current sensing resistor and both current through, and voltage across the capacitor are plotted on the computer.



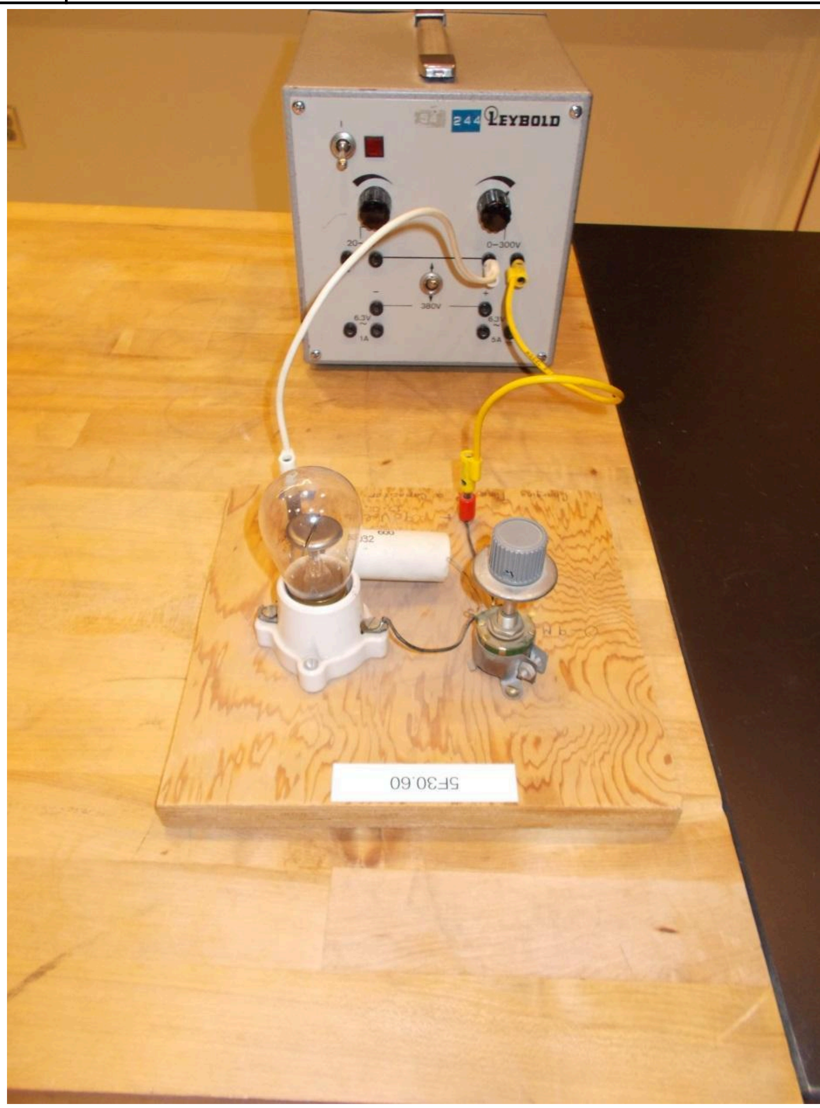


Location: Science Workshop Cabinet, Hb2, Hb3

Electricity and Magnetism	5F30.60	DC CIRCUITS
RC Circuits		

Relaxation Oscillator

	A neon bulb in parallel with a capacitor will light periodically as the capacitor charges and discharges. Use the variable resistor to change the period.



Location: Ha7

Electricity and Magnetism	5G10.15	MAGNETIC MATERIALS

Magnets

Magnetite

	A Sample of magnetite.

Location: Hb4

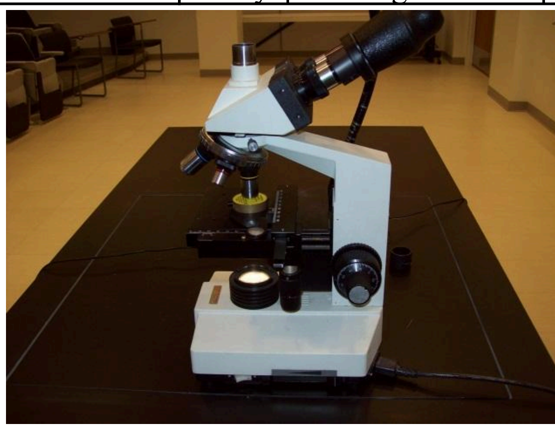
Electricity and Magnetism	5G10.55	MAGNETIC MATERIALS
Magnets		
Gauss Accelerator		
	A Gauss accelerator made from ball bearings and a spherical magnet. Place the ball bearings on the track and roll a ball bearing down the track toward them. Observe the motion of the last ball after the collision. Now repeat rolling the spherical magnet in place of the ball bearing.	

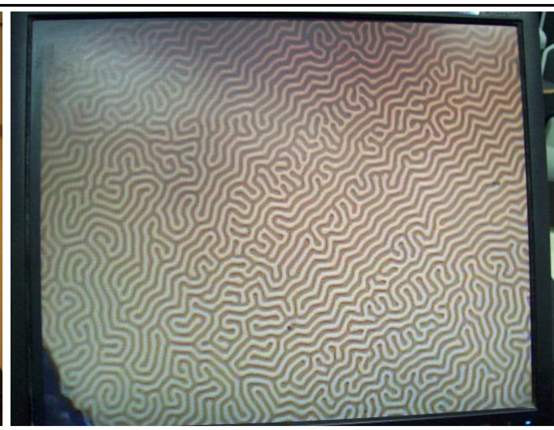
Location: Hb5

Electricity and Magnetism	5G20.20	MAGNETIC MATERIALS
Magnetic Domains and Magnetization		

Ferro-optical Garnet

	View a commercial ferro-optical garnet between crossed Polaroids with a color TV on a microscope (4D10.10) as the field is changed. If you get the magnet too close, you can magnetize the garnet. The eyepiece alignment adapter is stored with the 4D10.40.



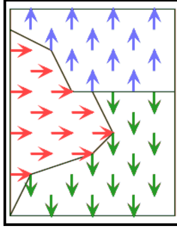


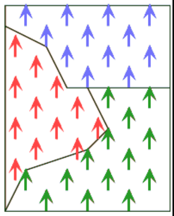
Location: Ga3, Hb4

Electricity and Magnetism	5G20.30	MAGNETIC MATERIALS

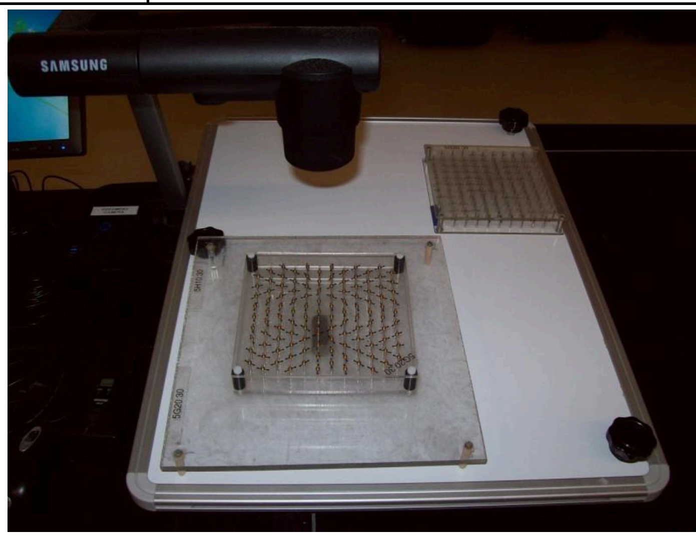
Magnetic Domains and Magnetization

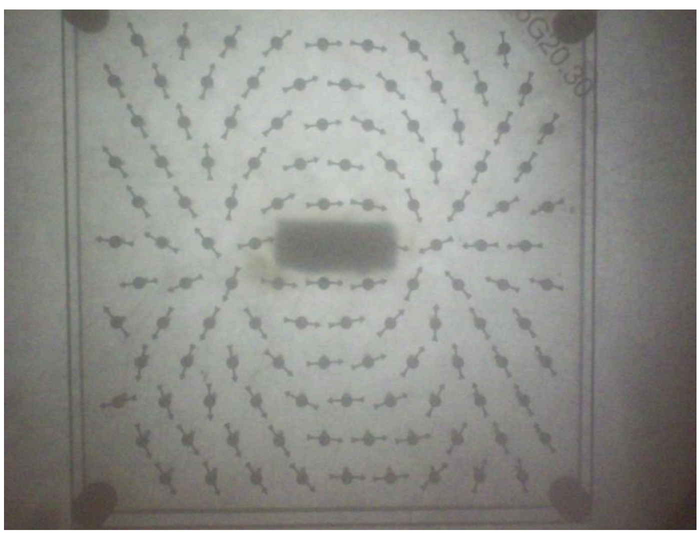
Magnetic Domain Models





There are two types of arrays: 1) Coplanar to show domains and 2) non-coplanar (random orientation). Bring a magnet near each array.



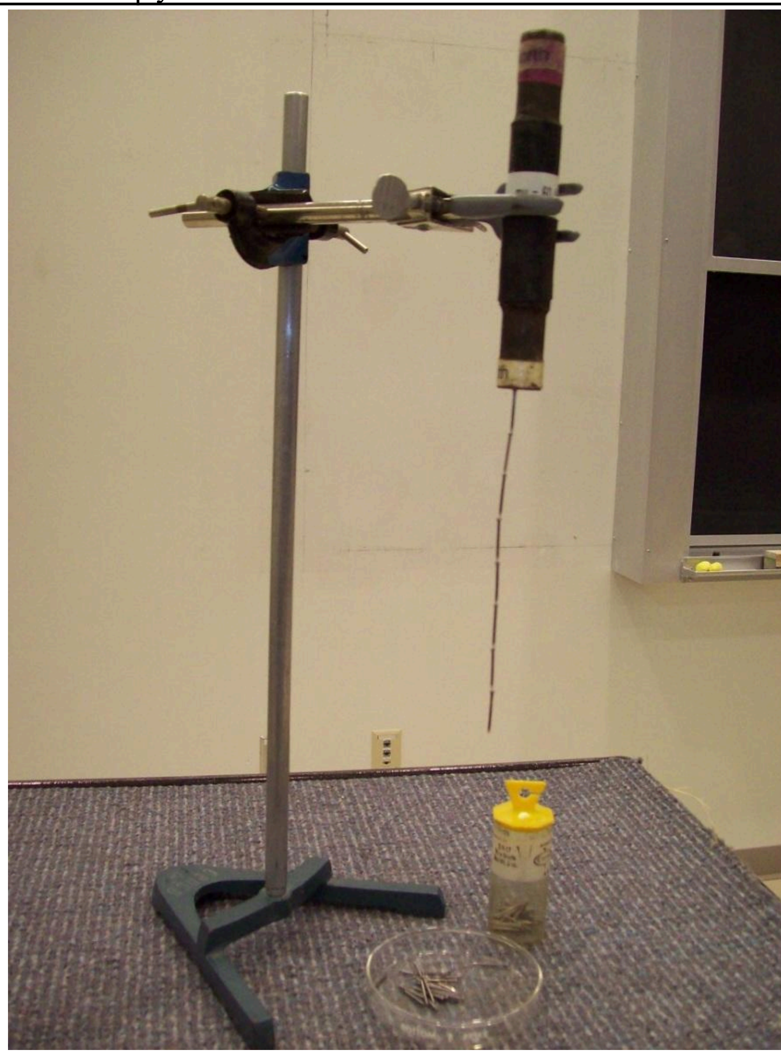


Location: Hb4

Electricity and Magnetism	5G20.45	MAGNETIC MATERIALS
Magnetic Domains and Magnetization		

Induced Magnetic Poles

	A chain of nails is held up by a magnet, each becoming a magnet by induction.

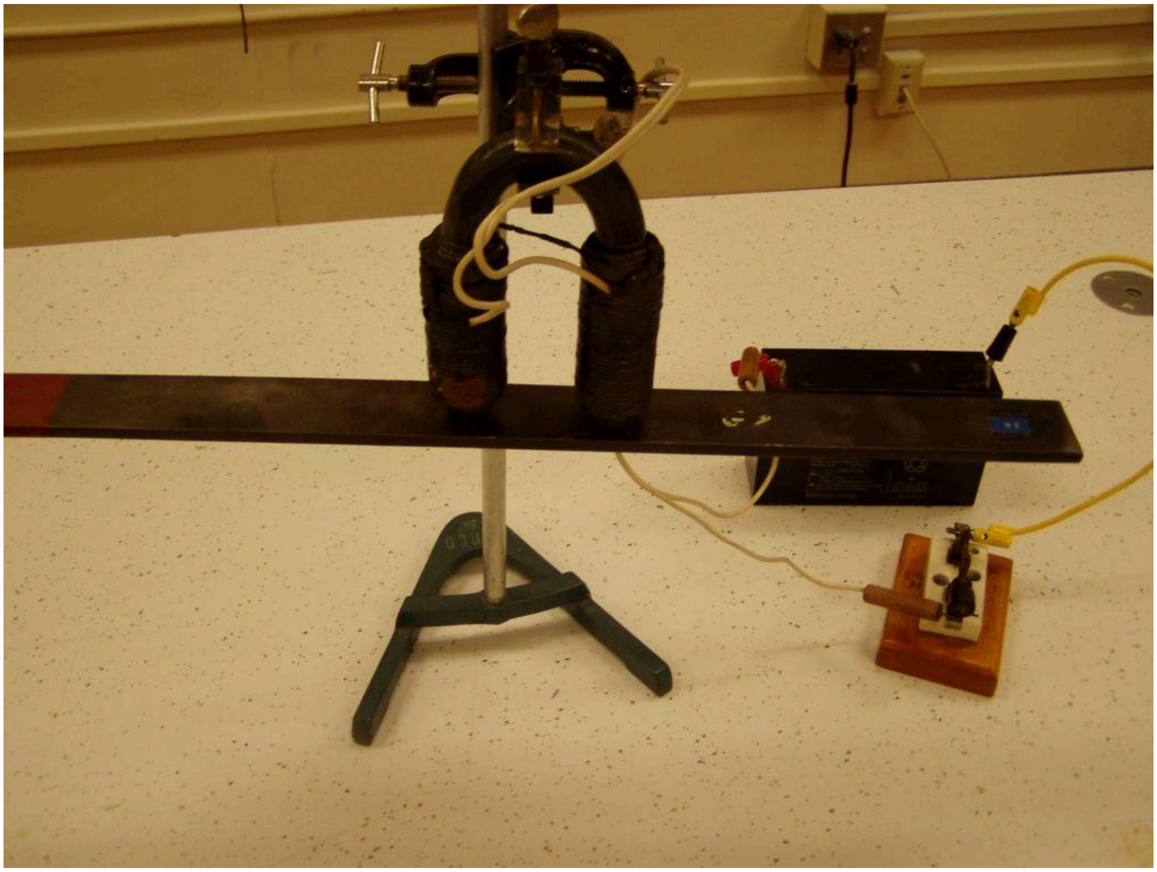


Location: Ib3

Electricity and Magnetism	5G20.55	MAGNETIC MATERIALS
Magnetic Domains and Magnetization		
Permalloy Rod		
	A staple sticks to the point of a Permalloy rod when it is parallel to the Earth's magnetic field but falls off when the rod is perpendicular to it.	

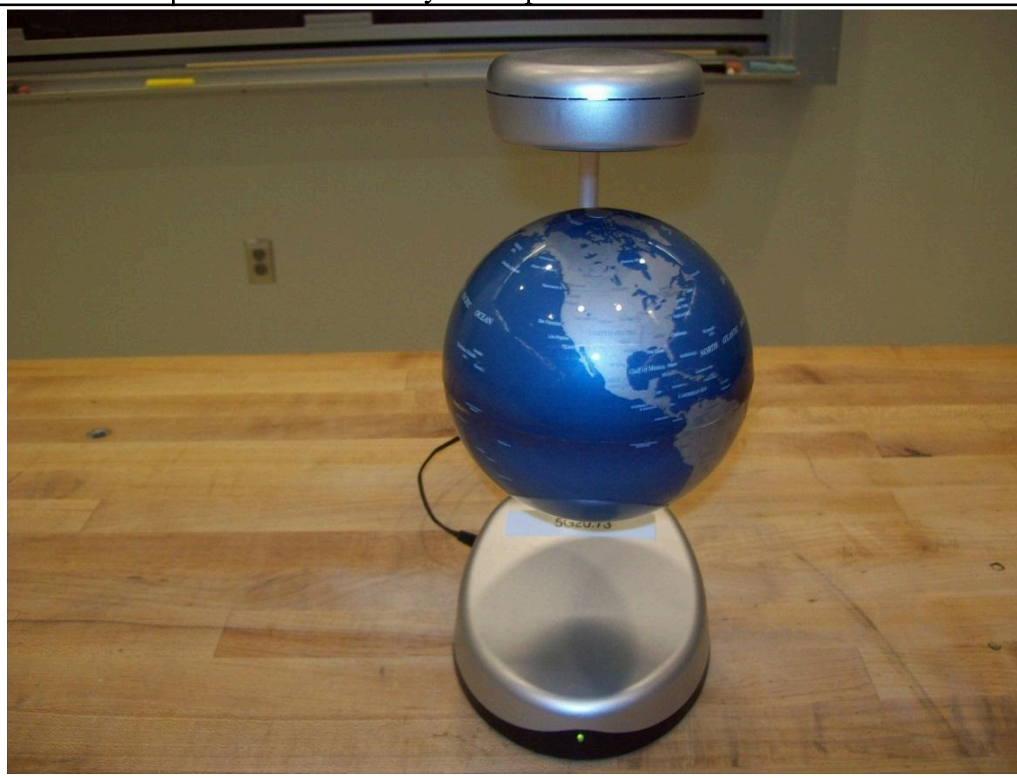
Location: Hb5

Electricity and Magnetism	5G20.70	MAGNETIC MATERIALS
Magnetic Domains and Magnetization		
Electromagnet		
	A simple electromagnet powered by a battery.	



Location: Hb2, Hb3, Hb4

Electricity and Magnetism	5G20.73	MAGNETIC MATERIALS
Magnetic Domains and Magnetization		
Magnetically Suspended Globe		
	A globe with a magnet in it is suspended under an electromagnet whose field is controlled by a computer connected to a field sensor.	



Location: Hb5

Electricity and Magnetism	5G30.08	MAGNETIC MATERIALS

Paramagnetism and Diamagnetism

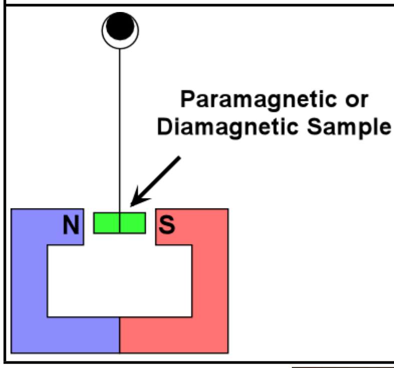
Diamagnetic Levitation

	A magnet is levitated between two blocks of diamagnetic material beneath another magnet. The diamagnetic blocks are made of very pure graphite.

Location: Hb4

Paramagnetism and Diamagnetism

Paramagnetism and Diamagnetism



Paramagnetic and diamagnetic crystals are inserted between the poles of a large magnet or electromagnet. The diamagnetic sample is reactor grade (very pure) graphite and the paramagnetic sample is brush grade graphite.

Location: Floor, Hb6

Electricity and Magnetism	5G30.16	MAGNETIC MATERIALS
Paramagnetism and Diamagnetism		

Dollar Bill Attraction

	A dollar bill is attracted by a magnet

Location: Hd5

Electricity and Magnetism	5G30.20	MAGNETIC MATERIALS
Paramagnetism and Diamagnetism		

Paramagnetism of Liquid Oxygen

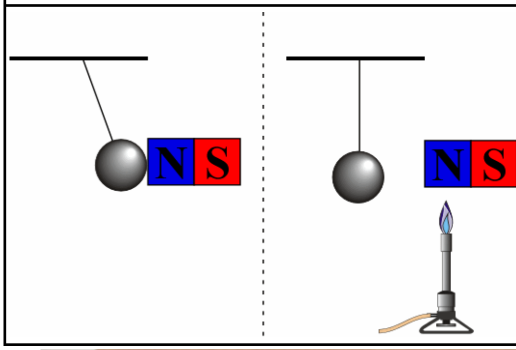
	Liquid oxygen sticks to the pole pieces of an electromagnet until it evaporates

Location: Floor, Hb6

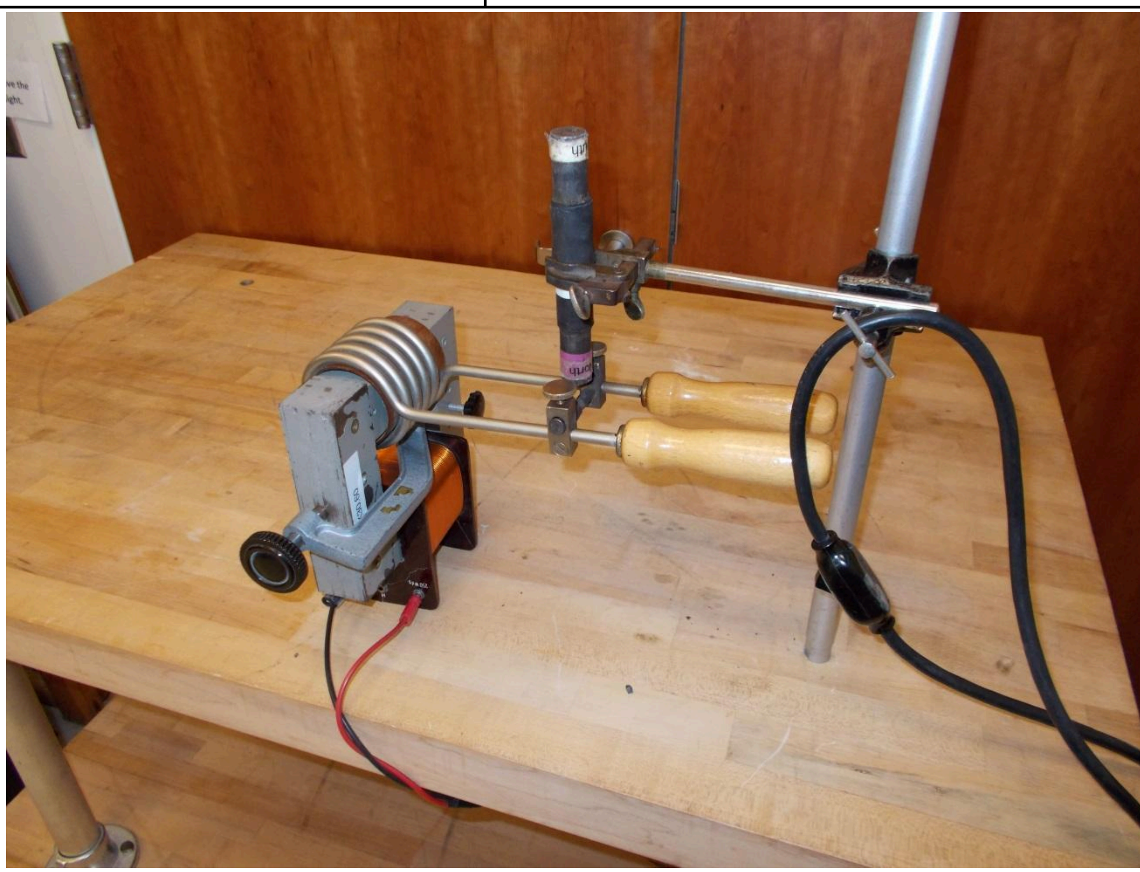
Electricity and Magnetism	5G50.10	MAGNETIC MATERIALS

Temperature and Magnetism

Curie Point



Iron under magnetic attraction is heated until it falls away. Upon cooling it is again attracted.



Location: Ia2, Ib3

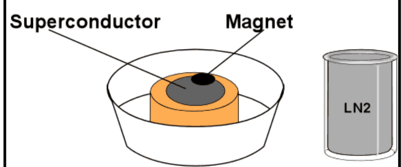
Electricity and Magnetism	5G50.20	MAGNETIC MATERIALS
Temperature and Magnetism		
Magnetic Heat Motor		
	A thin strip of magnetic alloy around the rim of a well balanced wheel is placed in the gap of a magnet (ours has been modified with modern Neodymium-Iron-Boron magnets as pole pieces) with a light focused on a point just above the magnet. Heating changes the permeability of the alloy and the wheel rotates.	

Location: Hb6, Jd3

Electricity and Magnetism	5G50.50	MAGNETIC MATERIALS

Temperature and Magnetism

Meissner Effect



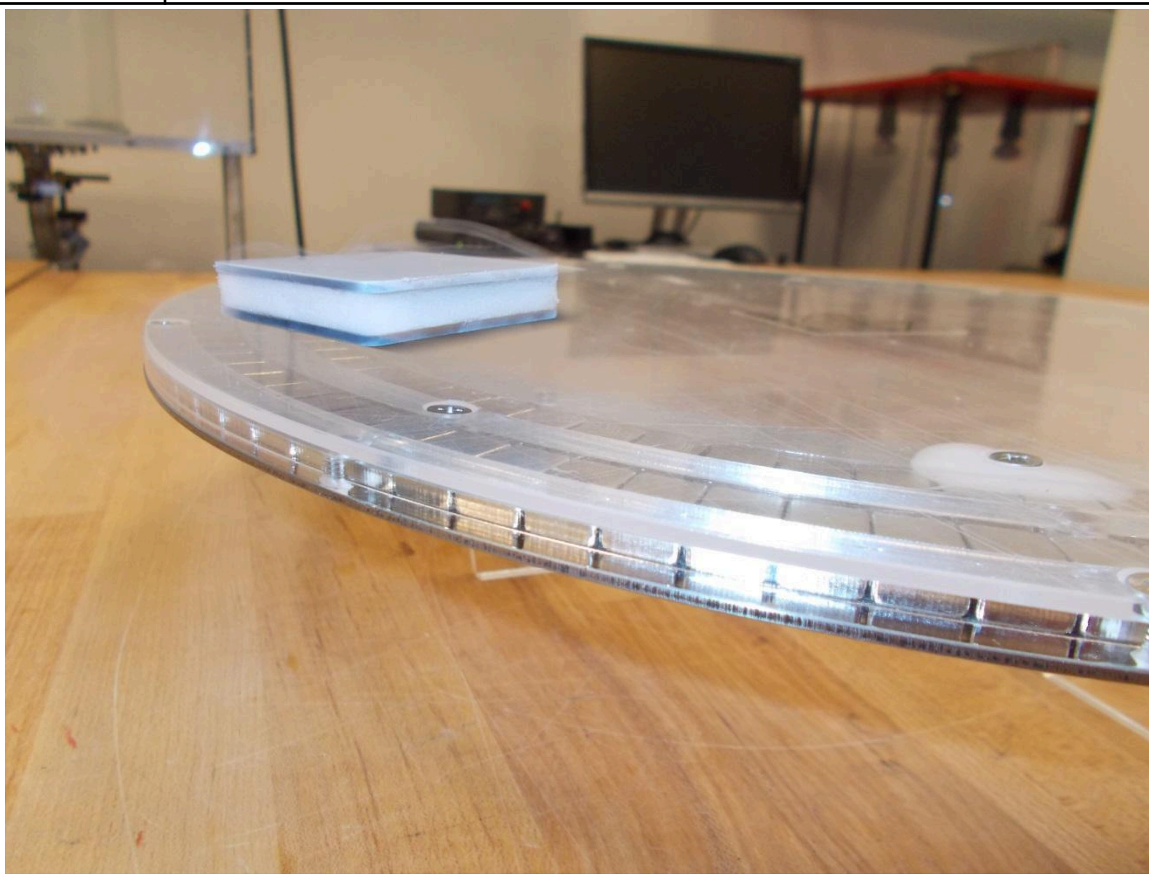
Place a magnet on warm superconducting disk to show how nothing happens, then remove. Add LN2 to the Styrofoam container holding the super conducting disk. When the boiling stops, the disk is cold. Use the plastic tweezers to place one of the magnets on the disk. The magnet will float above the disk.

Location: Hb4, Ga2

Electricity and Magnetism	5G50.51	MAGNETIC MATERIALS
Temperature and Magnetism		

Maglev Track

	A superconductor floats over a track consisting of two rings of magnets. The inner ring is polarized up and the outer ring is polarized down. Because of flux pinning, the superconductor stays over the track and because the flux is nearly constant, it moves with almost no friction. It will float for about a minute and a half.



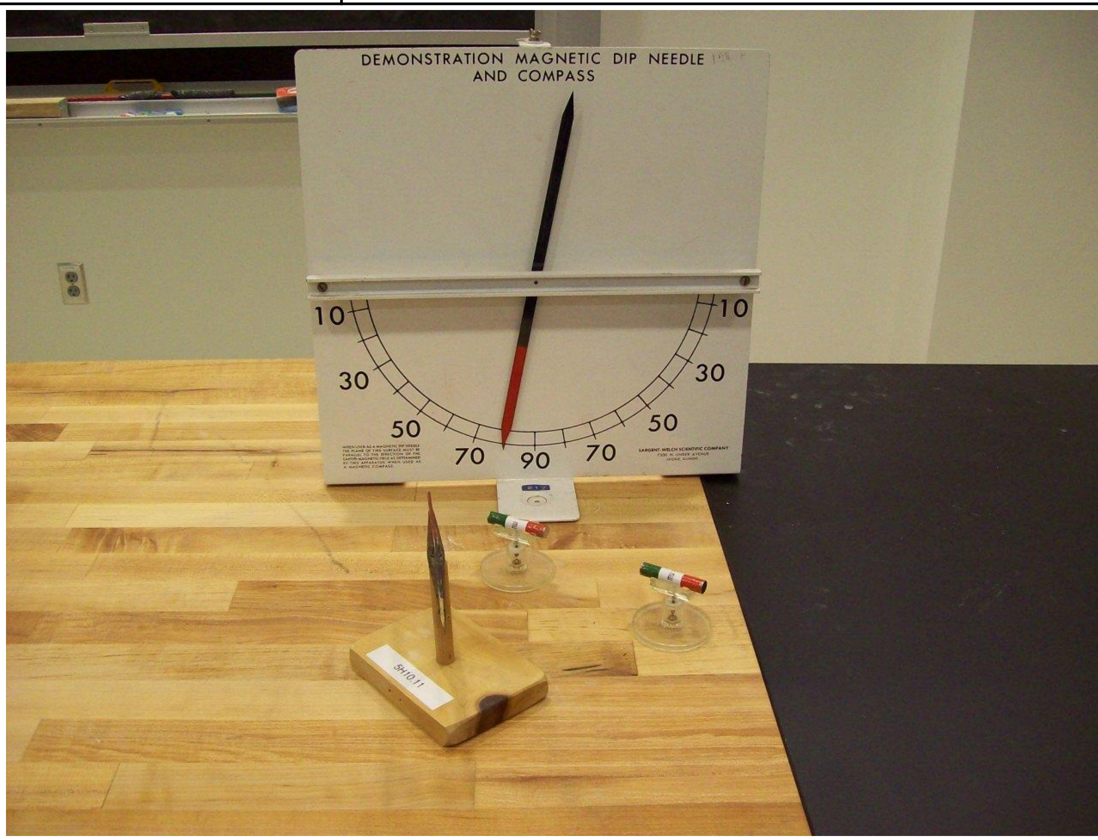
Location: Hb5, Ga2

Electricity and Magnetism	5H10.11	MAGNETIC FIELDS AND FORCES

Magnetic Fields

Compass Needle and Magnets

	A large compass, small compasses for use on an overhead projector, a small magnet on a pivot and a bar magnet are used to show magnetic fields.

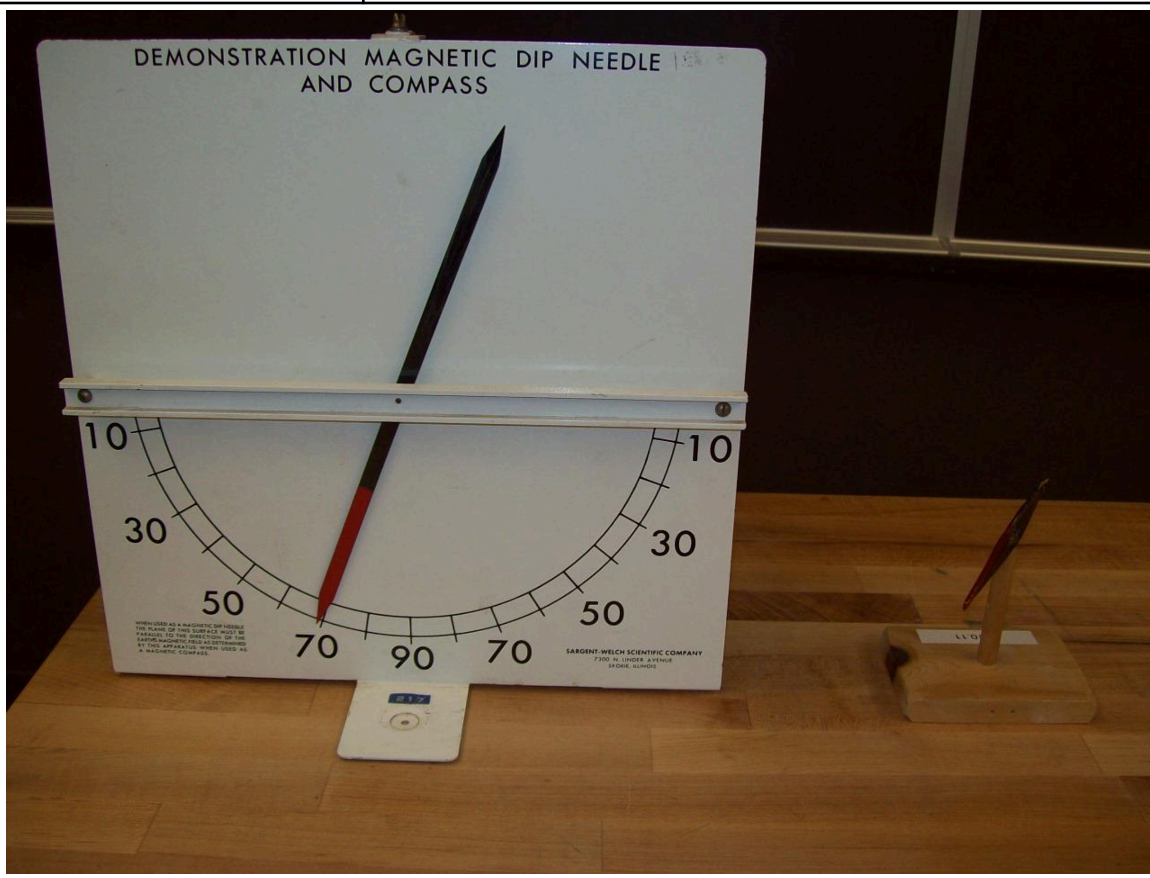


Location: Hb7

Electricity and Magnetism	5H10.15	MAGNETIC FIELDS AND FORCES
	Magnetic Fields	

Dip Needle

	A dip needle is used to show the inclination of the Earth's magnetic field.

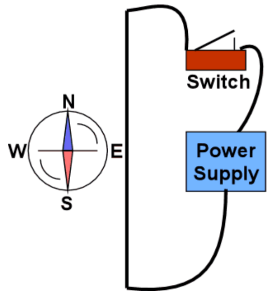


Location: Hb7

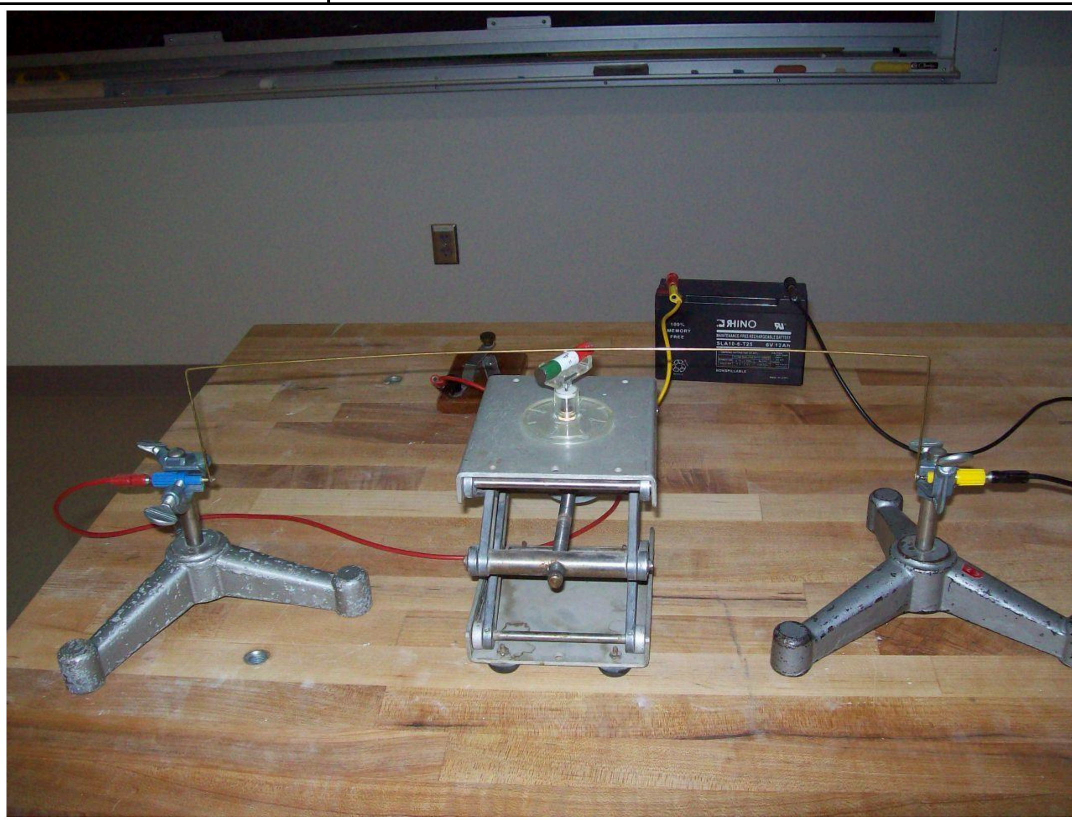
Electricity and Magnetism	5H10.20	MAGNETIC FIELDS AND FORCES

Magnetic Fields

Oersted's Effect



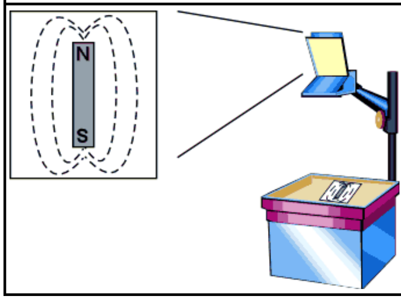
Turn the compass needle so it is approximately parallel to the wire. Close the switch to send the current through the wire for a few seconds. The compass will align itself with the magnetic field.

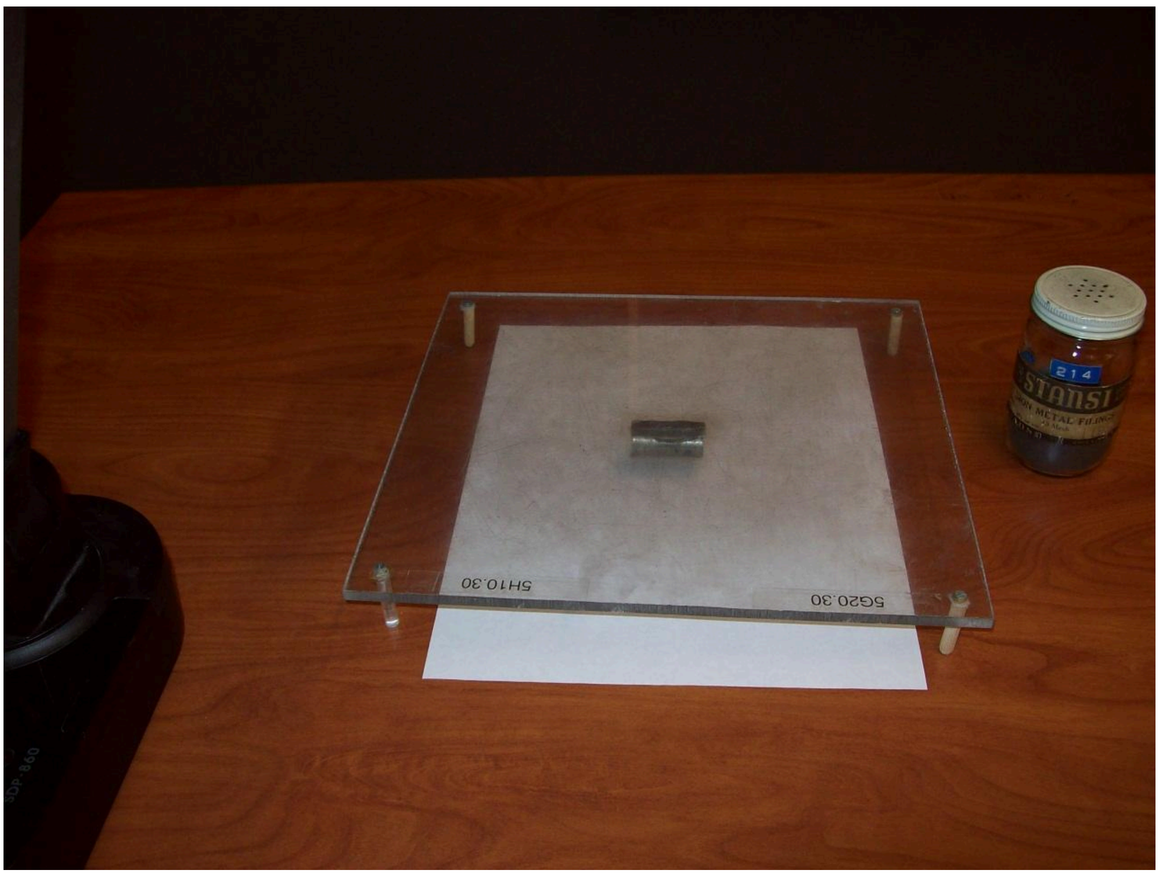


Location: Hb7

Electricity and Magnetism	5H10.30	MAGNETIC FIELDS AND FORCES
	Magnetic Fields	

Magnet and Iron Filings

	Sprinkle iron filings on the Plexiglas plate. Tap the Plexiglas to encourage alignment.

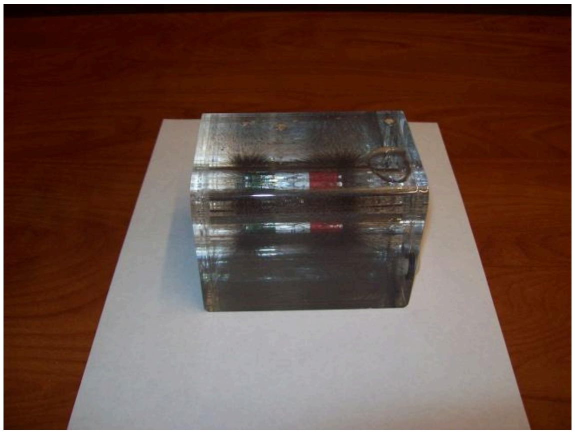


Location: Hb4, Hc1

Electricity and Magnetism	5H10.31	MAGNETIC FIELDS AND FORCES
	Magnetic Fields	

Iron Filings in Oil

	A suspension of iron filings in silicone oil is used to show a three dimensional representation of the magnetic field around a bar magnet.

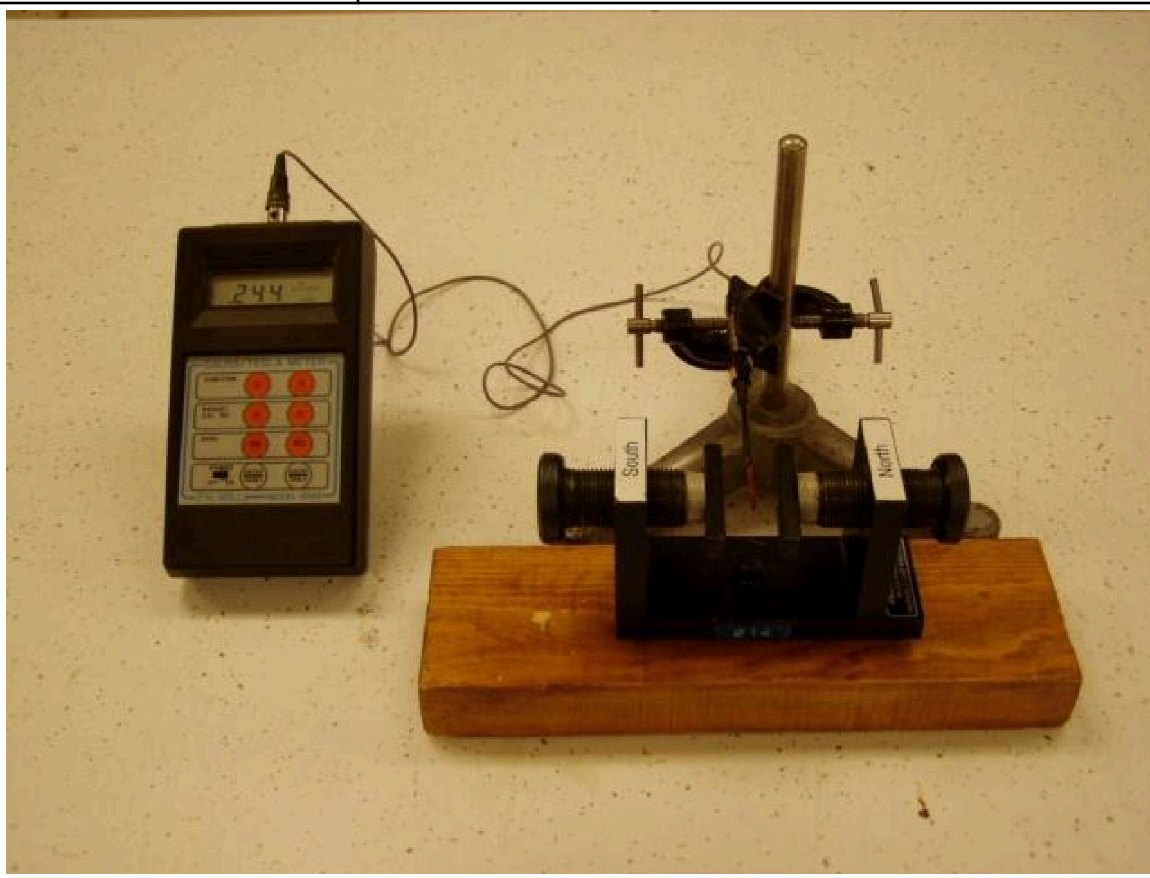


Location: Hc1

Electricity and Magnetism	5H10.55	MAGNETIC FIELDS AND FORCES
Magnetic Fields		

Gap and Field Strength

	Vary the gap of a magnet and measure the field with a gaussmeter.

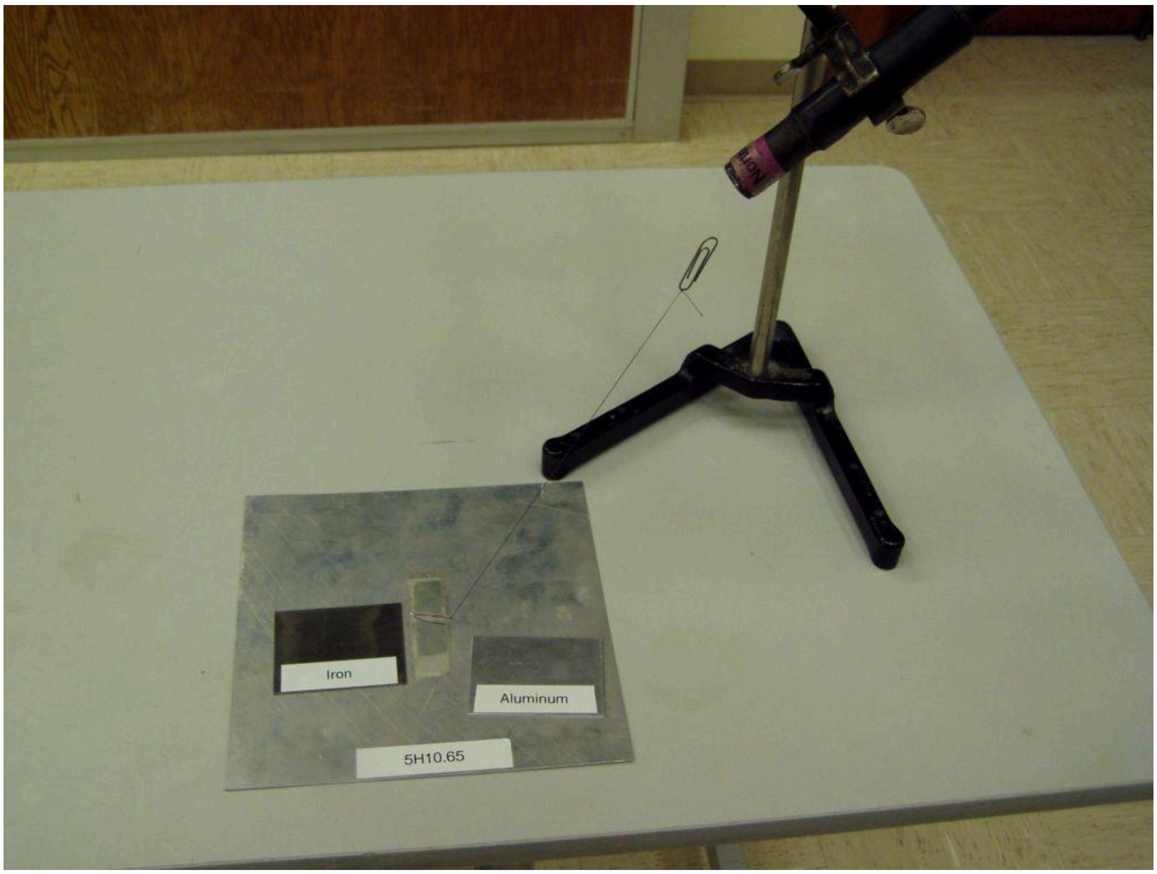


Location: Hc1, Ia5

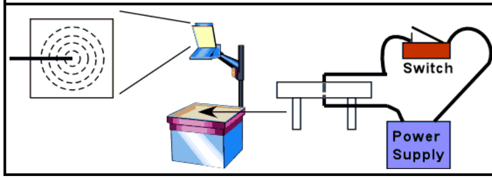
Electricity and Magnetism	5H10.65	MAGNETIC FIELDS AND FORCES
Magnetic Fields		

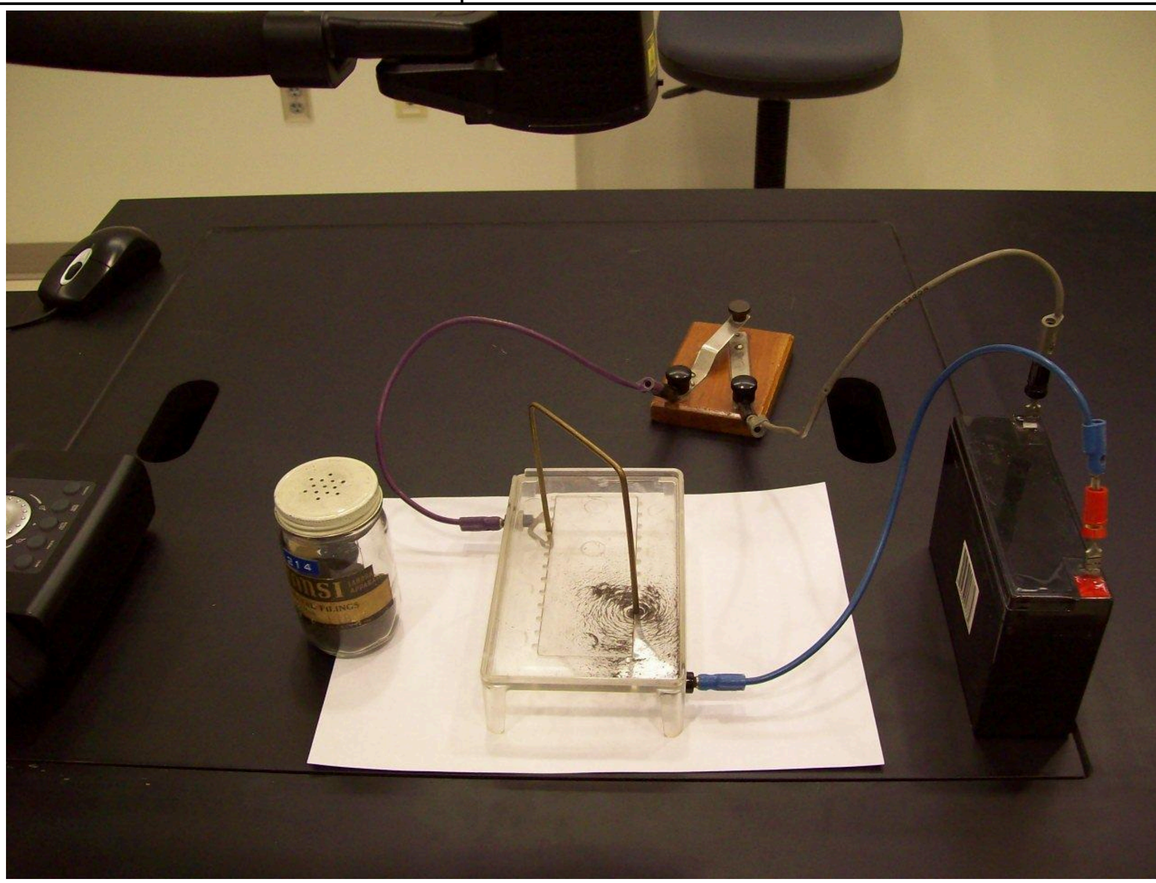
Magnetic Screening

	Hold a magnet above a paper clip held by a string then interpose a sheet of iron; repeat with a sheet of aluminum.



Location: Hb7

Electricity and Magnetism	5H15.10	MAGNETIC FIELDS AND FORCES
Fields and Currents		
# Magnetic Field around a Wire		
	Sprinkle iron filings on the Plexiglas. Hold down the switch briefly connecting the bottom while tapping the Plexiglas to encourage alignment.	

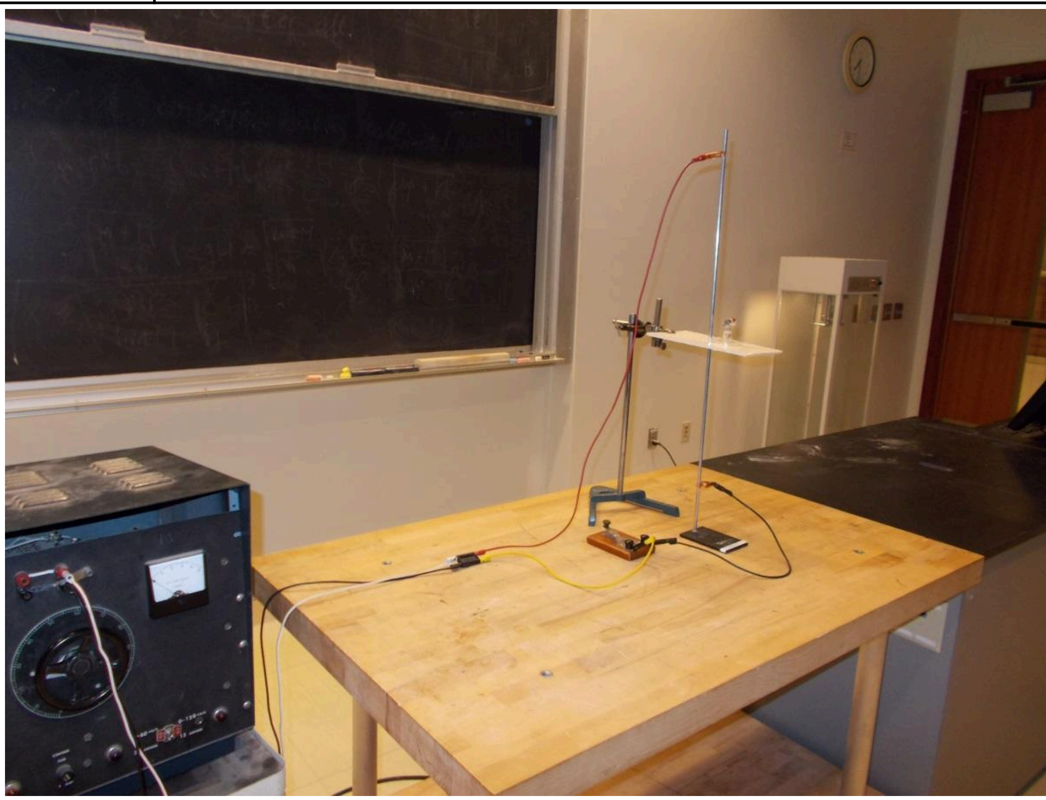


Location: Hc2

Electricity and Magnetism	5H15.13	MAGNETIC FIELDS AND FORCES
Fields and Currents		

Right Hand Rule

	Move a compass around a vertical current carrying wire. Do not hold the tap key down for more than a second or two. Set the power supply to supply about 25 amperes of current.

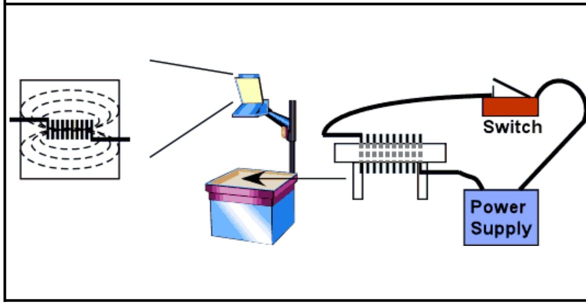


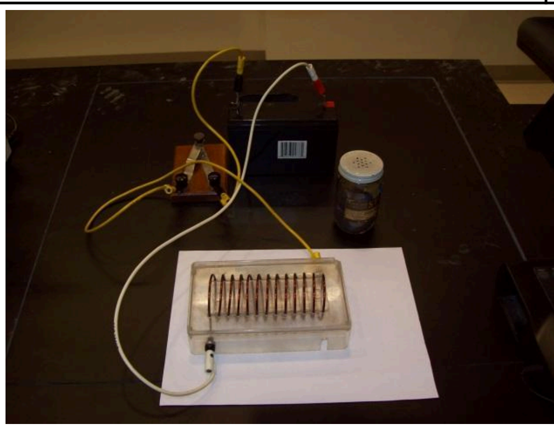
Location: Hb2, Hb7, Hc2

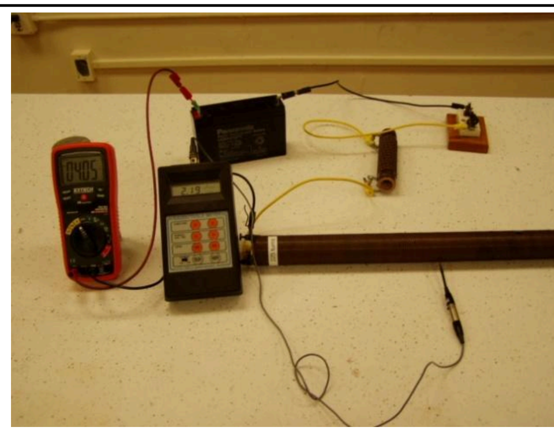
Electricity and Magnetism	5H15.40	MAGNETIC FIELDS AND FORCES

Fields and Currents

Field of a Solenoid

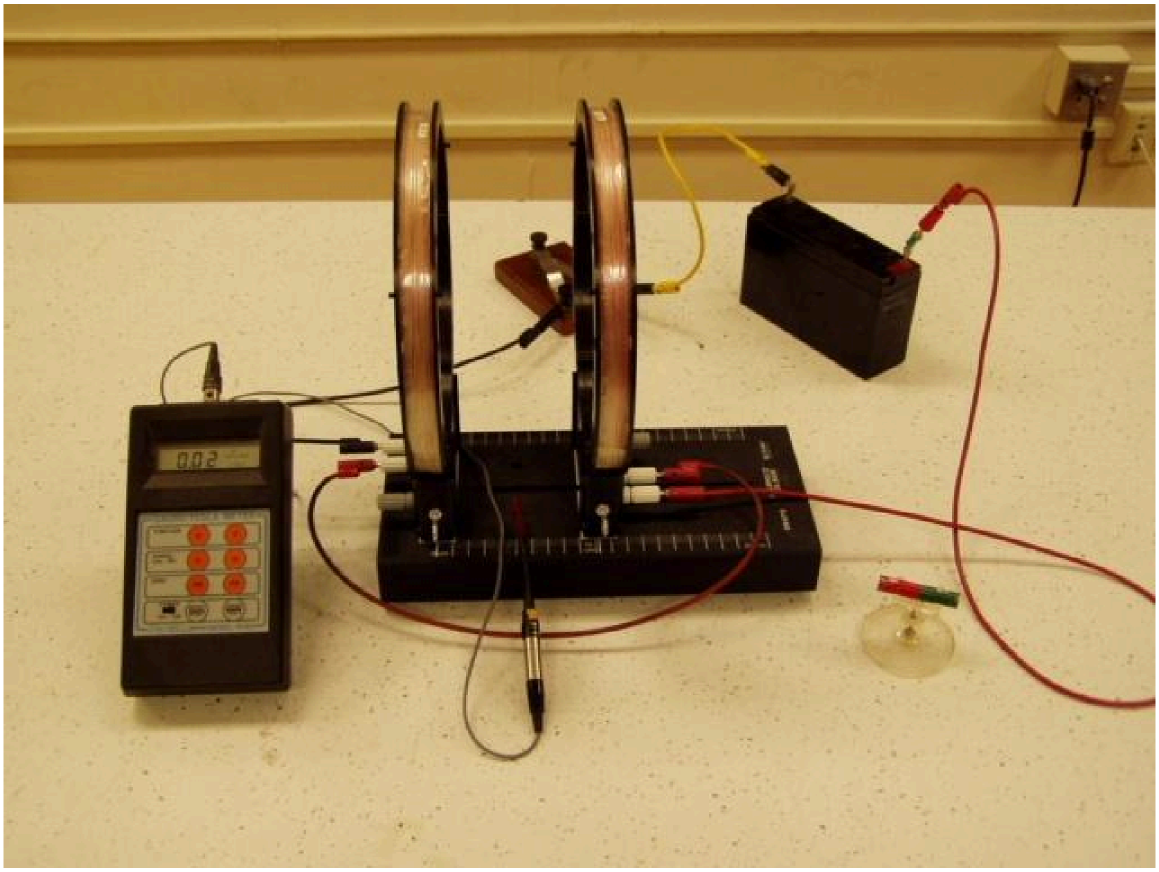
	Sprinkle iron filings on the Plexiglas. Hold down the tap switch briefly connecting the bottom while tapping the Plexiglas to encourage alignment. In the second photograph, the field of the solenoid is measured with a gaussmeter, with an ammeter measuring the current.





Location: Hb2, Hb3, Hc2, Ia5

Electricity and Magnetism	5H15.46	MAGNETIC FIELDS AND FORCES
	Fields and Currents	
	Helmholtz Coils	
	Generation of a large uniform field with a set of Helmholtz coils can be shown with a Hall probe.	

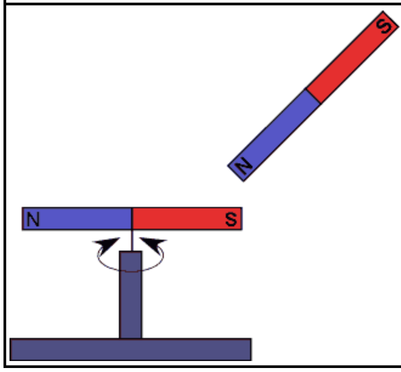


Location: Hc2, Ia5, Hb2, Hb3, Hb7

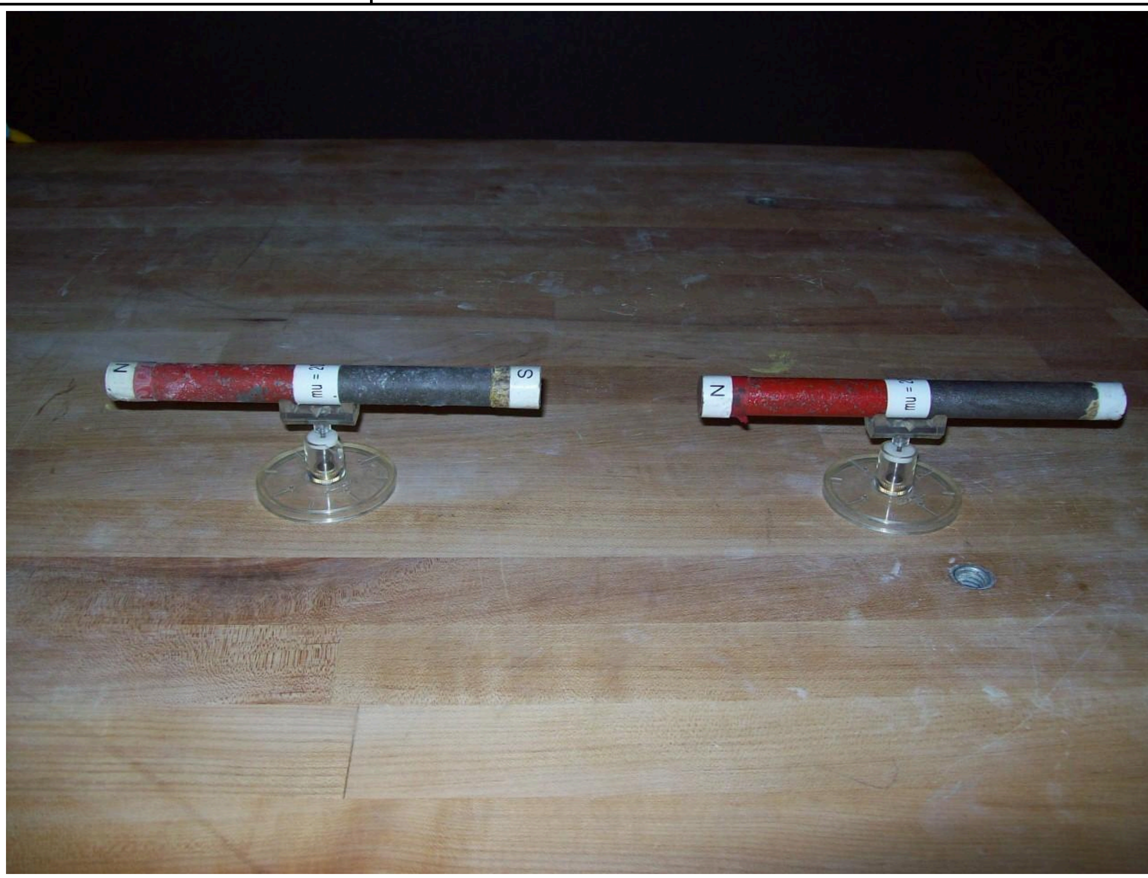
Electricity and Magnetism	5H20.10	MAGNETIC FIELDS AND FORCES

Forces on Magnets

Magnets and Pivot

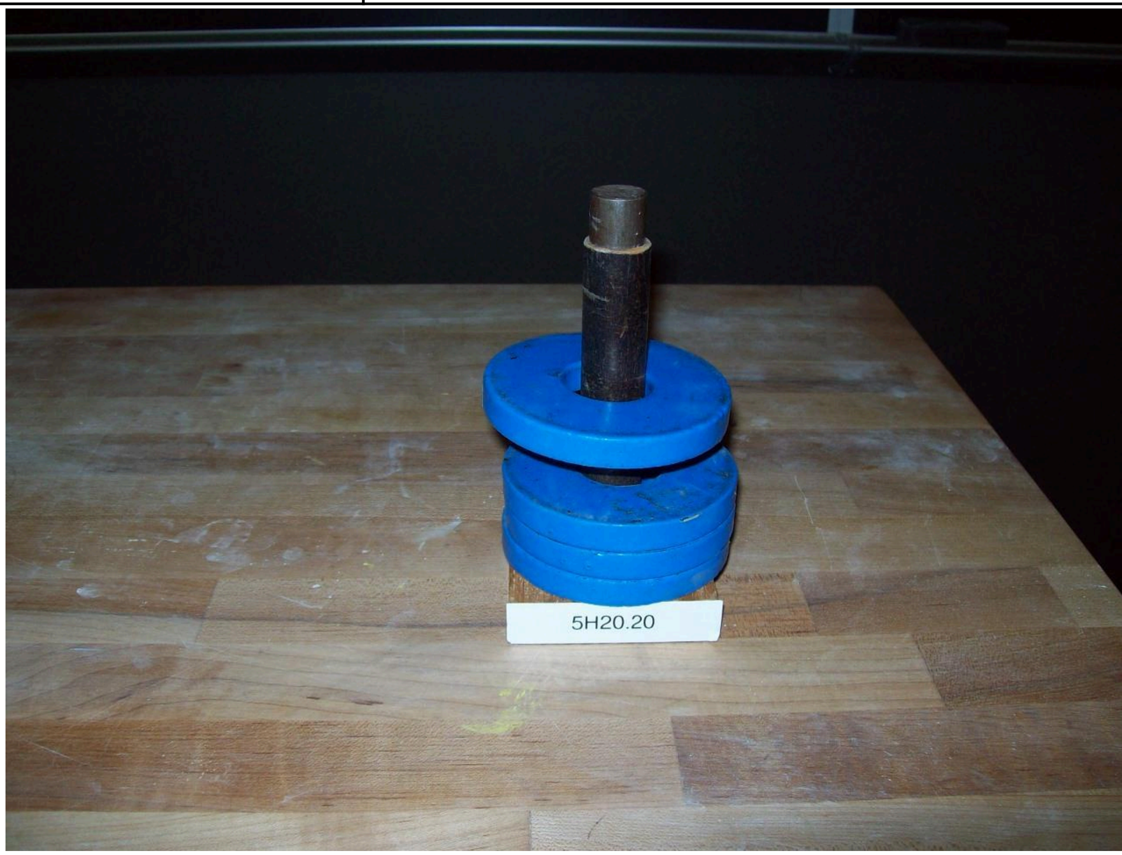


One magnet is centered on a pivot. Hold one end of the second magnet near one end of the magnet on the pivot. Repeat with the opposite end.



Location: Hb7

Electricity and Magnetism	5H20.20	MAGNETIC FIELDS AND FORCES
Forces on Magnets		
Levitation Magnets		
	A ring magnet is suspended above a stack of ring magnets.	

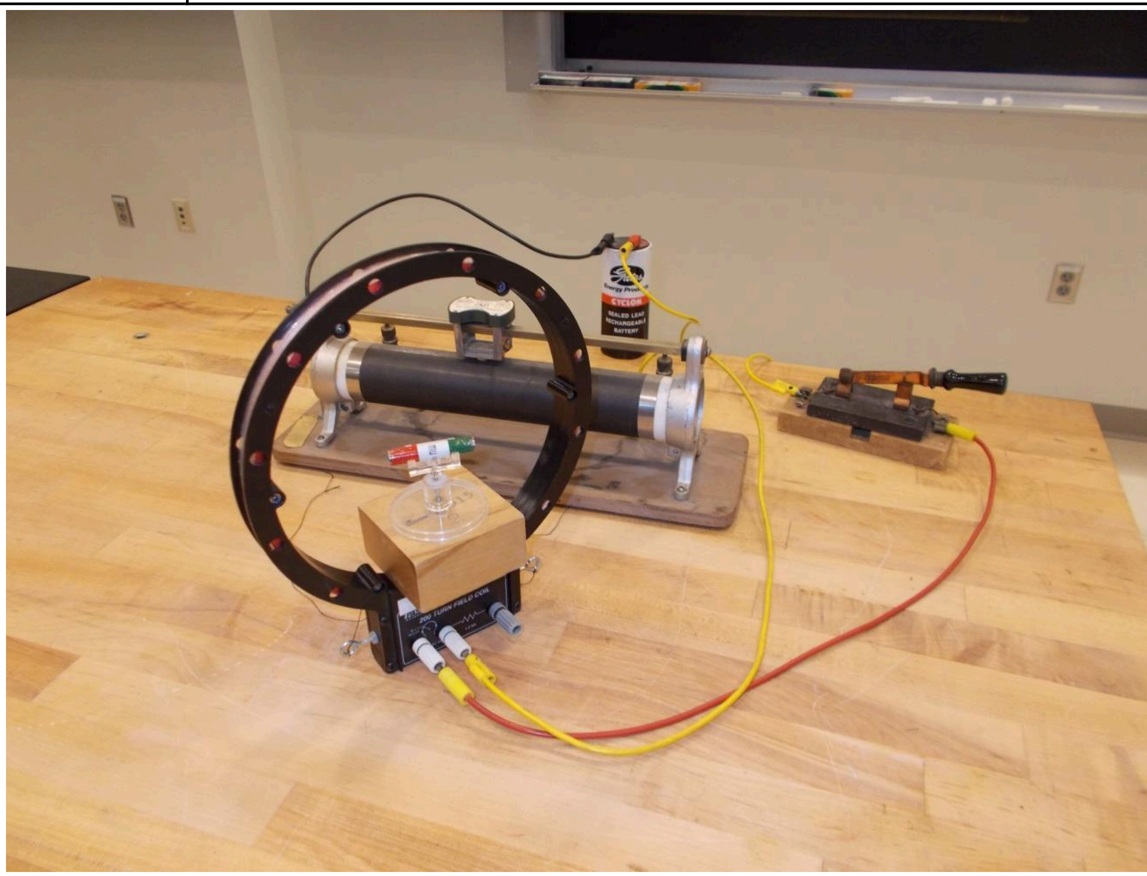


Location: Hb7

Electricity and Magnetism	5H20.22	MAGNETIC FIELDS AND FORCES
Forces on Magnets		
Spin Stabilized Magnet Levitation		
	The Levitron toy. The top must be balanced (have the right mass) and the platform must be leveled. The mass needed is temperature dependent.	

Location: Hc3

Electricity and Magnetism	5H25.10	MAGNETIC FIELDS AND FORCES
Magnet/Electromagnet Interaction		
Magnets in a Coil		
	A compass needle is placed in the center of a large coil oriented in the plane of the Earth field's magnetic meridian. The current in the coil is proportional to the tangent of the angle through which the needle is deflected.	



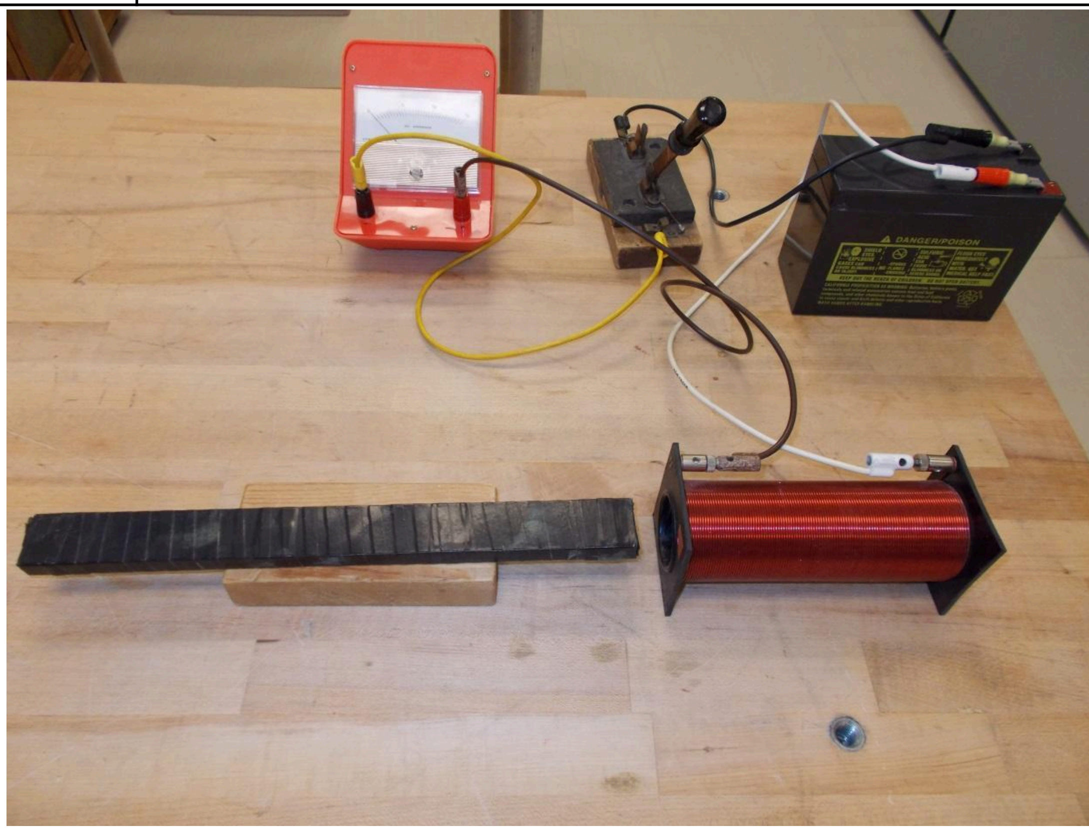
Location: Hb7, Hc2, Hc3

Electricity and Magnetism	5H25.25	MAGNETIC FIELDS AND FORCES

Magnet/Electromagnet Interaction

Force on a Solenoid Core

When a dielectric is brought near the charged plates of a capacitor, it is drawn in. The energy to pull it in is accounted for by the reduction in the energy stored in the capacitor, since the charge remains constant and the voltage across the capacitor drops. If an iron bar is brought near a current carrying solenoid, it is drawn in, but in this case the stored energy goes up since the current is the same and the inductance has gone up. Where does the energy come from to draw the iron bar in?



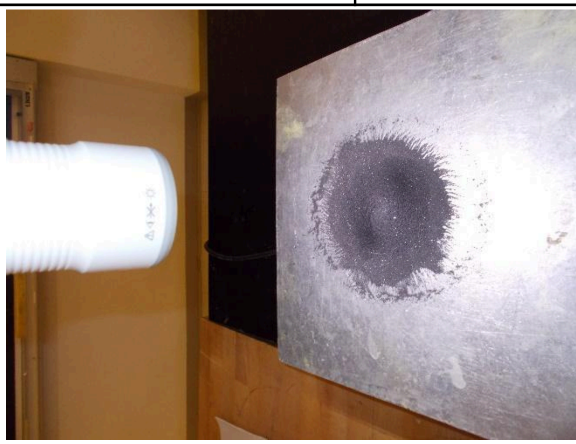
Location: Hc3

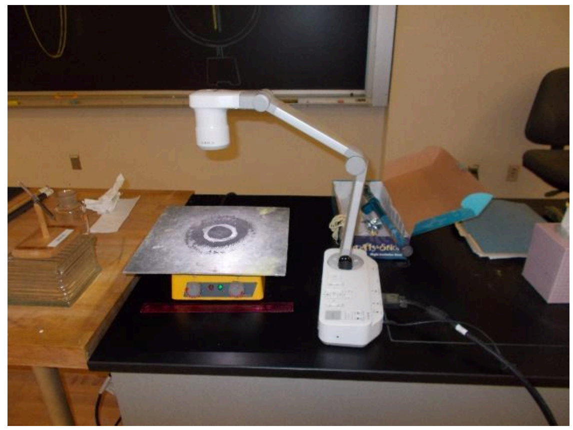
Electricity and Magnetism	5H25.75	MAGNETIC FIELDS AND FORCES

Magnet/Electromagnet Interaction

Ampere's Ants

	Iron filings on a aluminum plate that is on top of a magnetic stirrer.

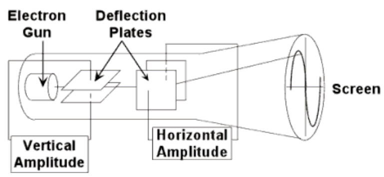




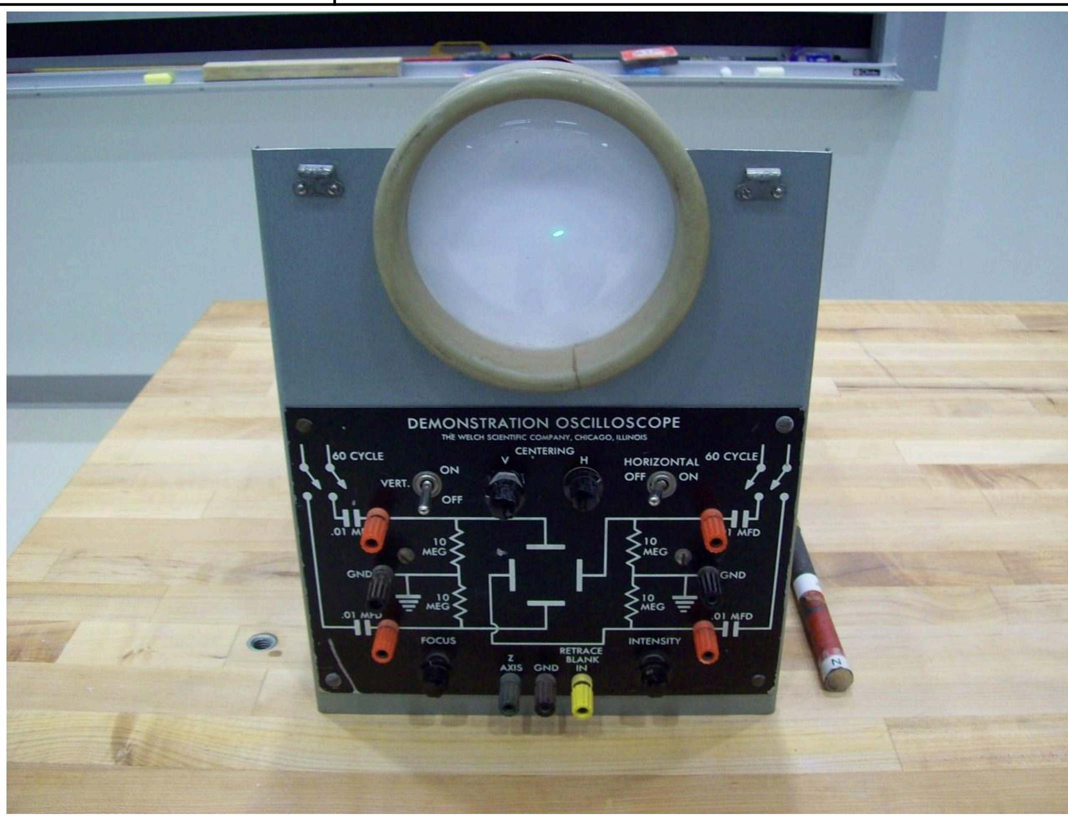
Location: Gb2, Hc3

Electricity and Magnetism	5H30.10	MAGNETIC FIELDS AND FORCES
	Force on Moving Charges	

Cathode Ray Tube



Plug in the cathode ray tube. Deflect the beam of the CRT by holding a permanent magnet near the edge of the tube. If the beam disappears, you are holding the magnet too close.
OR, deflect the beam by attaching a battery to the binding posts and adjusting the variable control knob.
OR connect the battery directly to the deflection plate terminals.



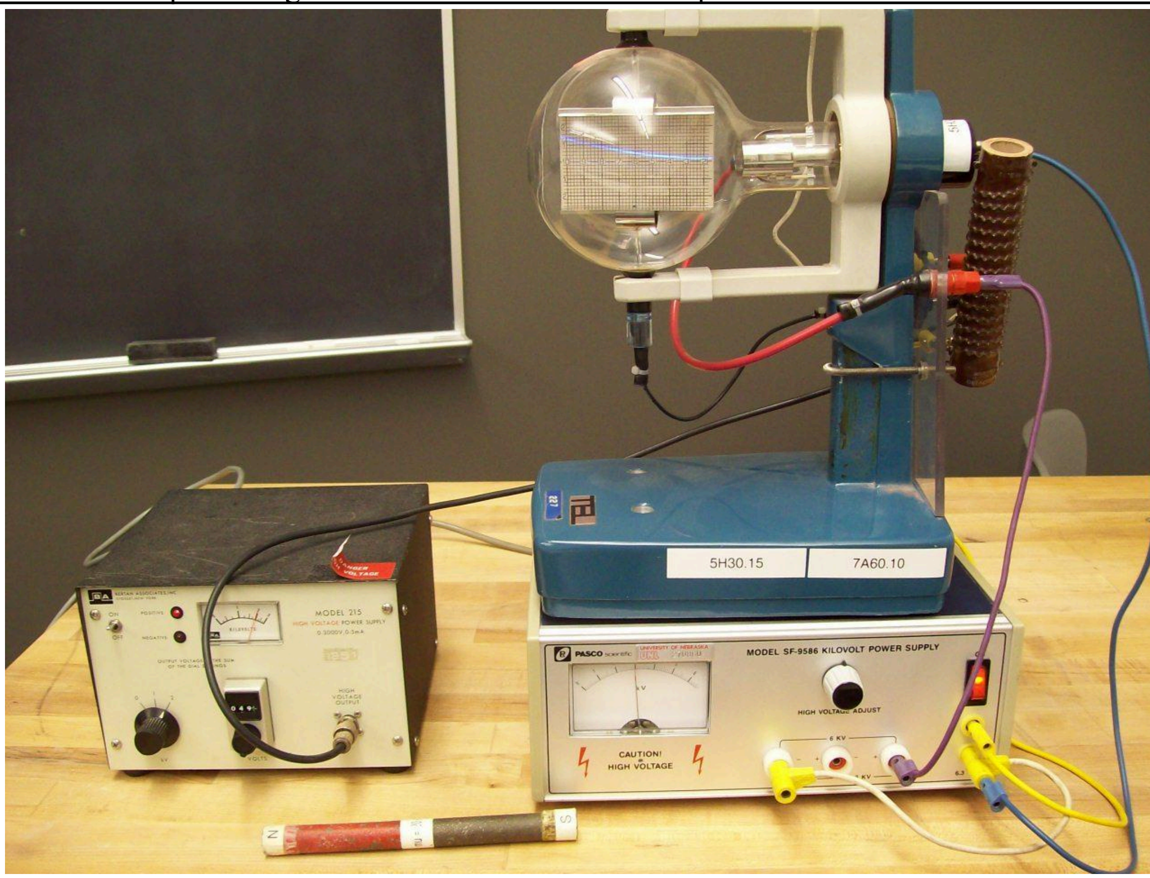
Location: Hc3, Ib3

Electricity and Magnetism	5H30.15	MAGNETIC FIELDS AND FORCES

Force on Moving Charges

Bending an Electron Beam

	An electron beam along a fluorescent screen is bent using either a deflecting potential or a magnetic field. Typical values: electron energy, 5 keV, deflecting potential 2kV. The 1 ohm resistor is used to limit current to the filament extending the life of the tube which is expensive.

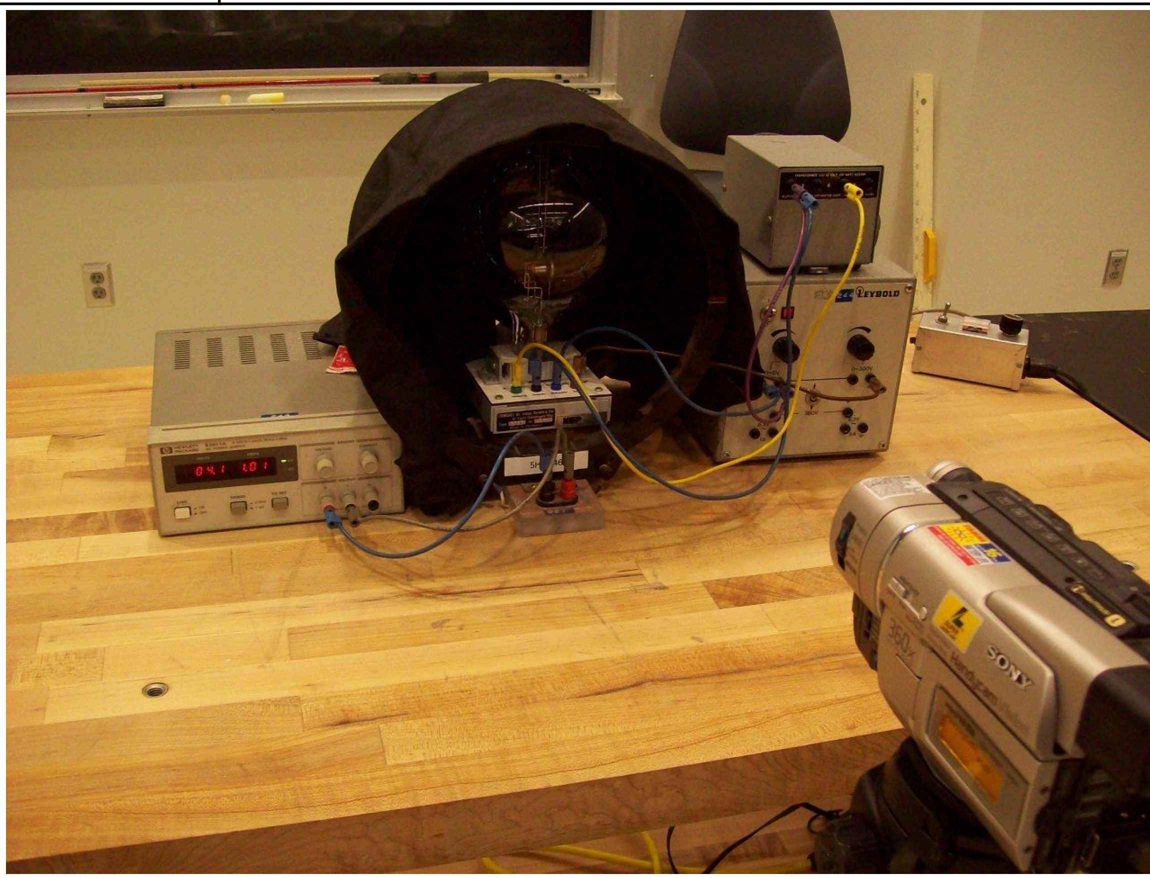


Location: Hc4

Electricity and Magnetism	5H30.20	MAGNETIC FIELDS AND FORCES
Force on Moving Charges		

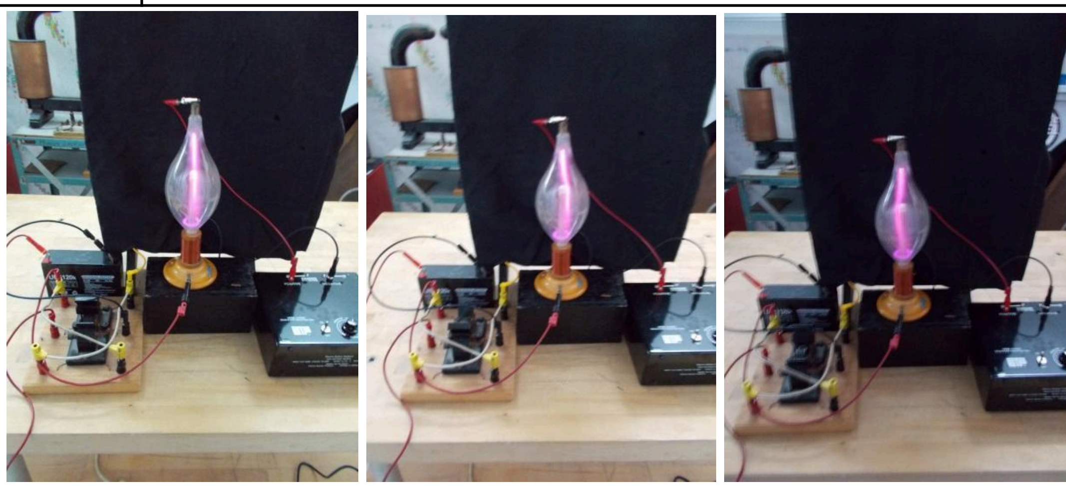
e/m Tube

	Use the power supply connected to the Helmholtz coils to bend the electron beam into a circle. This needs to be done in a darkened room with a TV camera.



Location: Hc4, Hc2

Electricity and Magnetism	5H30.30	MAGNETIC FIELDS AND FORCES
Force on Moving Charges		
Rotating Plasma		
	A solid state induction coil is used to power a de la Rive tube. When the current to the coil powering the electromagnet is turned on, the plasm spirals one way or the other depending on the direction of the current. The gas in the tube is rarified air. The induction coil is at about 30kV and the coil current is about 4 A.	



Location: Id1, Hc4, Hb3, Power Supplies

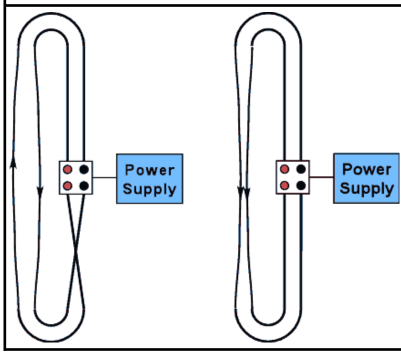
Electricity and Magnetism	5H30.55	MAGNETIC FIELDS AND FORCES
Force on Moving Charges		
Ion Motor/Magnetohydrodynamic Motor		
	A vessel containing copper Sulfate solution has a magnet in the center of its bottom and a current going from the periphery to the center. Lycopodium powder is sprinkled on the solution and you can see it rotate. Reverse the current flow and it rotates the other way.	

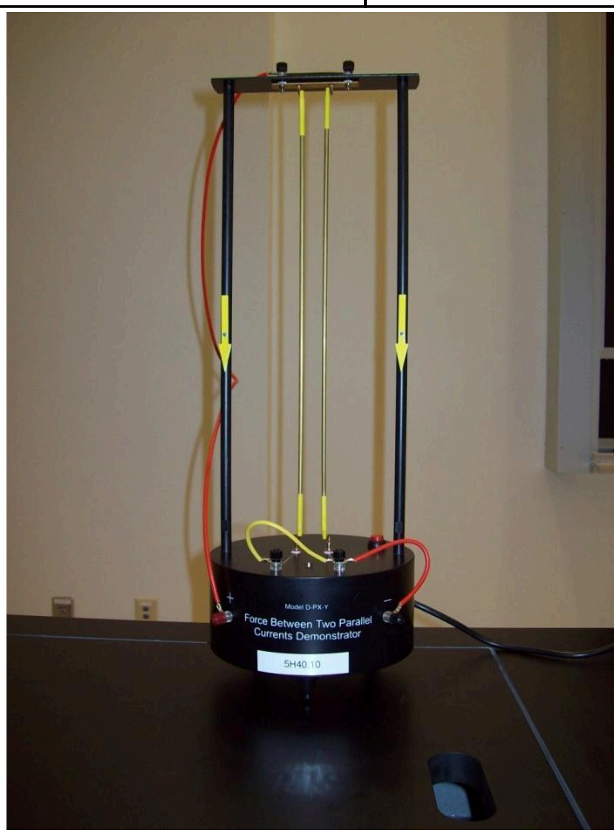
Location: Hc3

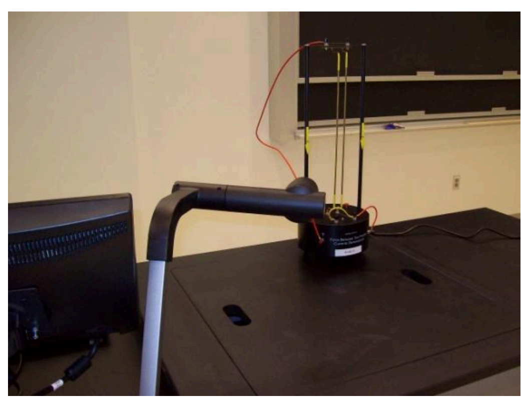
Electricity and Magnetism	5H40.10	MAGNETIC FIELDS AND FORCES

Forces on Current in Wires

Parallel Wires

	Two wires pivot vertically from a frame. Press the button and the wires will attract or repel each other. Change the wiring for parallel or ant-parallel currents and use the yellow arrows to indicate the directions.

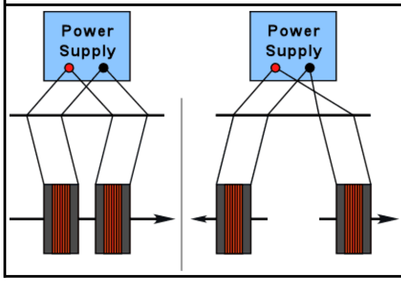




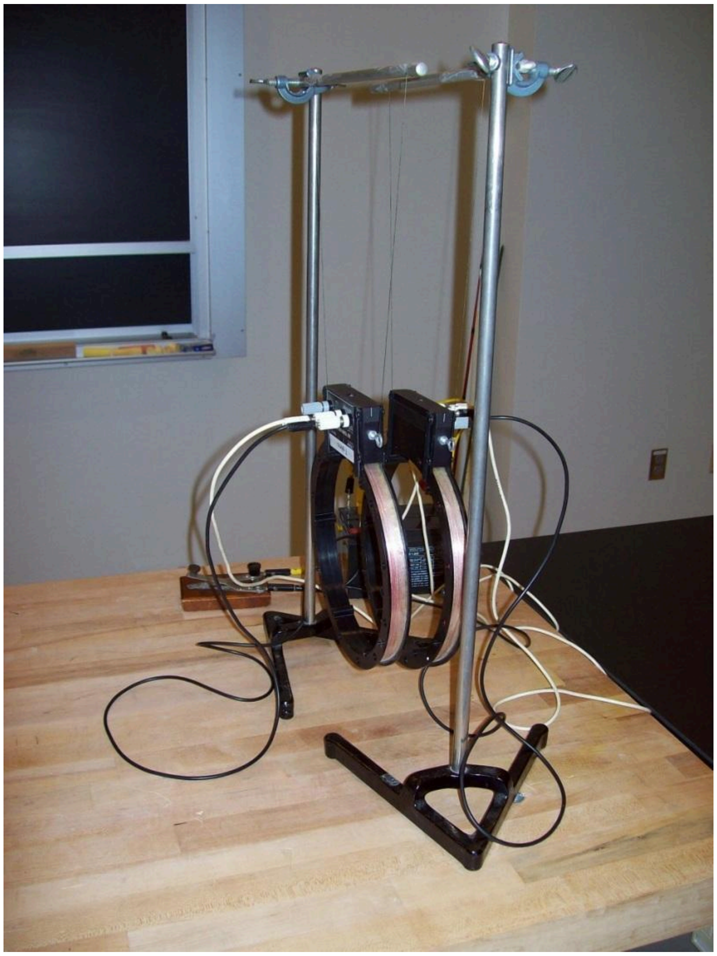
Location: Hb2, Hb3, Hc5

Electricity and Magnetism	5H40.15	MAGNETIC FIELDS AND FORCES
Forces on Current in Wires		

Interacting Coils

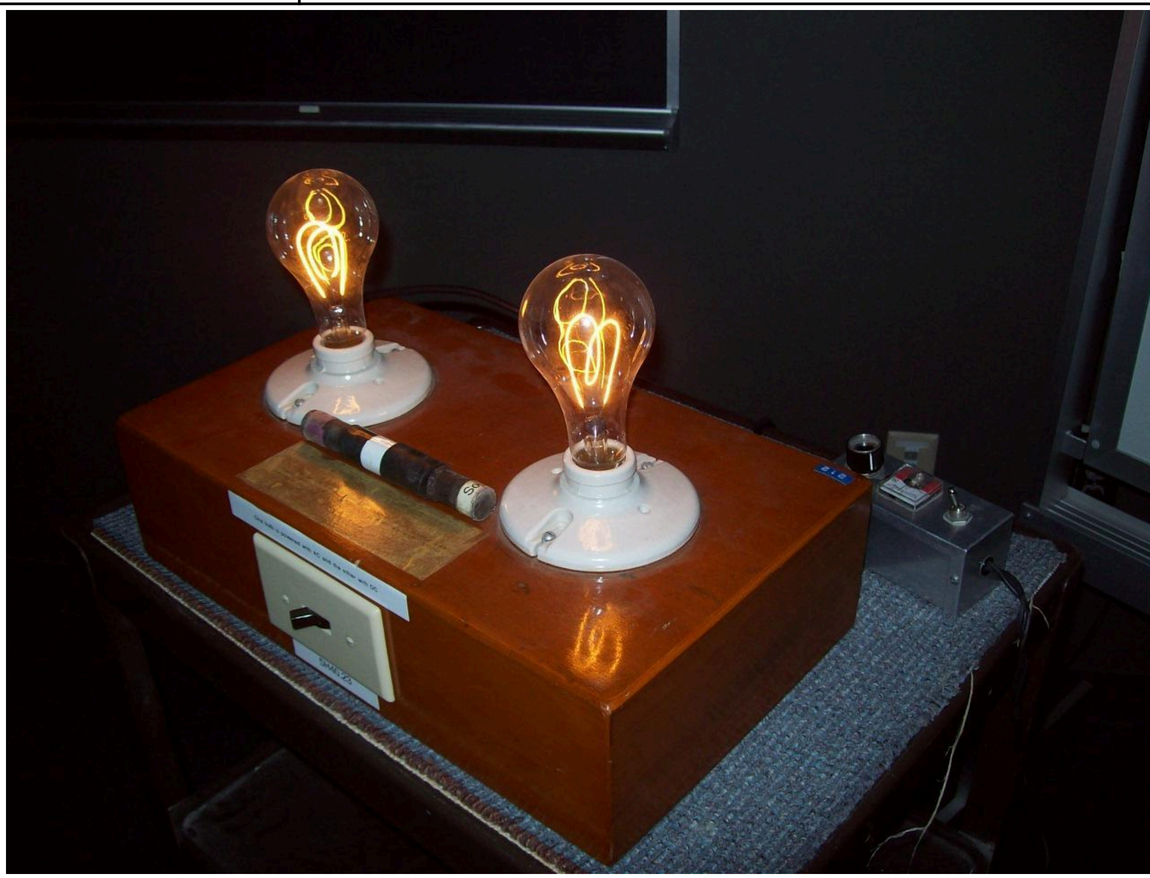


Hang two coils from a support rod. Connect the battery so that the current is in the same direction in both coils and watch them attract. Reverse the current in one of the coils and watch them repel. Do not hold the tap key down too long otherwise the coils may overheat.



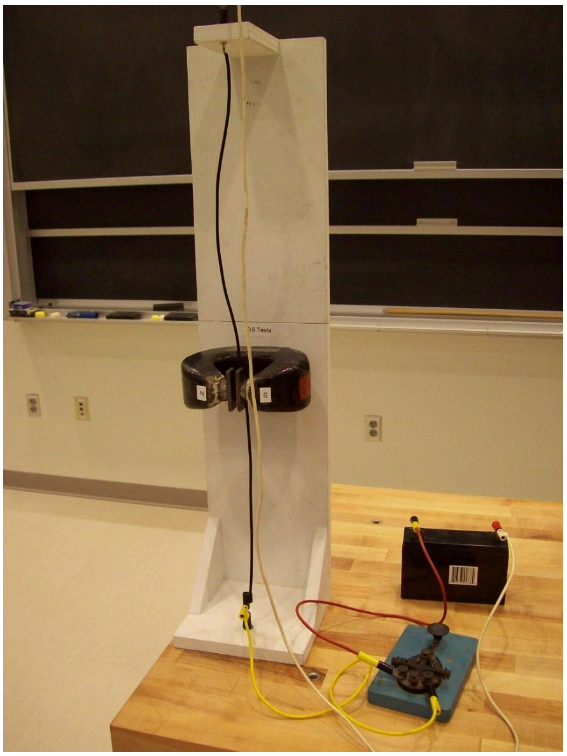
Location: Hb2, Hb3, Hc2

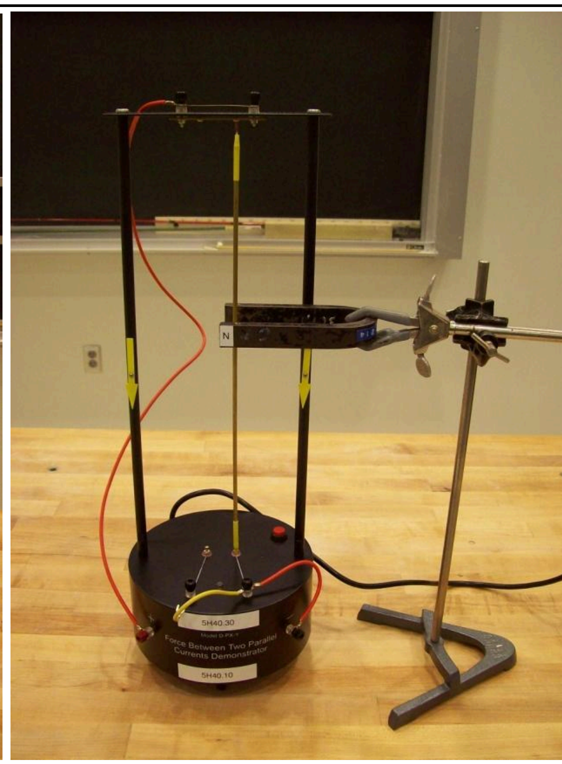
Electricity and Magnetism	5H40.23	MAGNETIC FIELDS AND FORCES
Forces on Current in Wires		
Vibrating Filament Lamp		
	A magnet is brought near carbon filament lamps, one powered by AC, the other by DC.	



Location: Hc5, Ib3

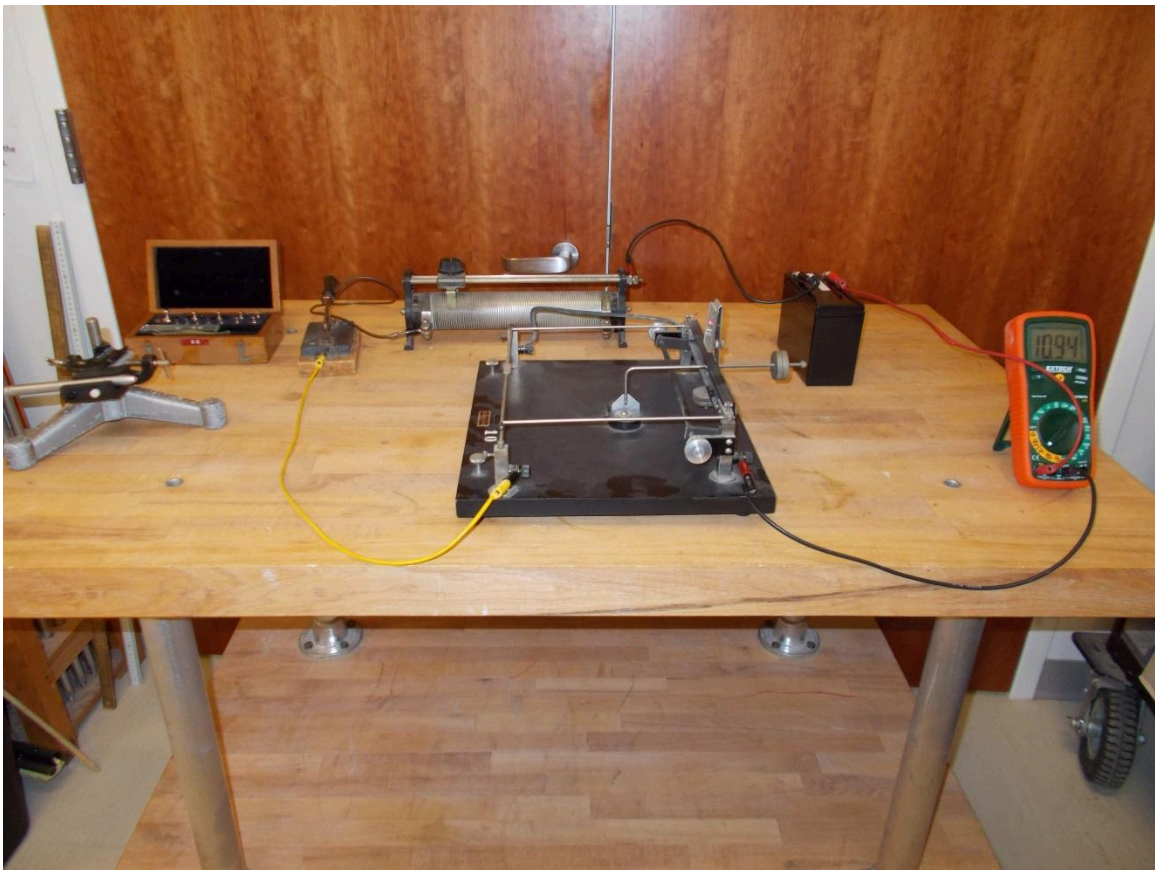
Electricity and Magnetism	5H40.30	MAGNETIC FIELDS AND FORCES
Forces on Current in Wires		
Jumping Wire		
	A long wire hangs between the poles of a magnet. Press the tap key and current flows through the wire causing to jump out away from the magnet or in toward the board on which the magnet is mounted, depending on the direction of the current. Two versions are shown.	





Location: Hb2, Hb3, Hc5

Electricity and Magnetism	5H40.43	MAGNETIC FIELDS AND FORCES
Forces on Current in Wires		
Current Balance		
	The Welch current balance. Use 10-20 A for a reasonable deflection. A laser used as a light lever.	



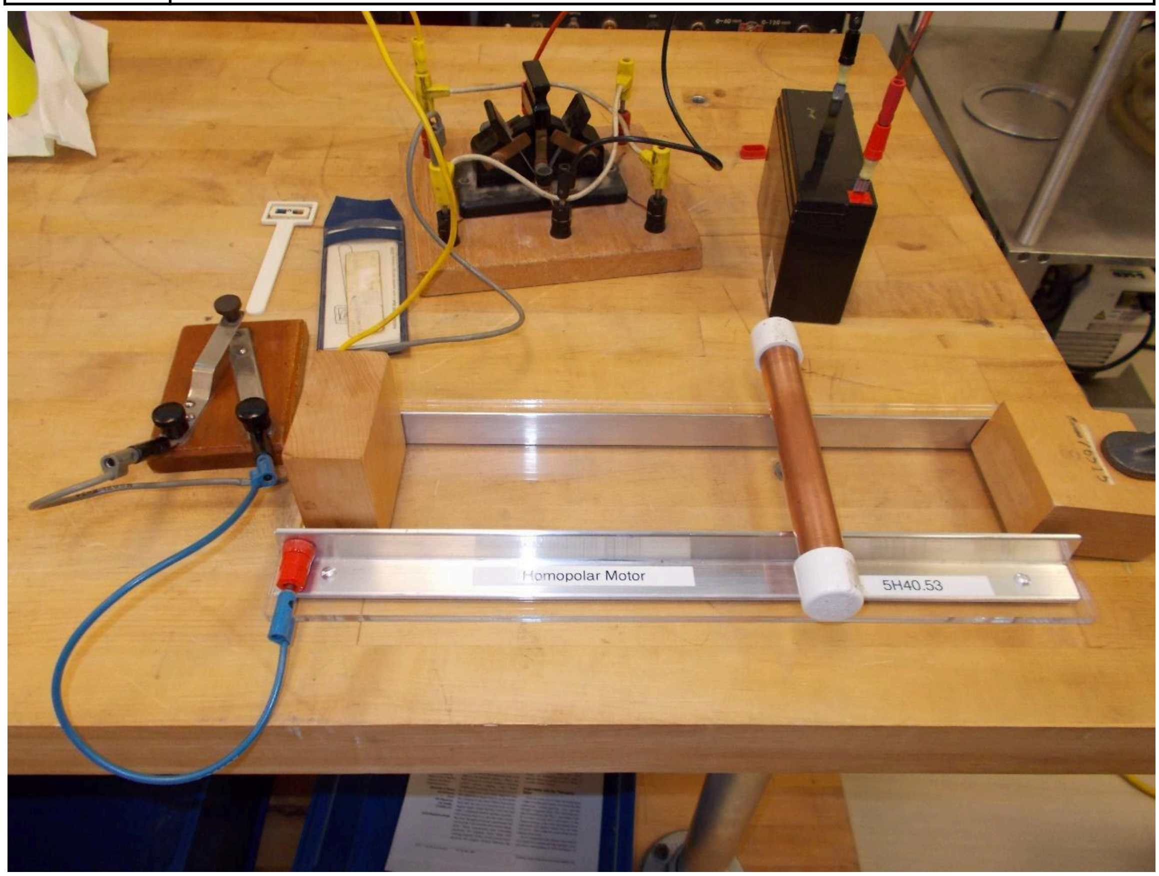
Location: Ha6, Hb2, Hb3

Electricity and Magnetism	5H40.53	MAGNETIC FIELDS AND FORCES

Forces on Current in Wires

Homopolar Motor

A copper pipe containing two magnets with opposing poles facing each other is placed on conducting rails, When current is passed through the pipe from the rails, the pipe will roll. Reverse the current and it rolls the other way. This is a subtle demonstration so be sure to read "A Different Twist on the Lorentz Force and Faraday's Law" The Physics Teacher, V. 36, Nov 1998, p. 474.

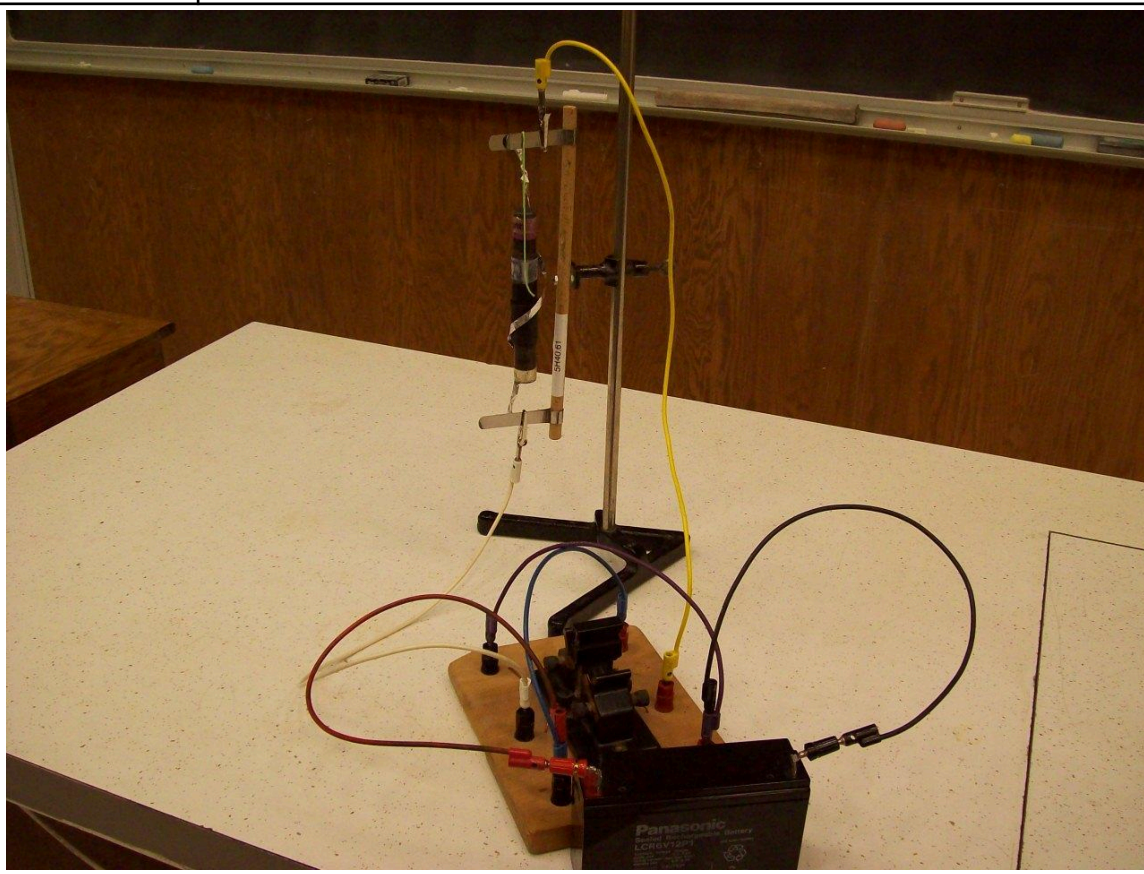


Location: Hc5

Electricity and Magnetism	5H40.61	MAGNETIC FIELDS AND FORCES
Forces on Current in Wires		

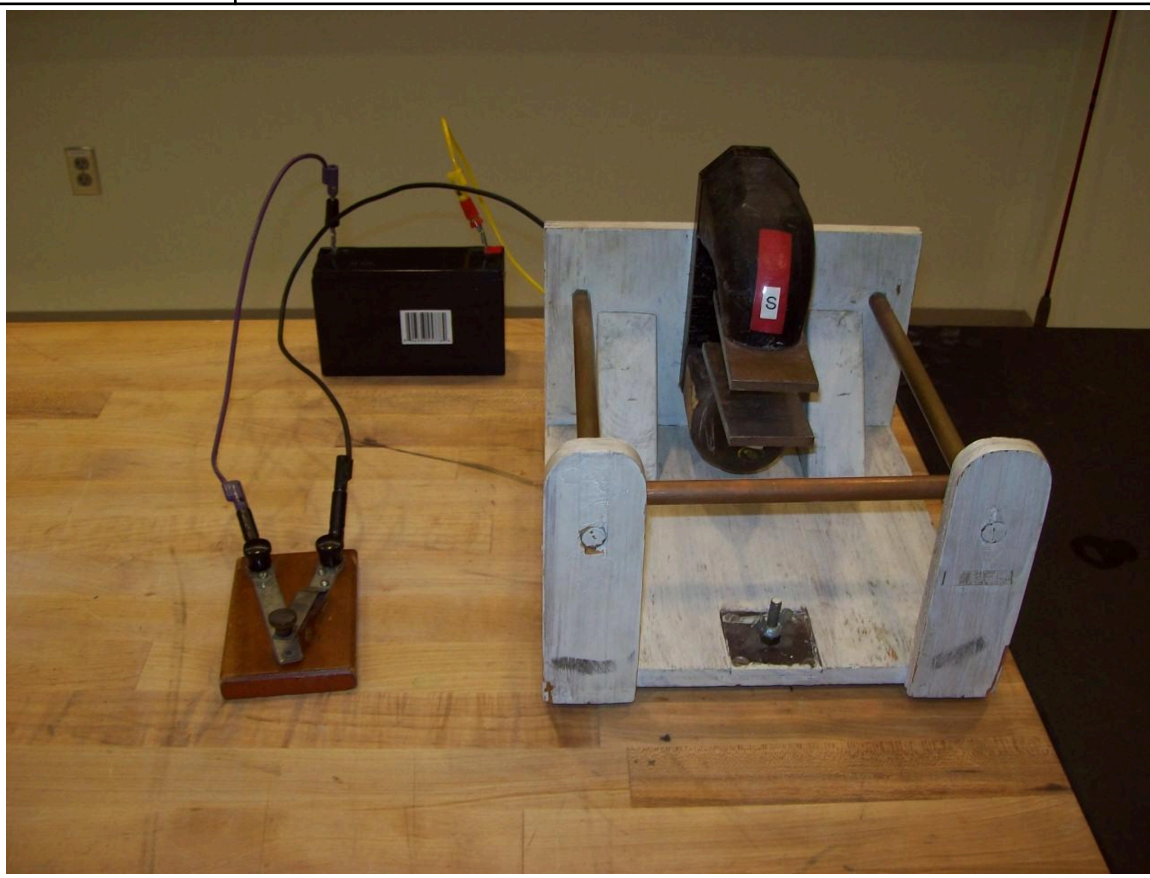
Magnetic Grapevine

	A flexible foil is suspended along side a vertical bar magnet. It will wrap itself around the magnet when there is a current in the foil. Use a reversing switch to make it wrap around the other way.



Location: Hb2, Hb3, Hc5

Electricity and Magnetism	5H40.71	MAGNETIC FIELDS AND FORCES
Forces on Current in Wires		
Ampere's Motor		
	A copper rod rolls along two electrified rails between the poles of a magnet. Reverse the current and it rolls in the opposite direction.	

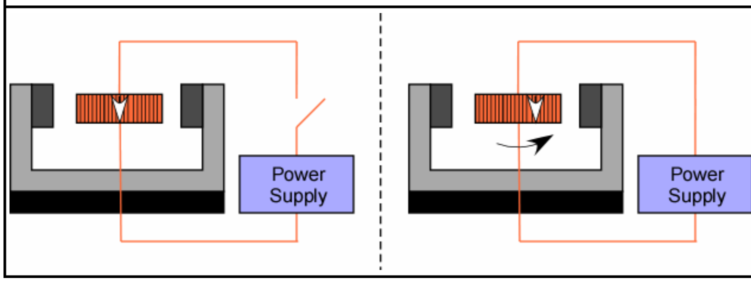


Location: Hb2, Hb3, Hd2

Electricity and Magnetism	5H50.10	MAGNETIC FIELDS AND FORCES

Torques on Coils

Model Galvanometer



A crude galvanometer with a large coil and magnet demonstrates the essentials.

Location: Hb2, Hb3, Hc5

Electricity and Magnetism	5H50.20	MAGNETIC FIELDS AND FORCES
Torques on Coils		

Force on a Current Loop

	A rectangular loop of current carrying wire aligns so that its dipole moment is parallel to the magnetic field of a large permanent magnet. Use the loop with the slip rings.

Location: Hb2, Hb3, Hd1

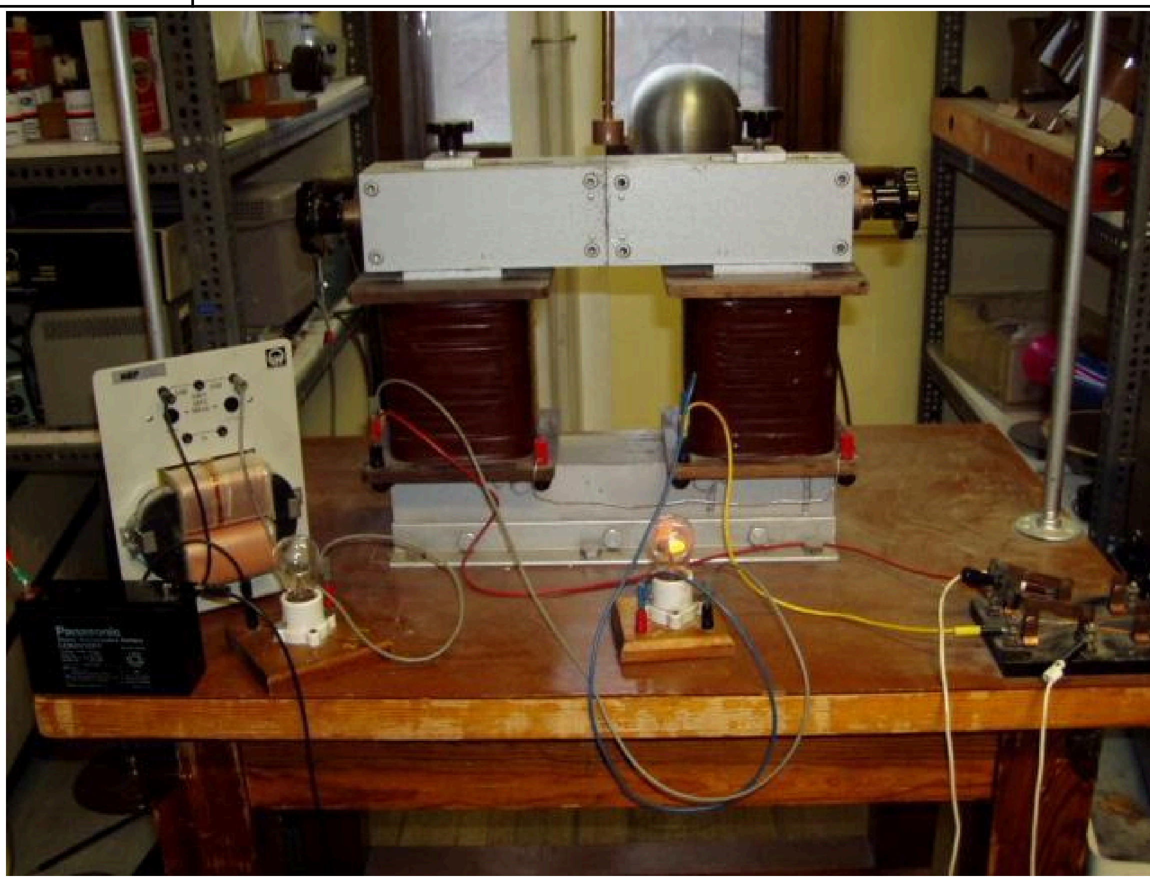
Electricity and Magnetism	5J10.10	INDUCTANCE
	Self Inductance	
	Inductor Assortment	
	Sample inductors are shown.	

Location: Hc7

Electricity and Magnetism	5J10.21, 5J10.23	INDUCTANCE
	Self Inductance	

Neon Self Induction

A 6 V battery lights a neon bulb (lights at 90 V) when the current to an inductor is interrupted.
Also shown: if the neon bulb is placed in parallel with an electromagnet. One side (the cathode) of the bulb lights up when the current flows and the other side lights up when the current is interrupted.

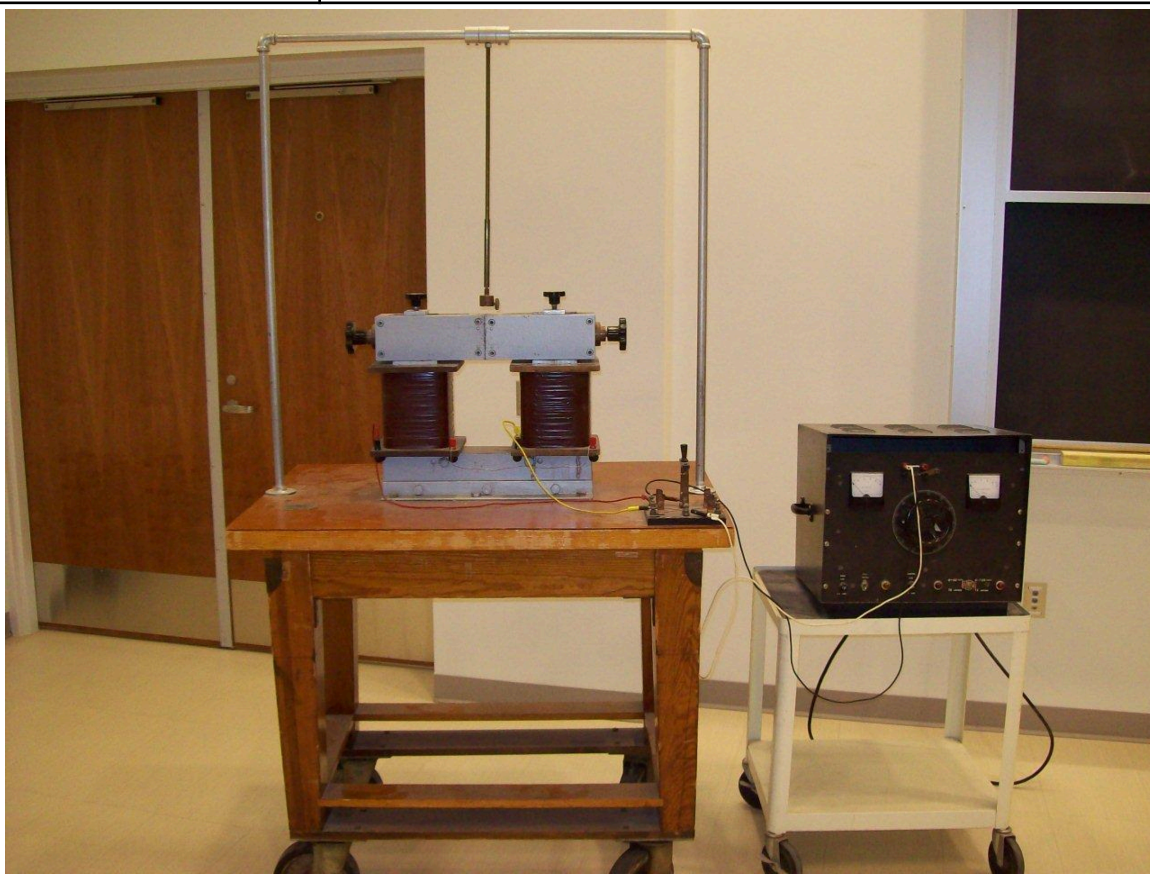


Location: Floor, Ha6, Hc7

Electricity and Magnetism	5J10.30	INDUCTANCE
Self Inductance		

Back EMF Spark

	A large spark is produced when the switch of a large electromagnet is opened.

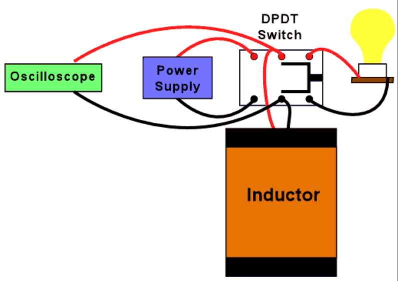


Location: Floor

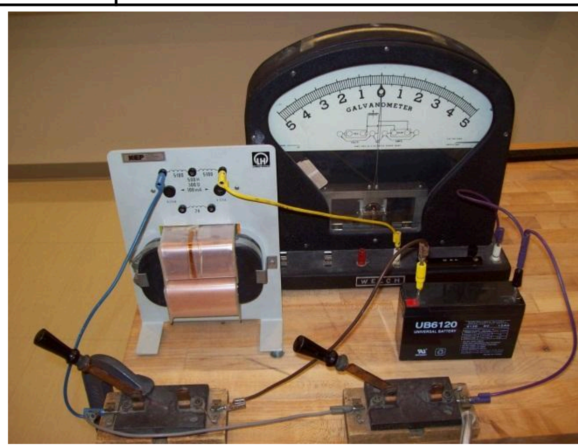
Electricity and Magnetism	5J20.10	INDUCTANCE

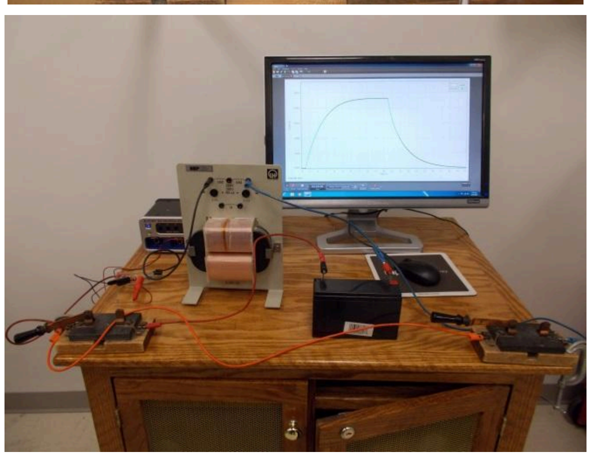
LR Circuits

LR Time Constant on Scope



Instead of a scope, I use a table galvanometer and a large inductance (500 H). The resistance used is that of the inductor (300 ohms). The inductor can be replaced in the circuit with a separate 300 ohm resistor for comparison. The switches are wired in a make-before-break configuration. This can also be done with the computer and Capstone, LR Circuit.cap.

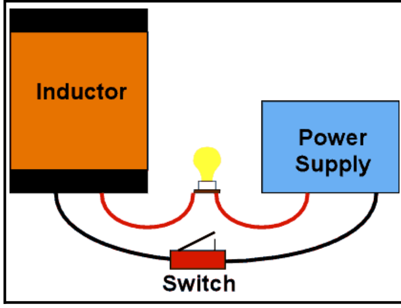




Location: Hb2, Hb3, Hc7

LR Circuits

Series or Parallel Lamps w/Inductor



Connect a light bulb in either series or parallel with a large inductance. In series, you can see an LR time delay; in parallel, you can see the energy stored (you can burn out the bulb if you set the voltage high enough).

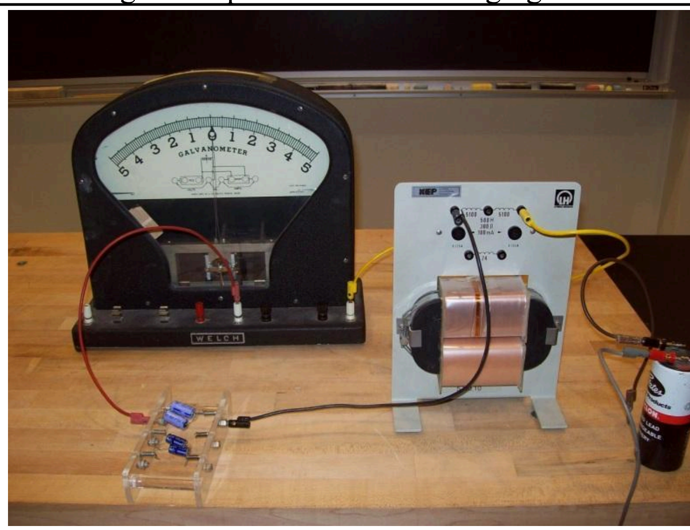
Location: Floor, Ha7

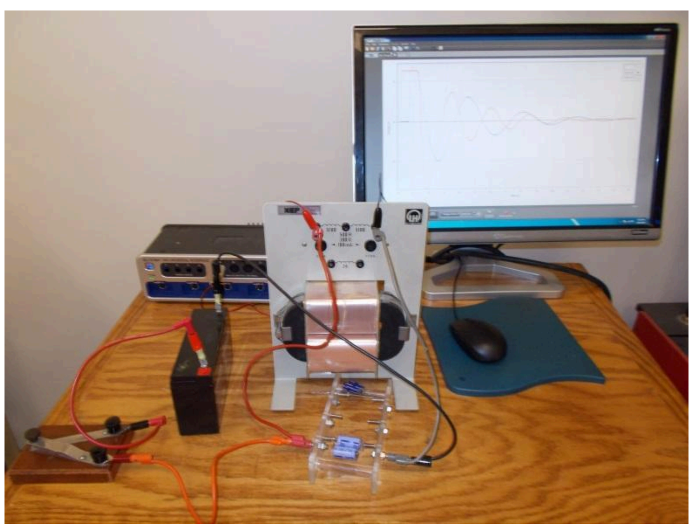
Electricity and Magnetism	5J30.10	INDUCTANCE

RLC Circuits - DC

RLC Ringing

The oscillating current through a slow RLC circuit is shown. Energize the circuit by placing a 2 V battery across the capacitor and then disconnecting the battery. The inductor is 500 H and two capacitor combinations, 200 uF and 440 uF are used. The capacitors are made of two smaller capacitors to eliminate polarity effects of the electrolytic capacitors. This can also be done with a computer using the Capstone file RLC Ringing.





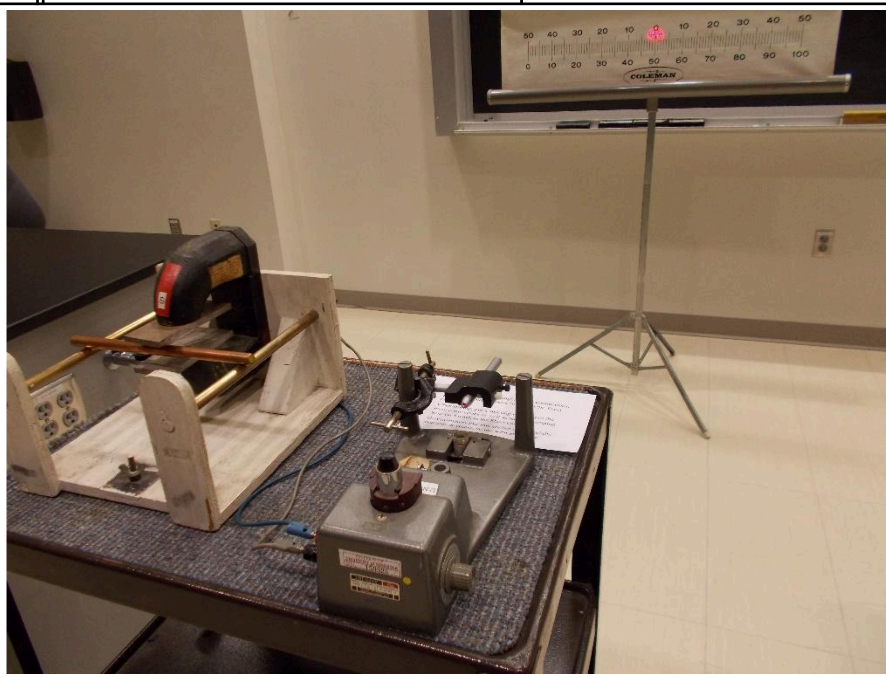
Location: Hb2, Hc7

Electricity and Magnetism	5K10.10	ELECTROMAGNETIC INDUCTION

Inducted Current and Forces

Sliding Rail Inductor

	Slide a bar on rails attached to a galvanometer between the poles of a magnetron magnet. Follow the instructions for use of the galvanometer carefully as it is irreplaceable. The Damping Switch should be in the S17 position when in use and in the short position otherwise.



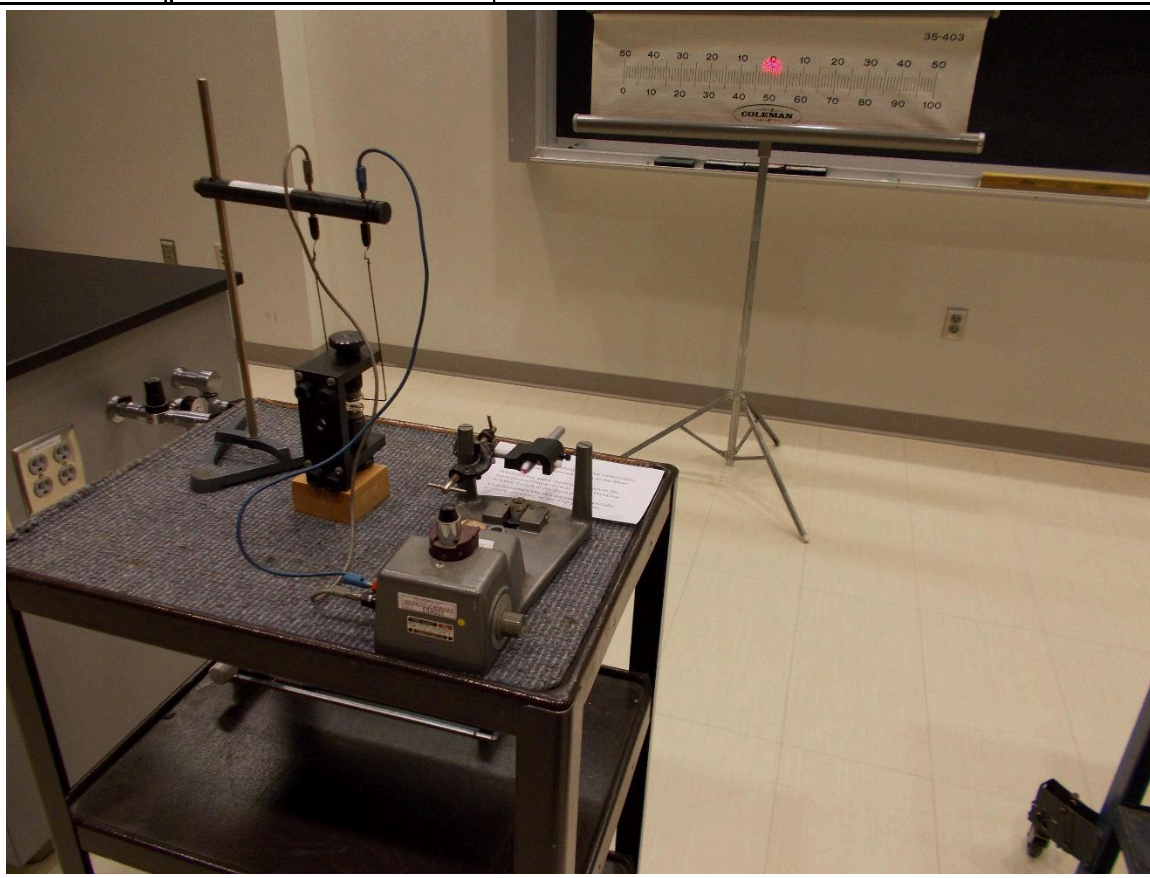
Location: Hd2

Electricity and Magnetism	5K10.17	ELECTROMAGNETIC INDUCTION

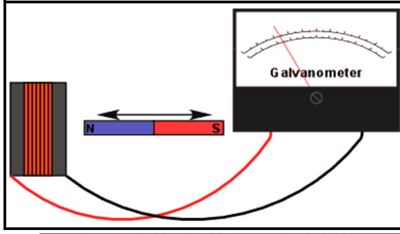
Inducted Current and Forces

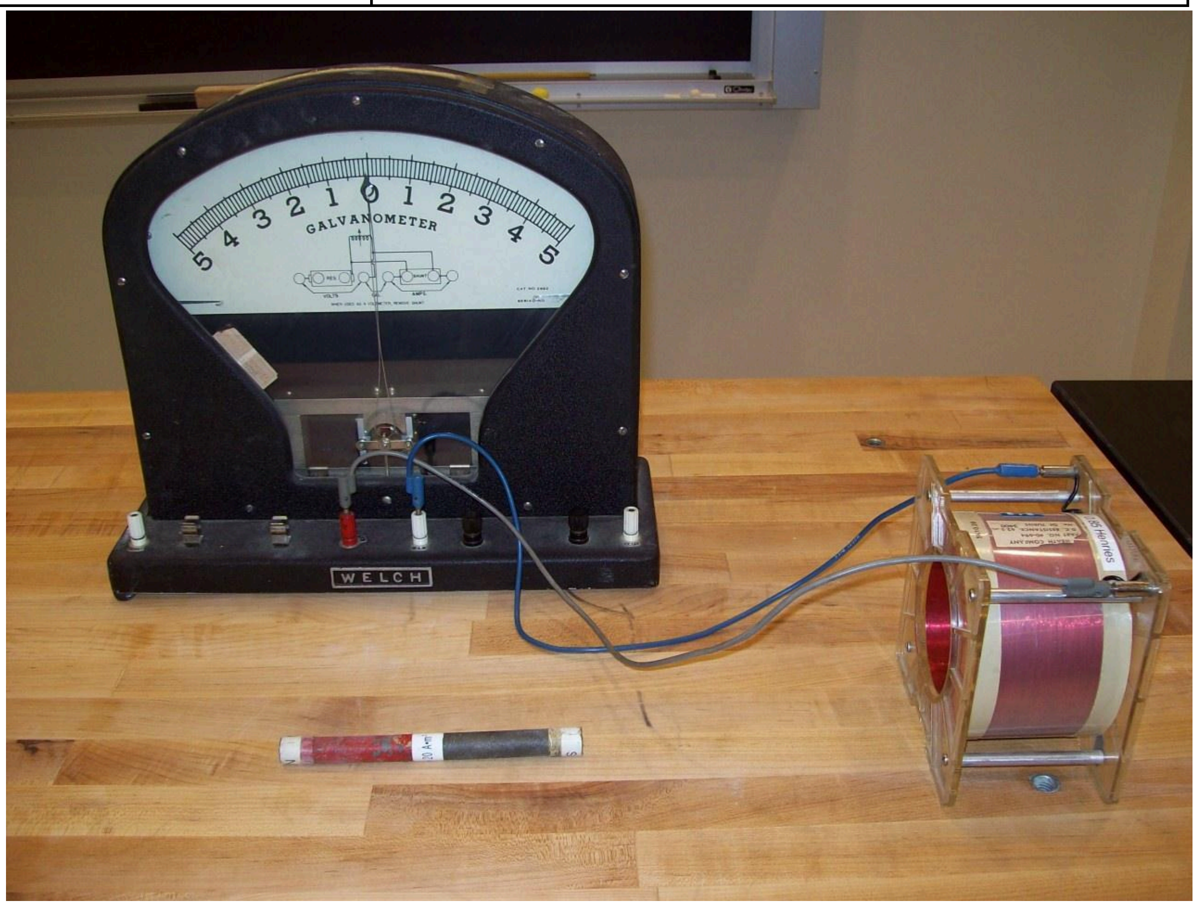
Swinging Wire in a Magnet

	A U shaped wire connected to a galvanometer is swung in and out from between the poles of a magnet. Carefully follow the instructions for use of the galvanometer. It is irreplaceable. The Damping Switch should be in the S17 position and in the Short position when not in use.



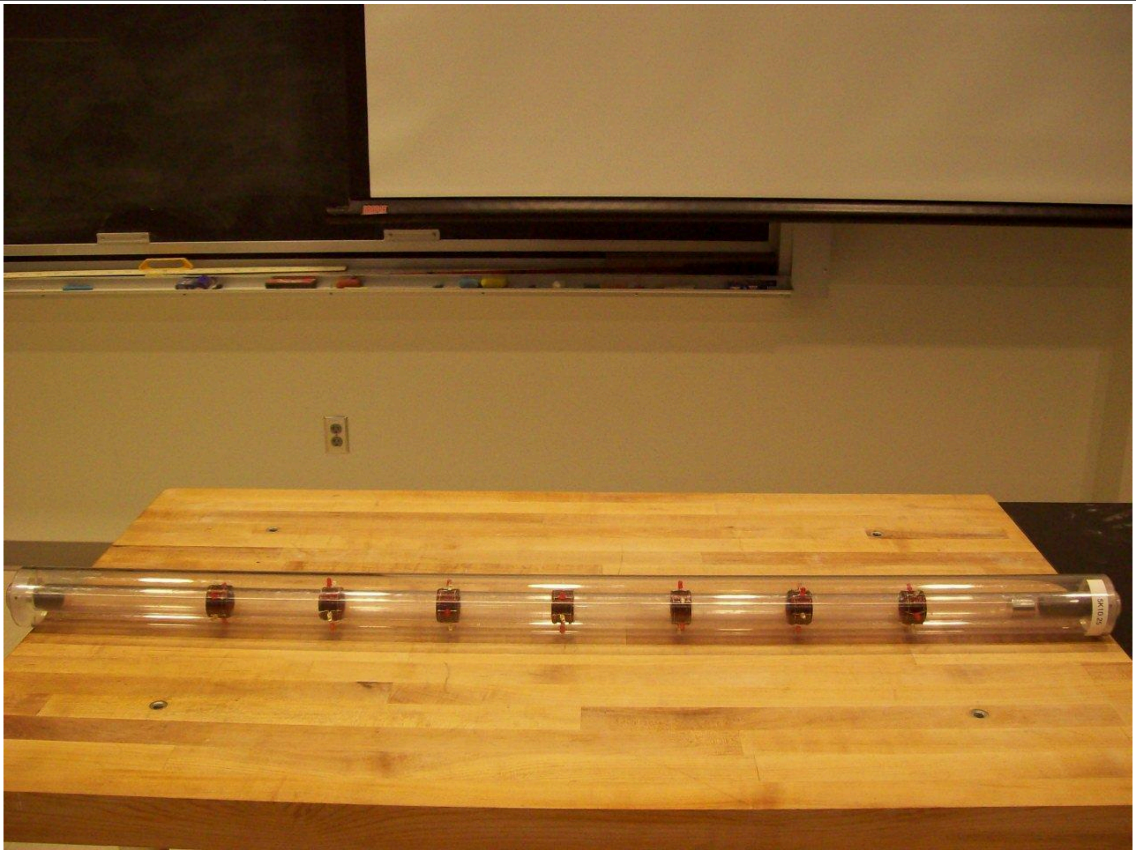
Location: Hc1, Hd2

<table>
<tr><td>Electricity and Magnetism</td><td>5K10.20</td><td>ELECTROMAGNETIC INDUCTION</td></tr>
<tr><td colspan="3">Inducted Current and Forces</td></tr>
<tr><td colspan="3"><h1>Induction Coil and Magnet</h1></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>
</td><td colspan="2">Move the magnet in and out of the coil connected to the galvanometer. We also place the galvanometer and coil on a moving platform and keep the magnet fixed as a demonstration of relativity.</td></tr>
</table>



Location: Hc2, Ib3

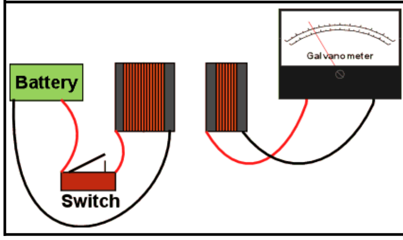
Electricity and Magnetism	5K10.25	ELECTROMAGNETIC INDUCTION
Inducted Current and Forces		
Coil, Lamp and Magnet		
	A magnet in a tube falls through coils that are connected to LEDs which light up as it passes.	



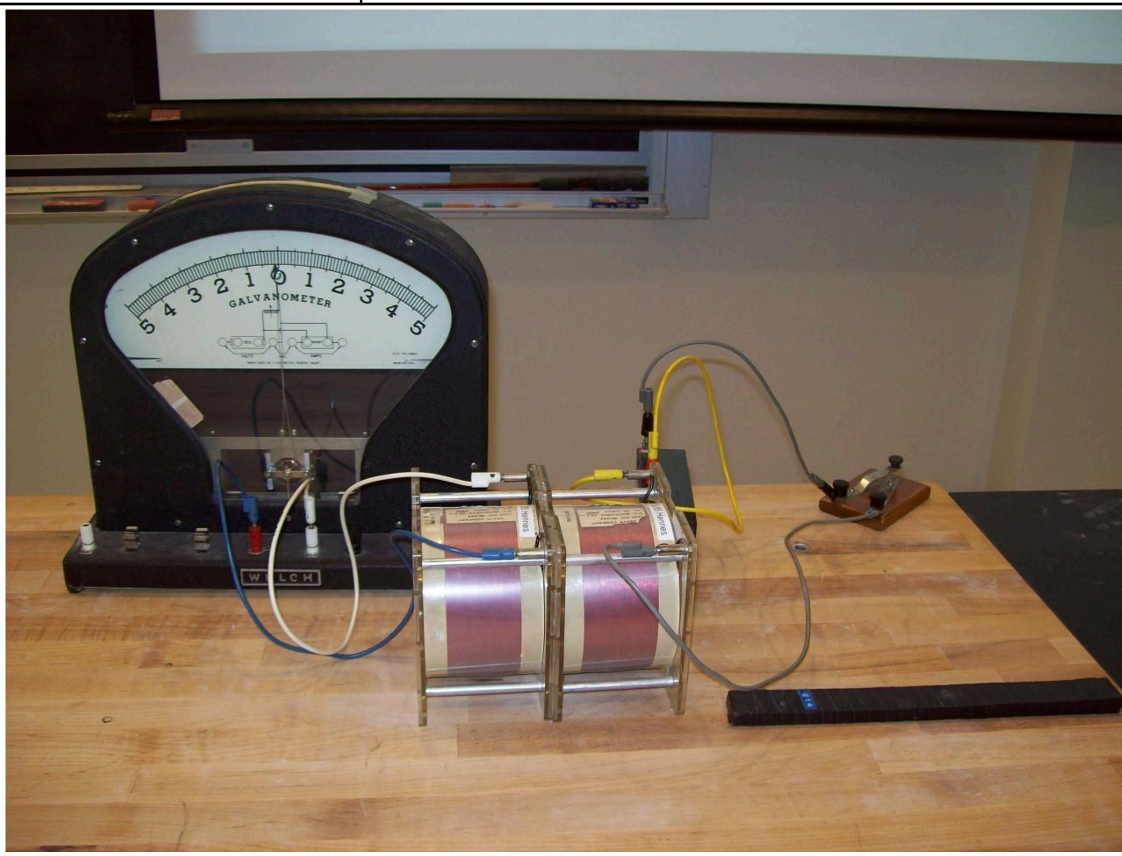
Location: HdT

Electricity and Magnetism	5K10.30	ELECTROMAGNETIC INDUCTION
Inducted Current and Forces		

Mutual Induction Coils with Battery

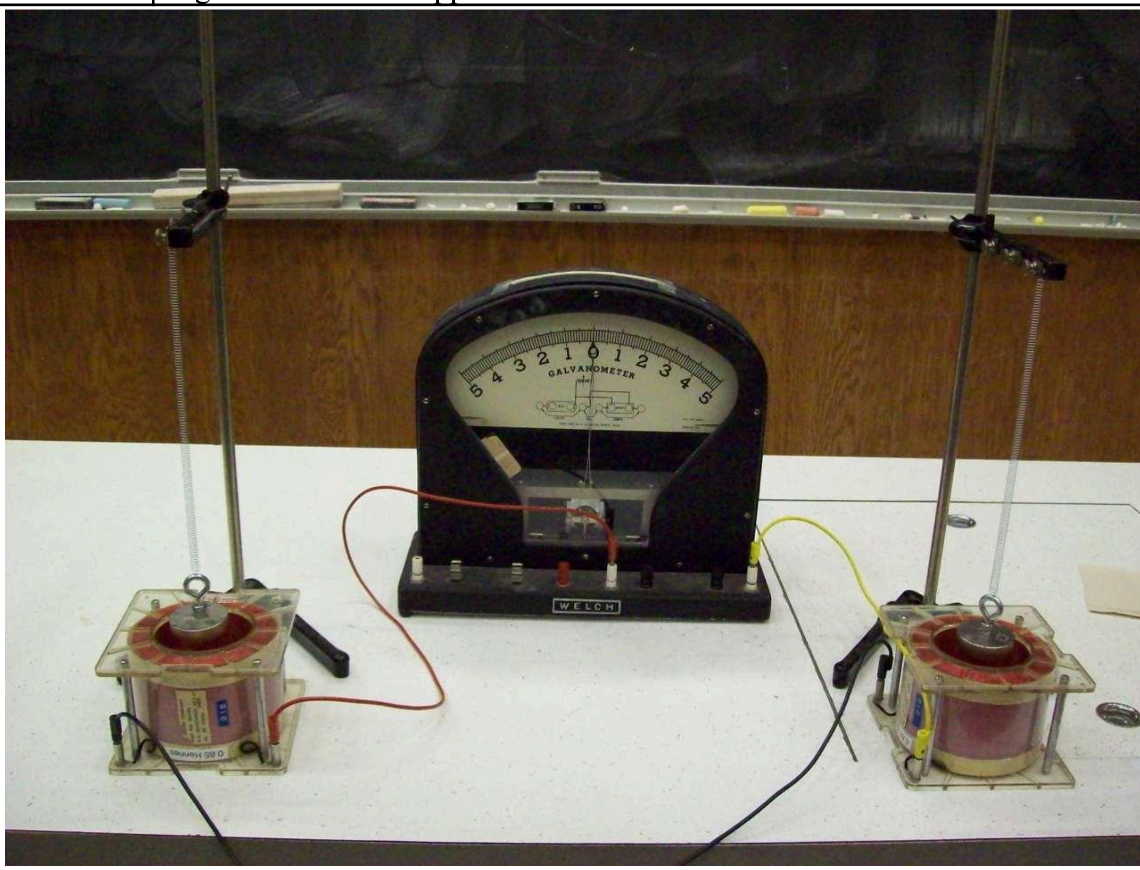


Two coils face each other, one attached to a galvanometer, the other to a battery and tap switch. Coupling can be increased with various cores. Aluminum, laminated iron, and other solid iron cores are available.



Location: Hb2, Hb3, Hc2, Hd6

Electricity and Magnetism	5K10.48	ELECTROMAGNETIC INDUCTION
Inducted Current and Forces		
Current Coupled Pendula		
	Magnets on springs are free to oscillate up and down into the bores of interconnected solenoids. Start one magnet oscillating and the other oscillates (in phase if the polarity is right). Try stopping one of the magnets and see what happens to the current and the damping; also try shorting one of the coils and observe the damping. Invert the polarity of one of the coils and watch the magnets oscillate in opposition.	



Location: Hc2, Hd4

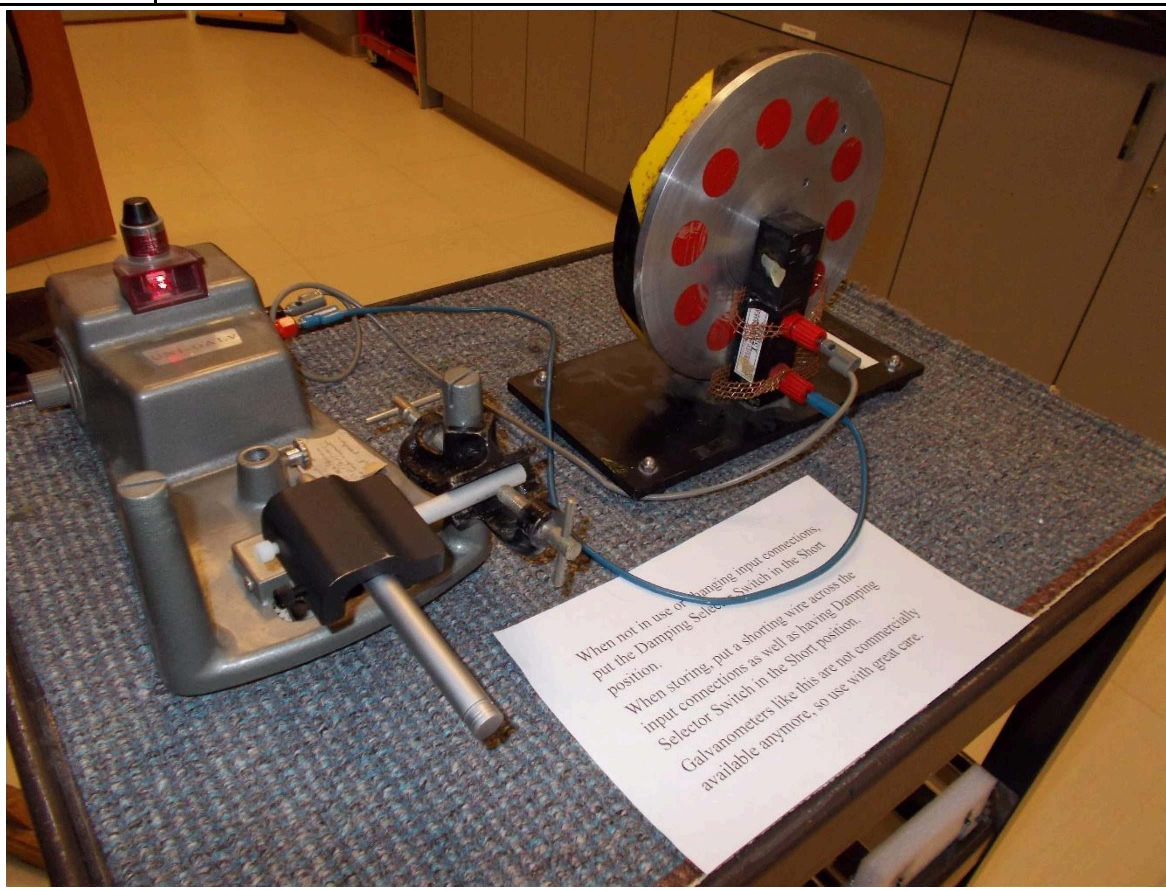
Electricity and Magnetism	5K10.65	ELECTROMAGNETIC INDUCTION
	Inducted Current and Forces	
	Jumping Rope	
	Play “jump rope” with a long wire attached to a galvanometer.	

Location: Meters, Wires

Electricity and Magnetism	5K10.70	ELECTROMAGNETIC INDUCTION
Inducted Current and Forces		
# What does a voltmeter measure?		
	Two identical voltmeters connected at the same points in a circuit around the core of a long solenoid give different readings.	

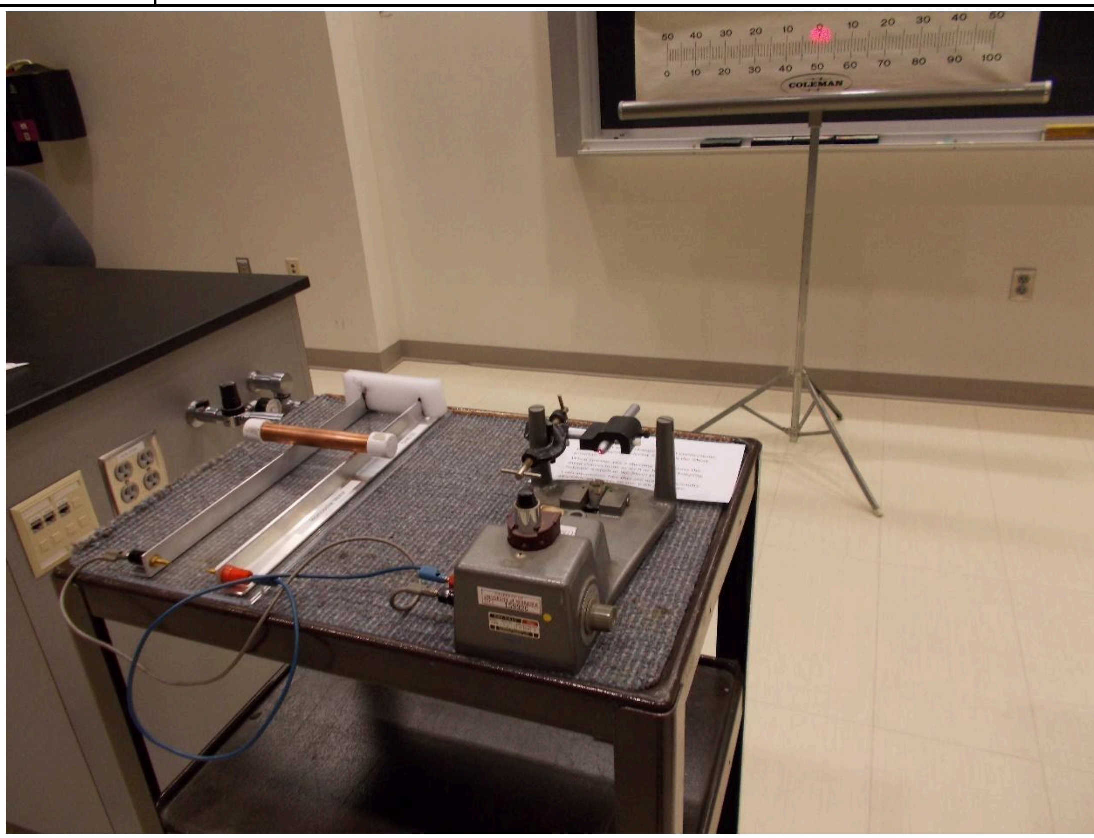
Location: Hd4, Hd6

Electricity and Magnetism	5K10.80	ELECTROMAGNETIC INDUCTION
Inducted Current and Forces		
Homopolar Generator		
	A homopolar generator shows the relation between electric and magnetic fields. Rotate the aluminum disk keeping the magnet disk still and galvanometer deflects; rotate the magnet disk while keeping the aluminum disk fixed and you get no deflection; rotate both, and you get a deflection. This apparatus was a poser for Einstein (he mentions it in his paper one the electrodynamics of moving bodies) so it would be good to read up on it before showing it. Follow the Galvanometer instructions carefully as it is irreplaceable. The Damping Switch should be in the S17 position when in use and in the short position otherwise.	



Location: Hd2

Electricity and Magnetism	5K10.82	ELECTROMAGNETIC INDUCTION
Inducted Current and Forces		
Homopolar Motor as a Generator		
TPT Vol. 36 Nov. 1998 p. 474		
	The homopolar motor (5H40.53) is connected to a galvanometer. When the magnet/copper tube assembly is slid along the rails no current is observed. However, if it is rolled along the rails, a current is observed. Compare this to 5K10.10 (Ampere's Motor used as a generator) for which it doesn't matter whether you roll or slide the conducting rod. The article in The Physics Teacher explains the "paradox". Follow the Galvanometer instructions carefully as it is irreplaceable. The Damping Switch should be in the S17 position when in use and in the short position otherwise.	

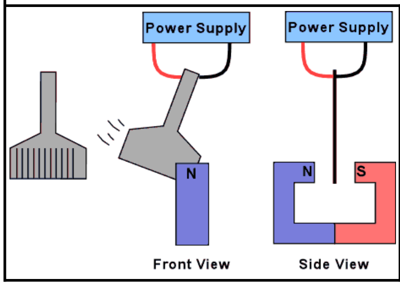


Location: Hc5

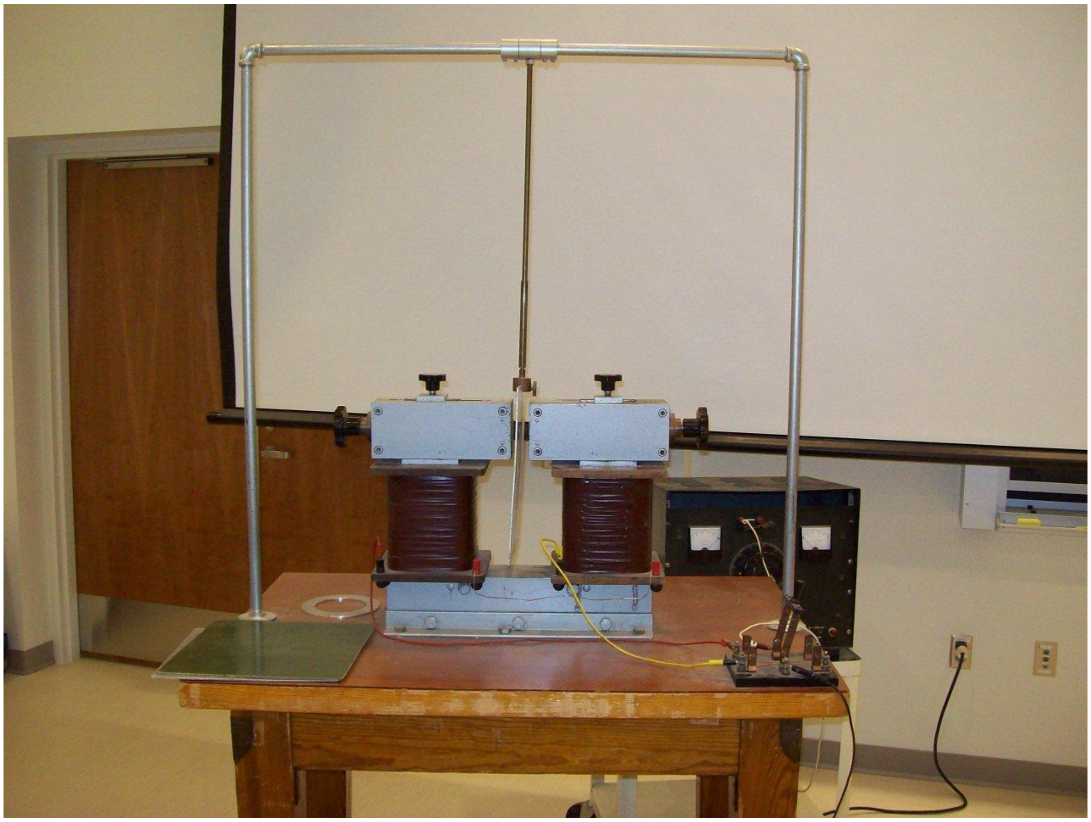
Electricity and Magnetism	5K20.10	ELECTROMAGNETIC INDUCTION

Eddy Currents

Pendulum in Big Electromagnet

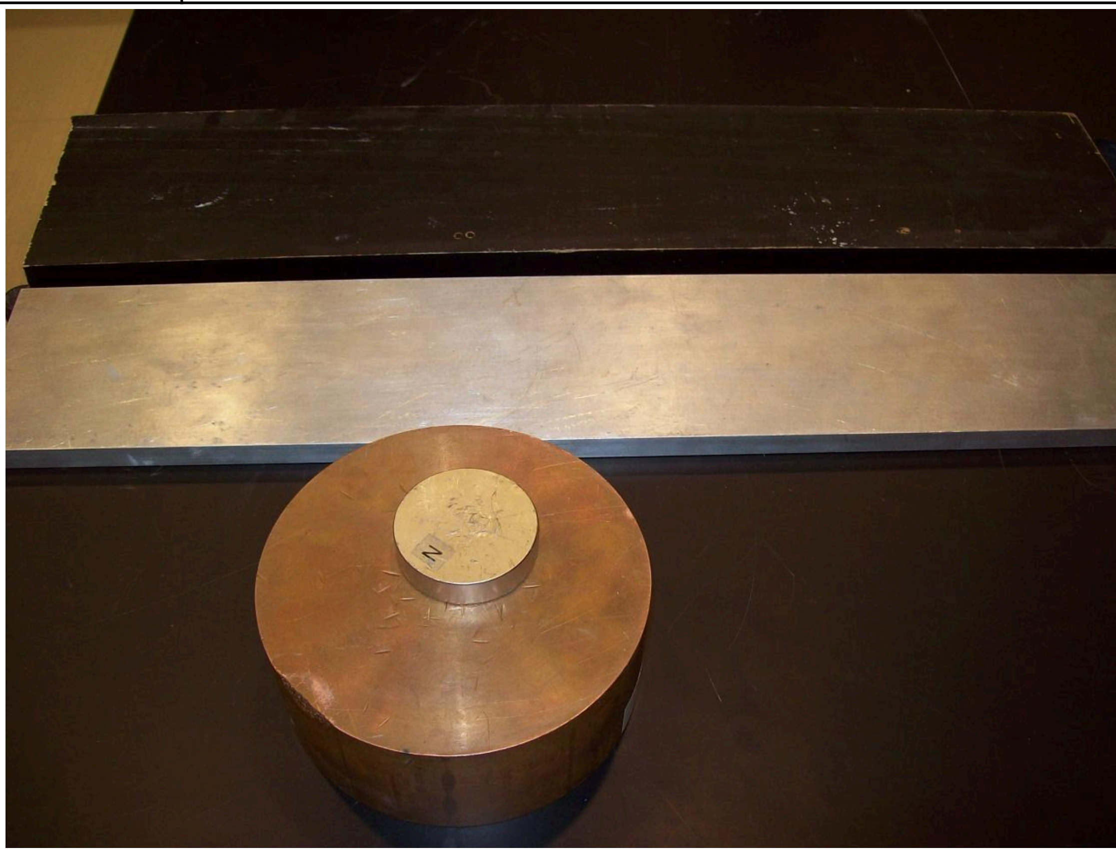


Show that a solid copper plate swings between the poles of the electromagnet when the power is off. Turn on the power. Displace the pendulum and let it swing. It stops dead between the poles. Repeat with the slotted plate, ring and slit ring.



Location: Floor

Electricity and Magnetism	5K20.24	ELECTROMAGNETIC INDUCTION
Eddy Currents		
Osheroff Demonstration		
	A very strong (Be Careful!) magnet is dropped onto a thick copper disc. IT will float down onto it. One can also let the magnet slide down either an aluminum or wooden plank.	



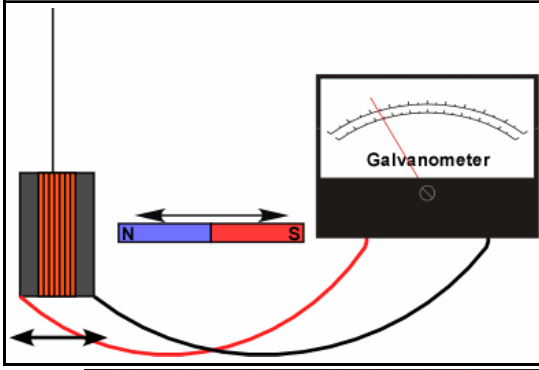
Location: Hd5

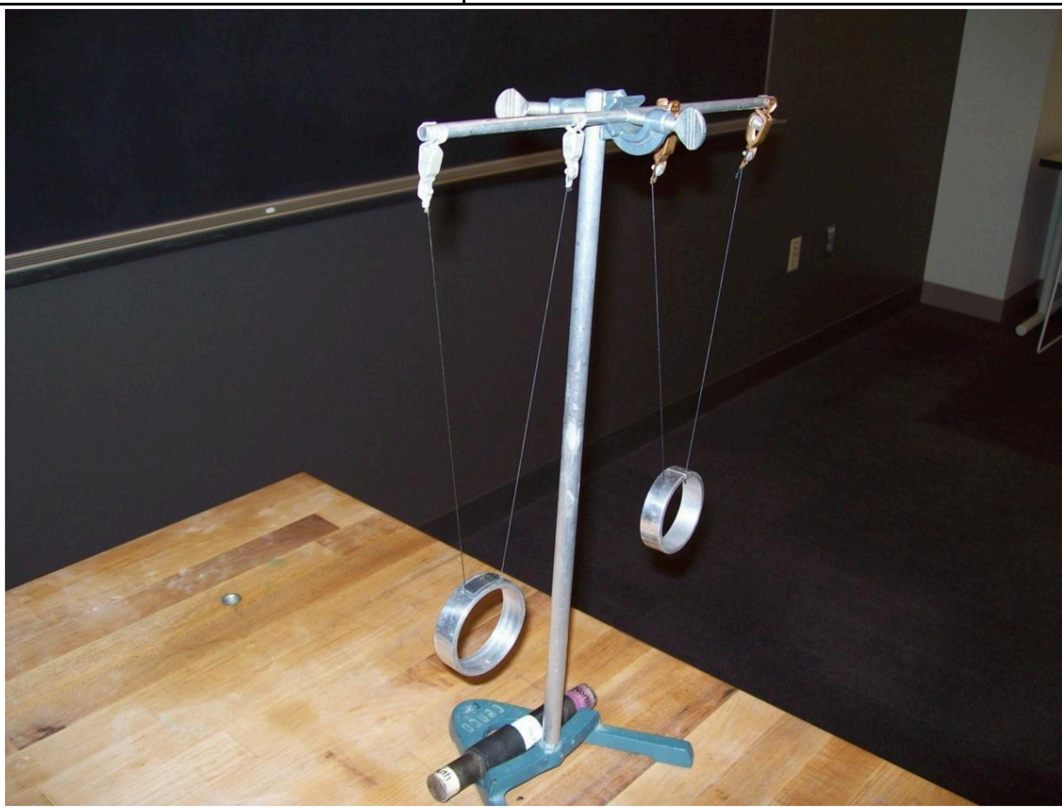
Electricity and Magnetism	5K20.25	ELECTROMAGNETIC INDUCTION
Eddy Currents		

Magnets and Tubes

	Drop a wooden dowel down a 55 cm copper tube with holes drilled in the side so the falling dowel can be seen. Repeat using a magnet of the same size. It will take the magnet about 5 seconds to fall through the tube. Also shown is the Coil, Lamp and Magnet apparatus; the person holding the tube can feel an extra force as the magnet goes through the coils.

Location: Hd5, HdT

<table>
<tr><td>Electricity and Magnetism</td><td>5K20.26</td><td>ELECTROMAGNETIC INDUCTION</td></tr>
<tr><td colspan="3">Eddy Currents</td></tr>
<tr><td colspan="3"><h1>Faraday Repulsion Coil</h1></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>
</td><td colspan="2">A magnet is inserted and withdrawn from a solid and split ring on a bifilar suspension. It is possible to "pump" the solid ring.</td></tr>
</table>

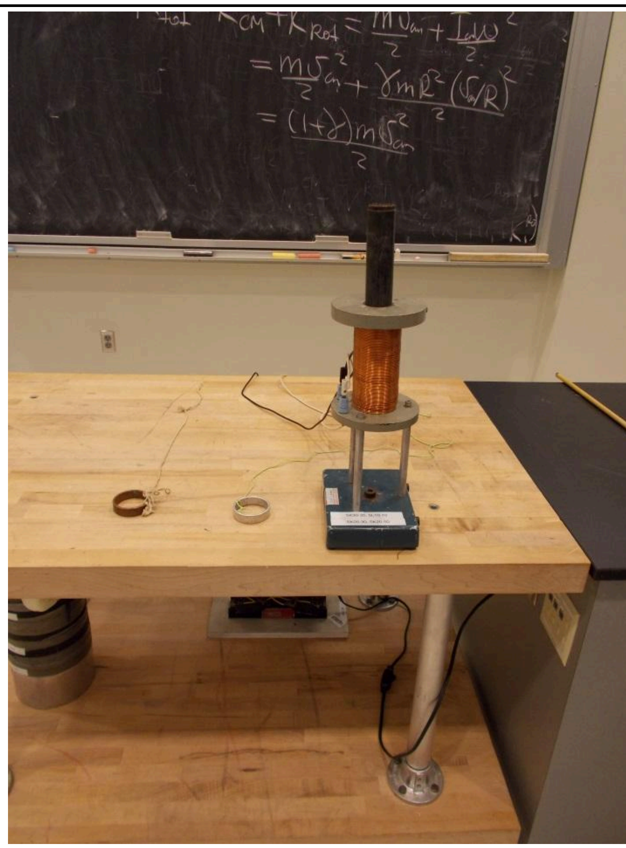


Location: Hd5, Ib3

Electricity and Magnetism	5K20.30	ELECTROMAGNETIC INDUCTION
Eddy Currents		

Jumping Ring

An aluminum ring is placed around the core of a coil. When the coil is energized with an AC current, the ring jumps. It will jump higher when cooled with LN2. This demonstration is a little involved to explain properly and the ring must be analyzed as an inductive circuit to explain the observations. The transformer has a DPDT switch on it. One position powers the coil directly from the AC line; the other places a stepped up voltage across the coil when a tap key is pressed. Do not hold the tap key down to avoid overheating and blown fuses.



Location: Hd3, Hd6

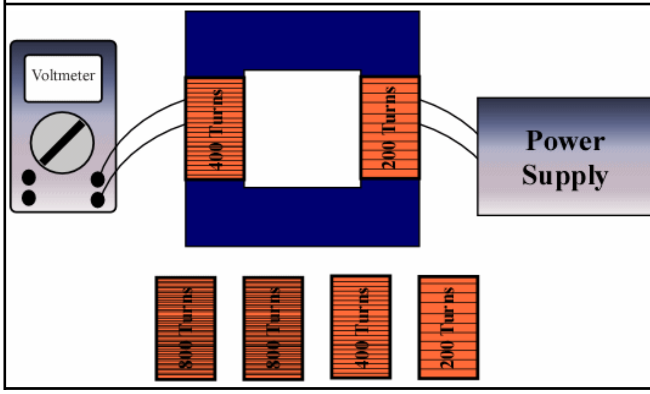
Electricity and Magnetism	5K20.50	ELECTROMAGNETIC INDUCTION
Eddy Currents		
Rotating Ball		
	A hollow copper ball rotates in a beaker atop a shaded pole. Also show that using a piece of steel to shade the pole doesn't work.	

Location: Hd6

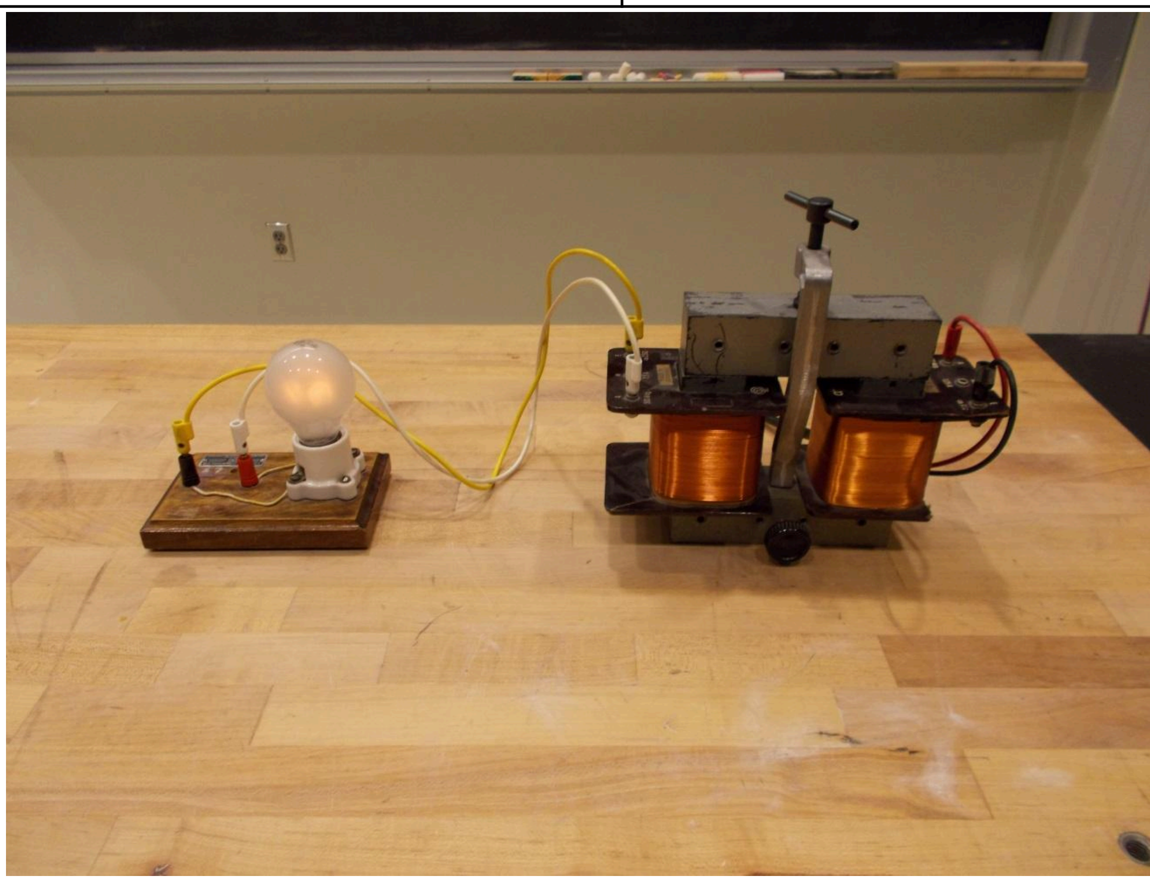
Electricity and Magnetism	5K30.20	ELECTROMAGNETIC INDUCTION

Transformers

Dissectible Transformer



Voltages can be shown on the primary and secondary coils of a dissectible transformer. Use a 230V bulb. Show it on either side of a 2 to 1 transformer and at line voltage. Show what happens when you remove the top core piece.



Location: Ia2

Electricity and Magnetism	5K30.35	ELECTROMAGNETIC INDUCTION
Transformers		
Light under Water		
	The secondary coil and light bulb are placed in a beaker of water and put on top of the core of a vertical coil.	

Location: Hd6

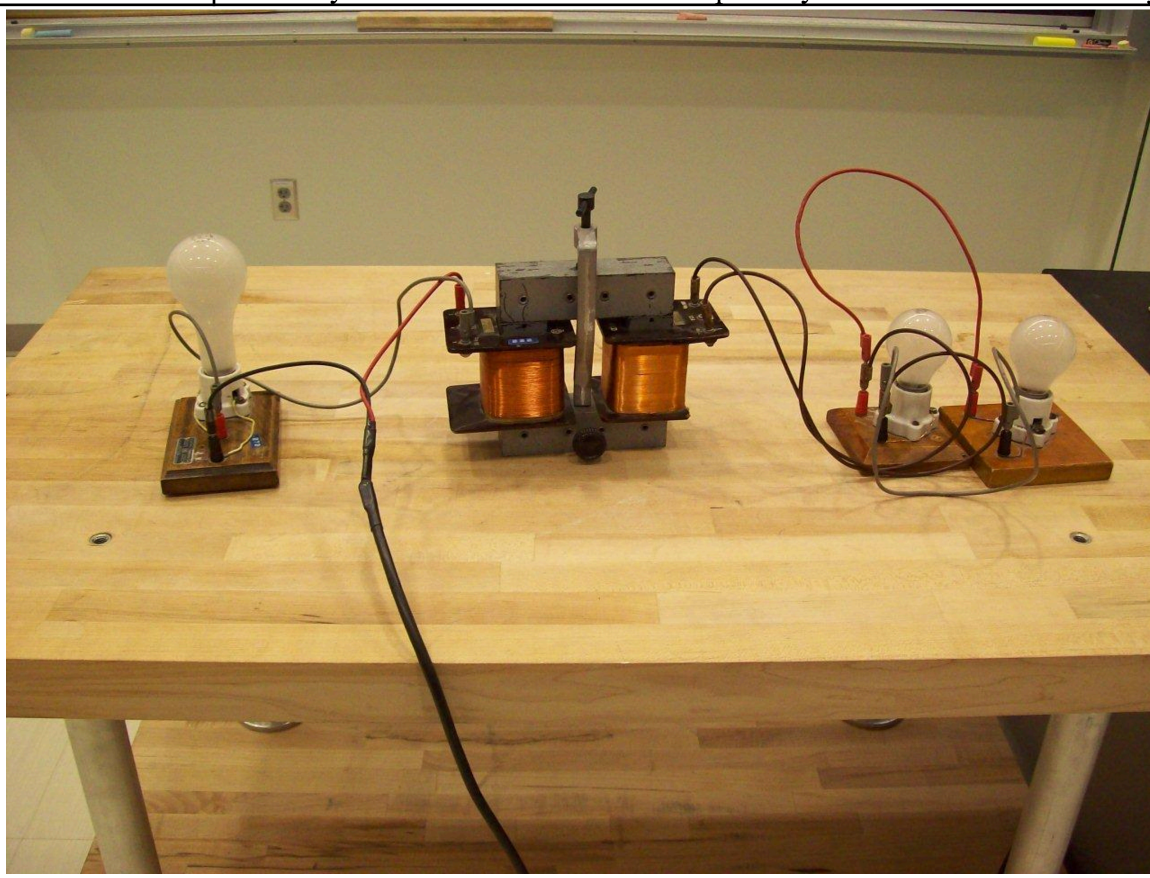
Electricity and Magnetism	5K30.40	ELECTROMAGNETIC INDUCTION
Transformers		
Melt a Nail		
	Use the 5 turn secondary with a 250 turn primary to melt a nail (20d, 4 inch) in two.	

Location: Ia2

Electricity and Magnetism	5K30.60	ELECTROMAGNETIC INDUCTION
Transformers		

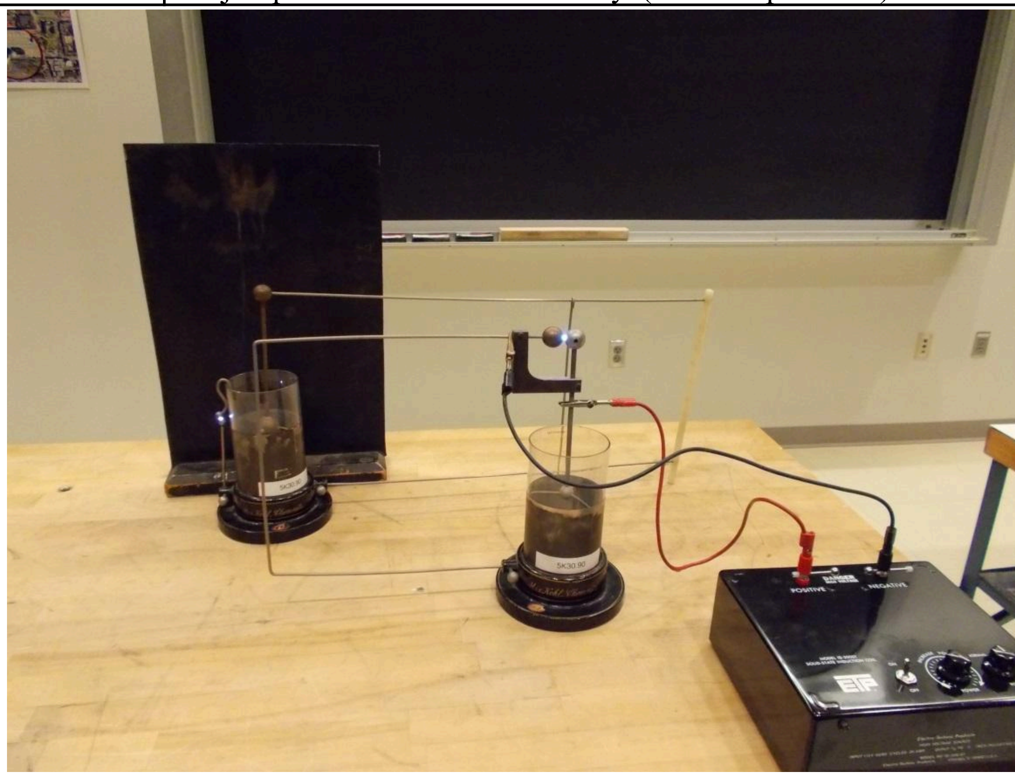
Reaction of Primary to Secondary Load

	A light bulb (100 W) brightens as the load (25 W, 230V bulbs) in the secondary is increased. Use a 500 turn primary and a 1000 turn secondary.



Location: Ha7, Ia2

Electricity and Magnetism	5K30.90	ELECTROMAGNETIC INDUCTION
Transformers		
Leyden Jar and Loop		
	When a spark jumps from a loop of wire to a Leyden jar, a small spark will jump in a similar device nearby. (Hertz Experiment).	



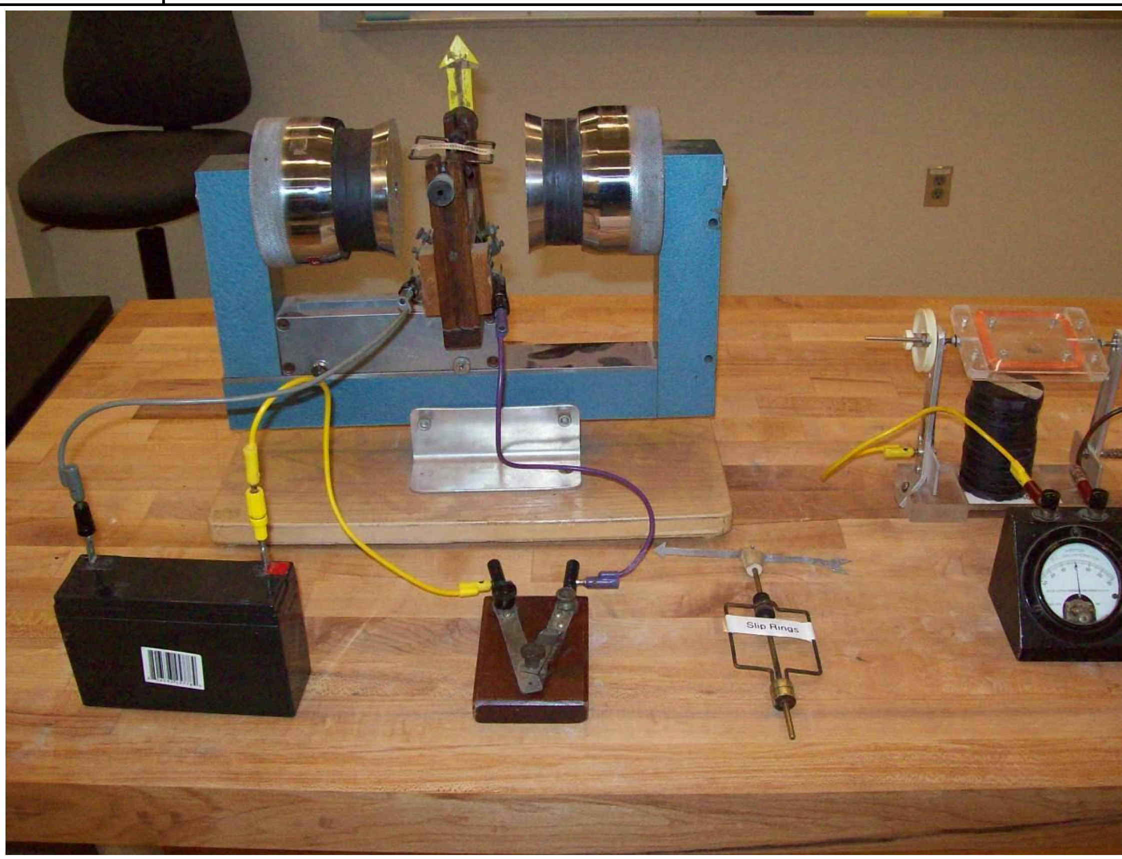
Location: Ia3

Electricity and Magnetism	5K40.40	ELECTROMAGNETIC INDUCTION

Motors and Generators

Motor / Generator

An armature with either split rings or slip rings is placed in a magnetic field. The split ring version can be operated either as a generator or a motor. A smaller 5000 turn AC generator with a stack of magnets is also shown in the photograph.

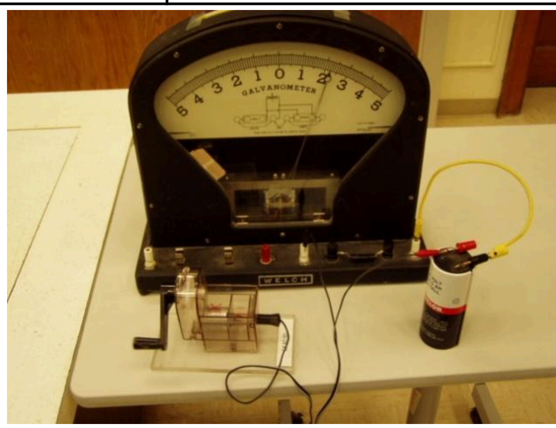


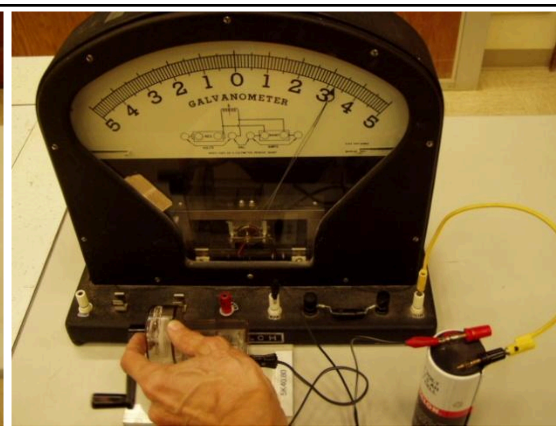
Location: Hb2, Hb3, Hd1, Hd4

Electricity and Magnetism	5K40.70	ELECTROMAGNETIC INDUCTION
Motors and Generators		

Back EMF in a Motor

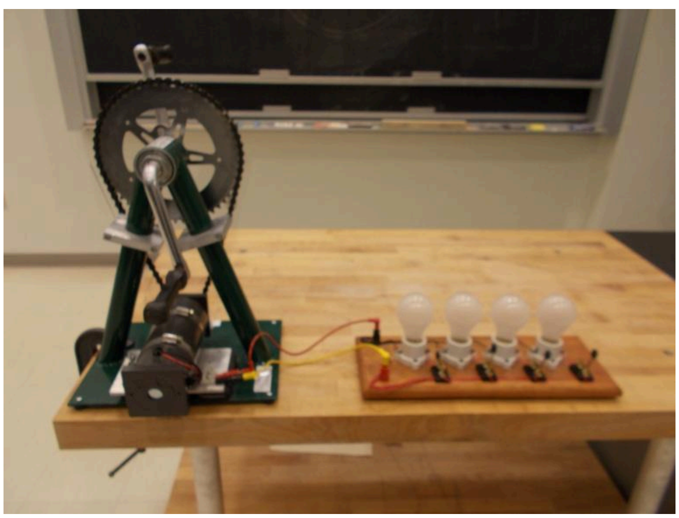
	An ammeter in series with a motor/generator and battery shows the current change as you put a load on the motor. You can also start cranking the motor/generator and cause current to reverse, charging the battery





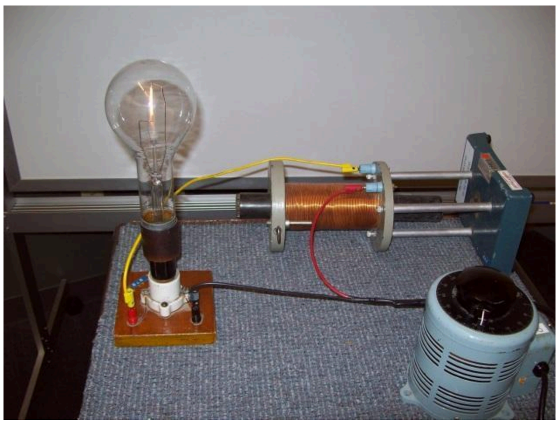
Location: Hb3, Hd4

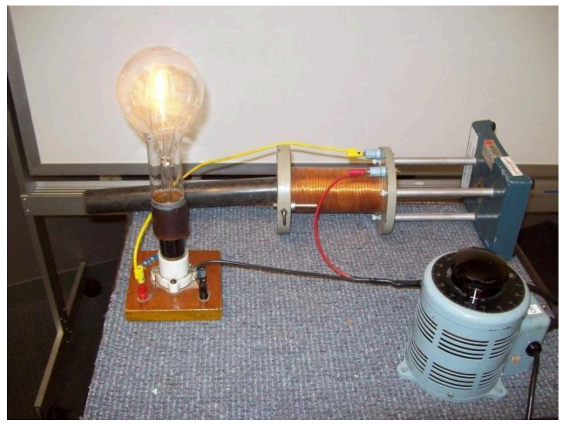
Electricity and Magnetism	5K40.80	ELECTROMAGNETIC INDUCTION
Motors and Generators		
# Hand Crank Generator		
	Use a hand cranked generator to light a bulb, charge a capacitor or make an identical generator turn. Also shown is a larger version with 4 25 watt bulbs.	



Location: Hd4, Hd7, Ha7

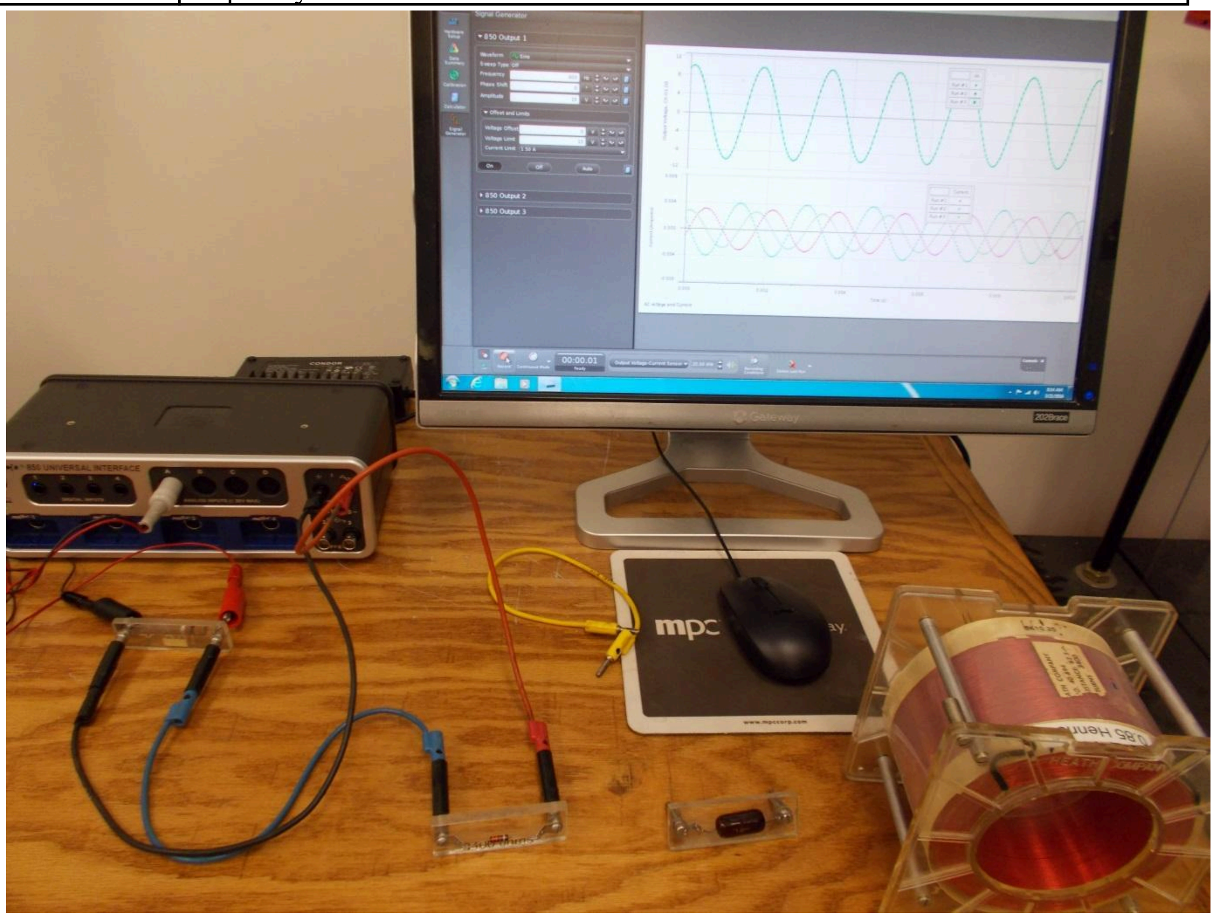
Electricity and Magnetism	5L10.10	AC Circuits
Impedance		
Inductive Reactance		
	Move a core in and out of a solenoid in series with a 300 W Lamp. To keep it from being too bright, use a Variac to lower the solenoid voltage to 50 V. Try it with a 15 W lamp. You can also try it with DC.	





Location: Ha7, Hd6

Electricity and Magnetism	5L20.10	AC Circuits
RLC Circuits -AC		
RLC – Phase Differences		
	A computer is used (Capstone: AC Circuits) to plot the current and voltage through and across various combinations of circuit elements. The usual circuit elements used are L: 0.85 H; C: 0.1 uf; R: 3400 ohms. The series resonant frequency of the combination is 527 Hz.	

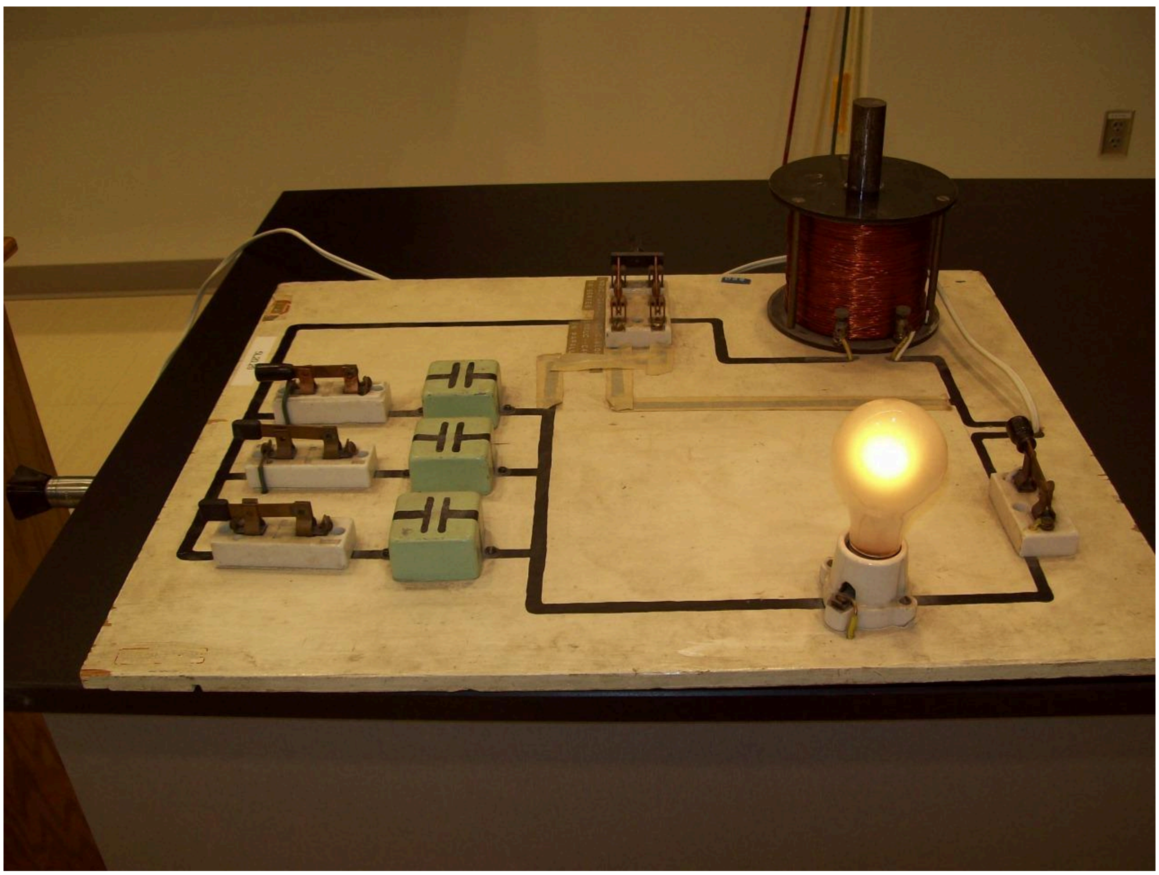


Location: Capstone Cabinet, Hb2, Hc2

Electricity and Magnetism	5L20.20	AC CIRCUITS
RLC Circuits - AC		

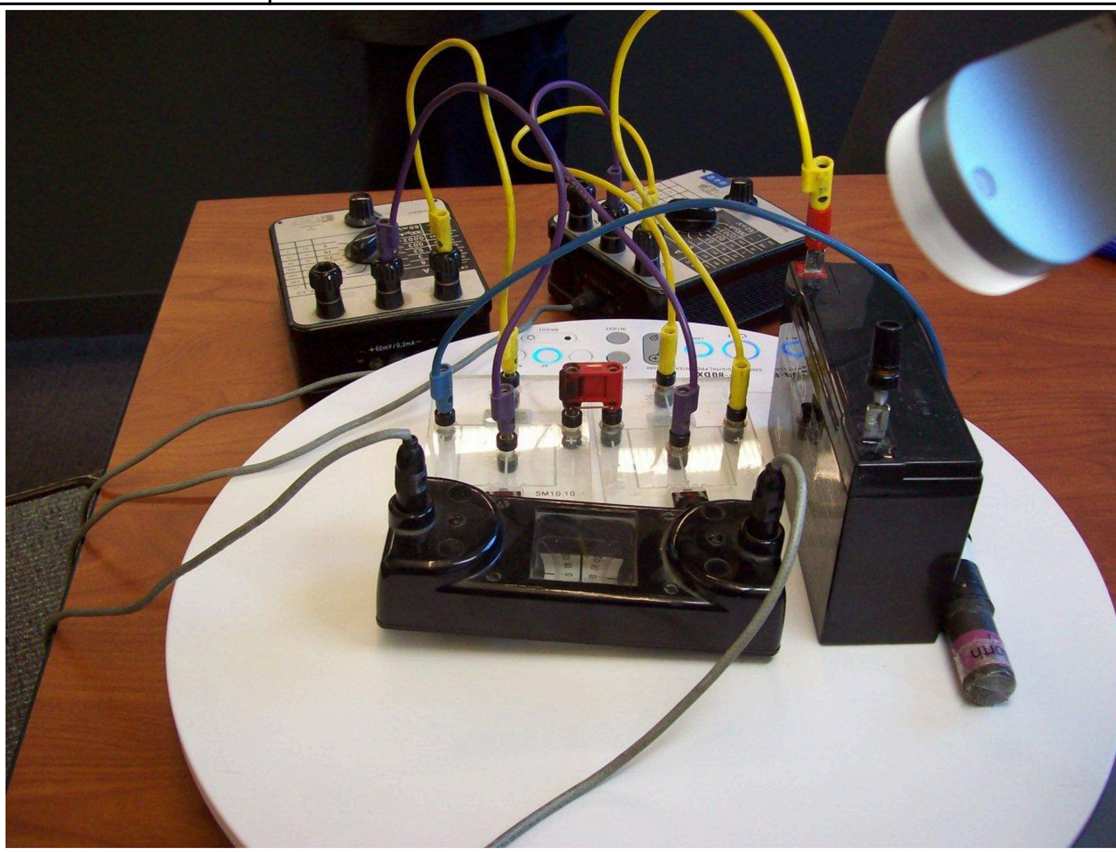
RLC Resonance

	The light bulb in a RLC circuit glows when the inductor core is moved through resonance.



Location: Ia4

Electricity and Magnetism	5M10.10	SEMICONDUCTORS AND TUBES
	Semiconductors	
	Hall Effect	
	Measure the transverse potential of N and P-doped germanium placed in a magnetic field.	

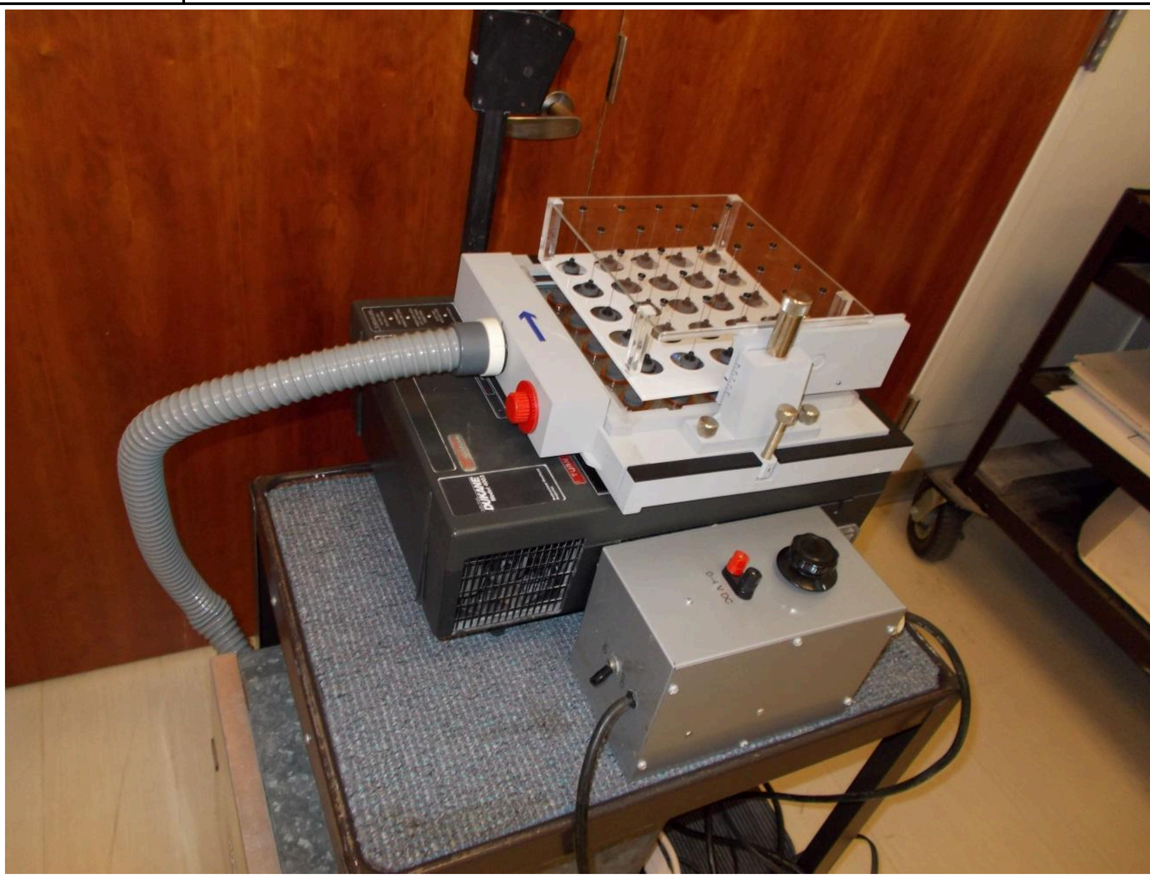


Location: Ia5, Ib3

Electricity and Magnetism	5M10.19	Semiconductors and Tubes
Semiconductors		

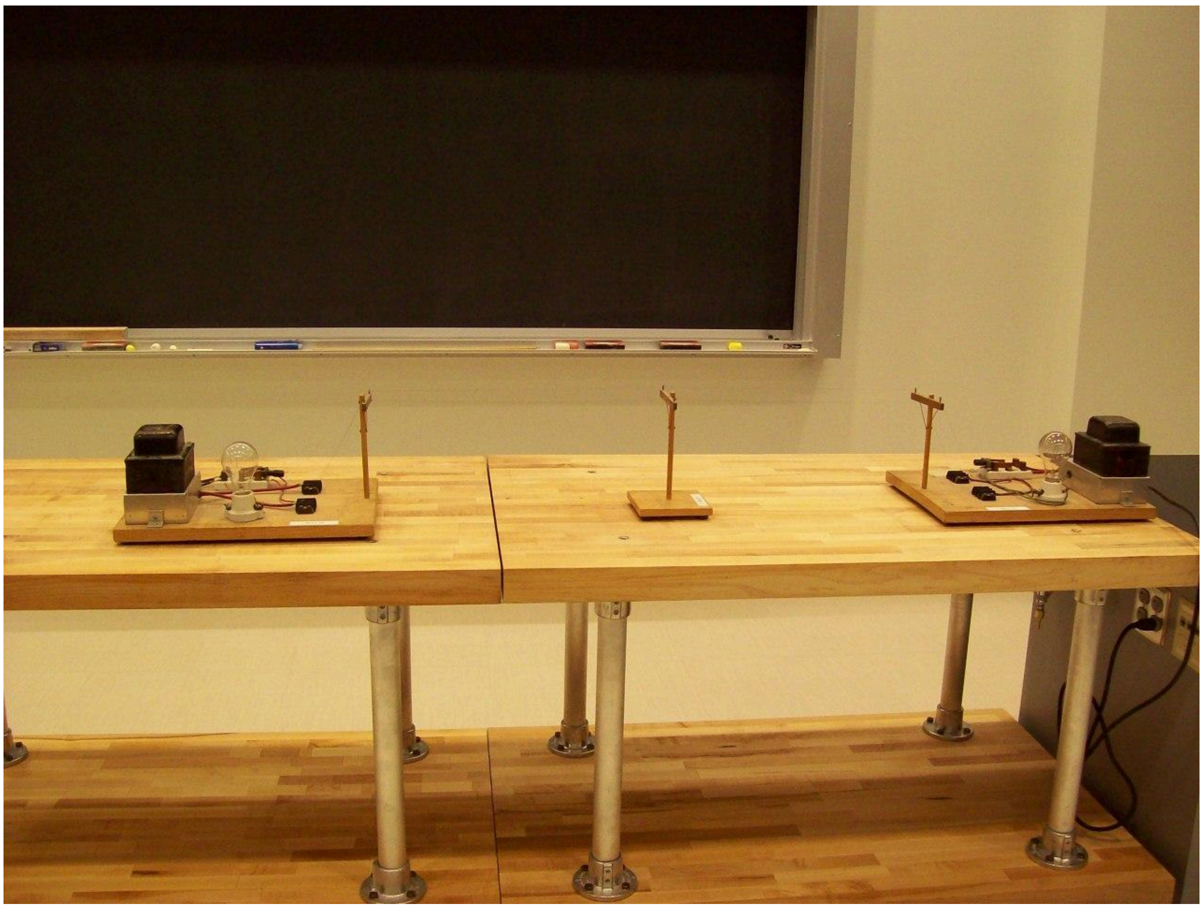
Model of a Semiconductor

	The Air Cushion Table is used to show bound charge carriers in an insulator; a free charge in an insulator, conduction in a semiconductor (N type and P type. Air Cushion Table manual: 2.4.9, 2.4.10, 2.4.11, 2.4.12, 2.4.13.



Location: Ga5

Electricity and Magnetism	5N10.15	ELECTROMAGNETIC RADIATION
Transmission Lines and Antennas		
High Voltage Line Model		
	A model transmission line with a lamp for a load hat shows a loss unless transformers are used to boost voltage up and back.	

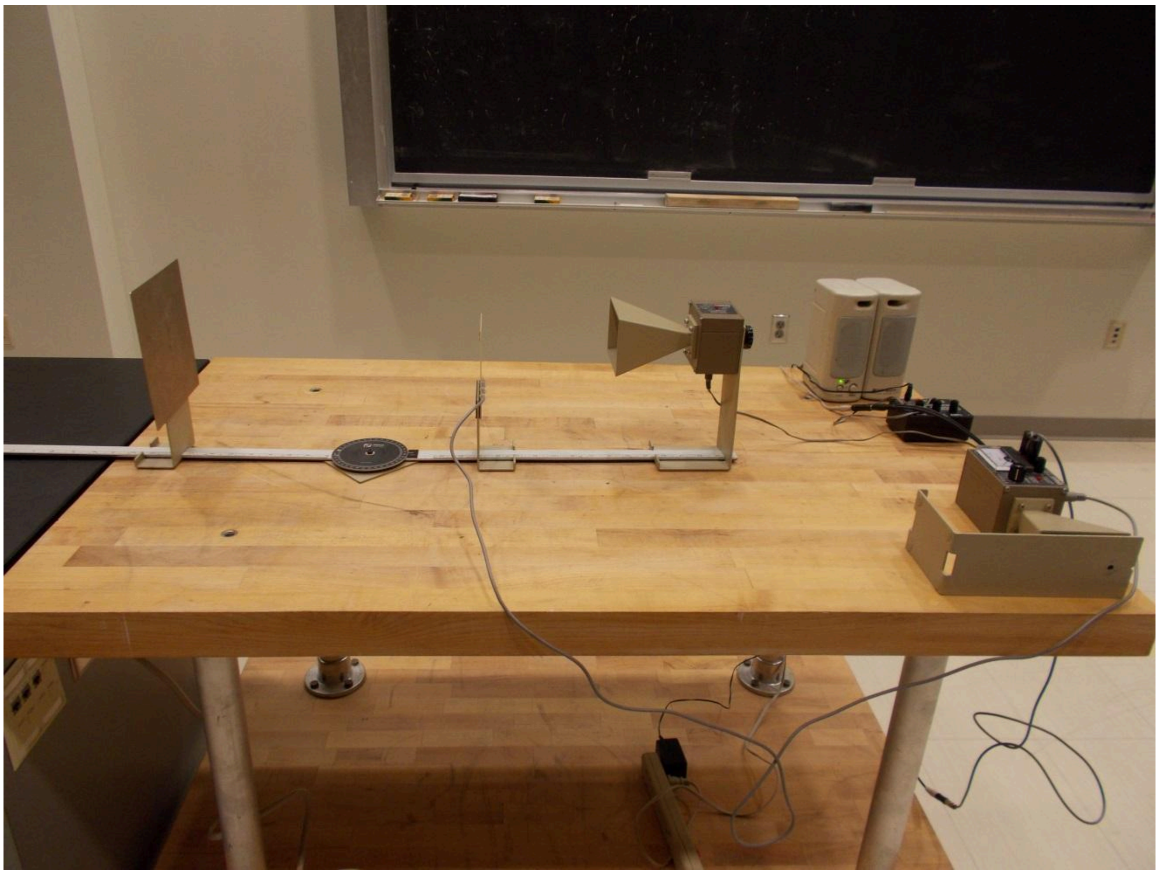


Location: Ia6

Electricity and Magnetism	5N10.55	ELECTROMAGNETIC RADIATION
Transmission Lines and Antennas		

Microwave Standing Waves

	Measure the wavelength of a microwave by using a movable mirror to set up standing waves.

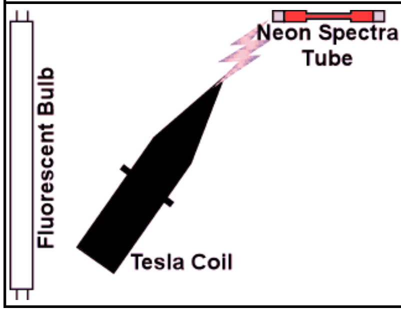


Location: Ia7

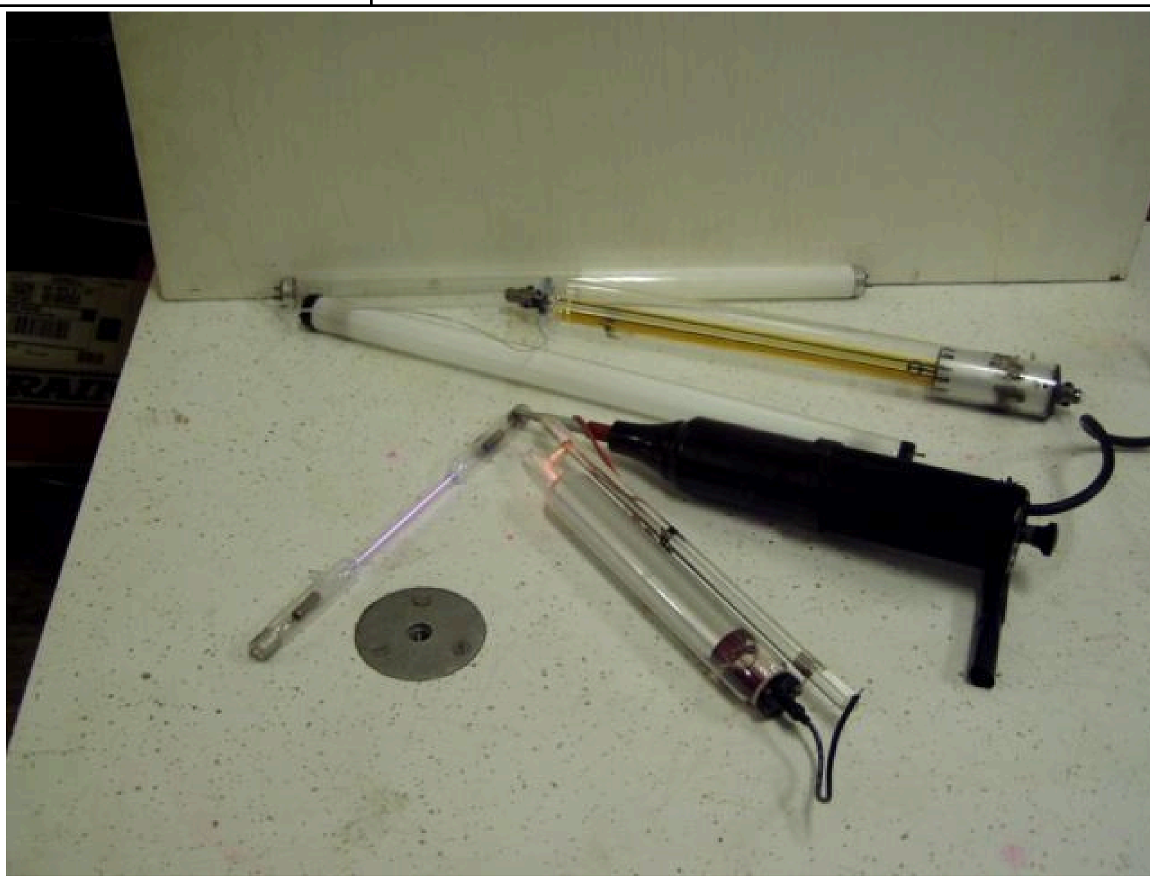
Electricity and Magnetism	5N20.10	ELECTROMAGNETIC RADIATION

Tesla Coil

Tesla Coil (Small)

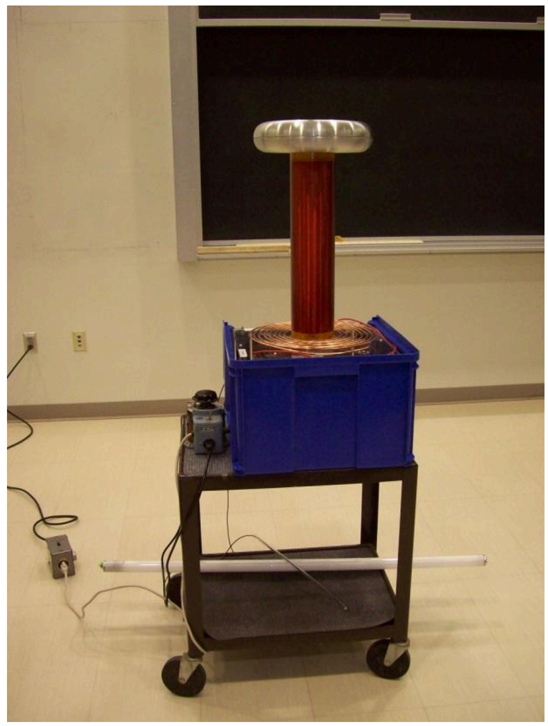


Turn on the Tesla coil. Take the spectra tube and hold it within 2 feet of the Tesla coil. Vary the distance. Do the same thing with the fluorescent tube. Using the grounding wire on the end of the tube can help avoid unpleasant shocks. Discuss shocks vs. burns and high frequency AC. We also have a large Tesla coil.



Location: Ia1

Electricity and Magnetism	5N20.40	ELECTROMAGNETIC RADIATION
Tesla Coil		
# Tesla Coil		
	Large version. **Be Careful: Lethal Voltages and Currents.** The unit is connected to the AC line through a grounded plugged (3 pin AC plug) Variac. A variety of corona, skin depth lighting fluorescent tube demonstrations can be show	

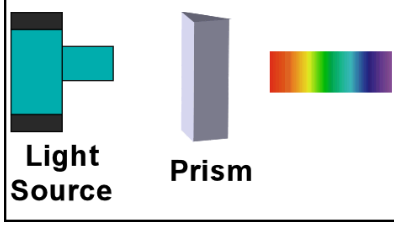



Location: Ia1

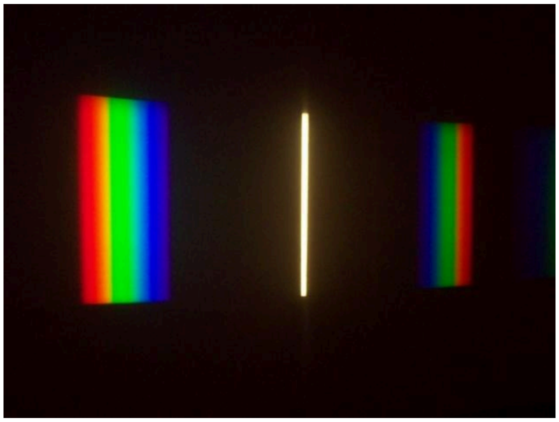
Electricity and Magnetism	5N30.10	ELECTROMAGNETIC RADIATION

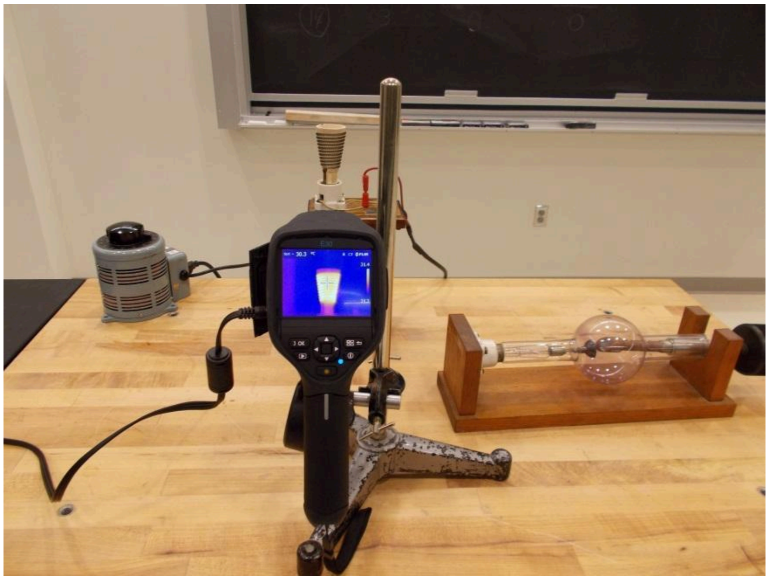
Electromagnetic Spectrum

Projected Spectrum w/Prism



White light is projected through a high dispersion prism and onto a screen. In the photo a grating was used and a Hg lamp was included for a line spectrum in addition to the continuous spectrum. Also shown is the FLIR camera and an IR source with an X-ray tube beside it.



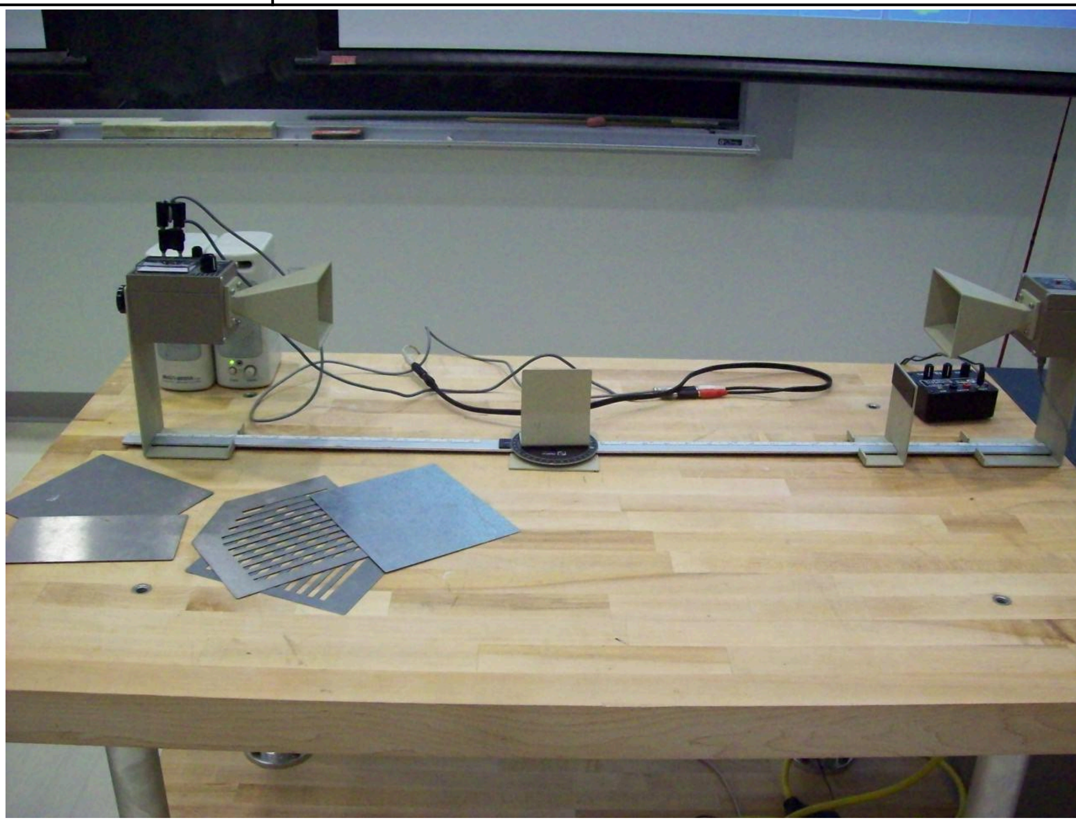


Location: Ib1

Electricity and Magnetism	5N30.30	ELECTROMAGNETIC RADIATION
Electromagnetic Spectrum		

Microwave Transmitter and Receiver

	Polarization, reflection, standing waves and absorption of microwaves are shown.



Location: Ia7