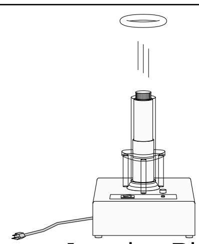
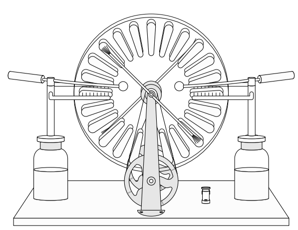
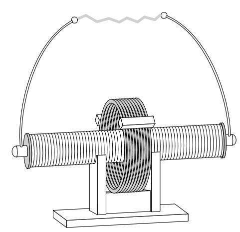
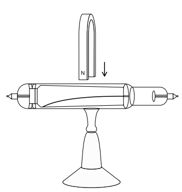
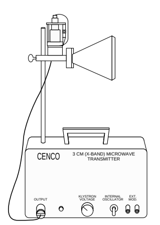
Notebook 'D': Electricity and Magnetism Lecture Demonstrations


Jumping Ring

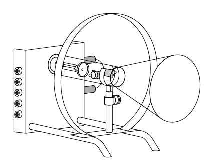

Wimshurst Machine

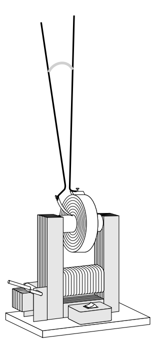

Tesla Coil

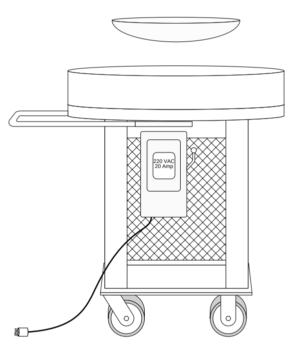

Cathode Ray Tube



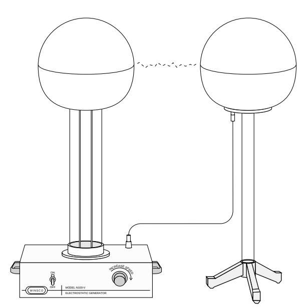
Microwaves


Braun Tube


Jacob's Ladder



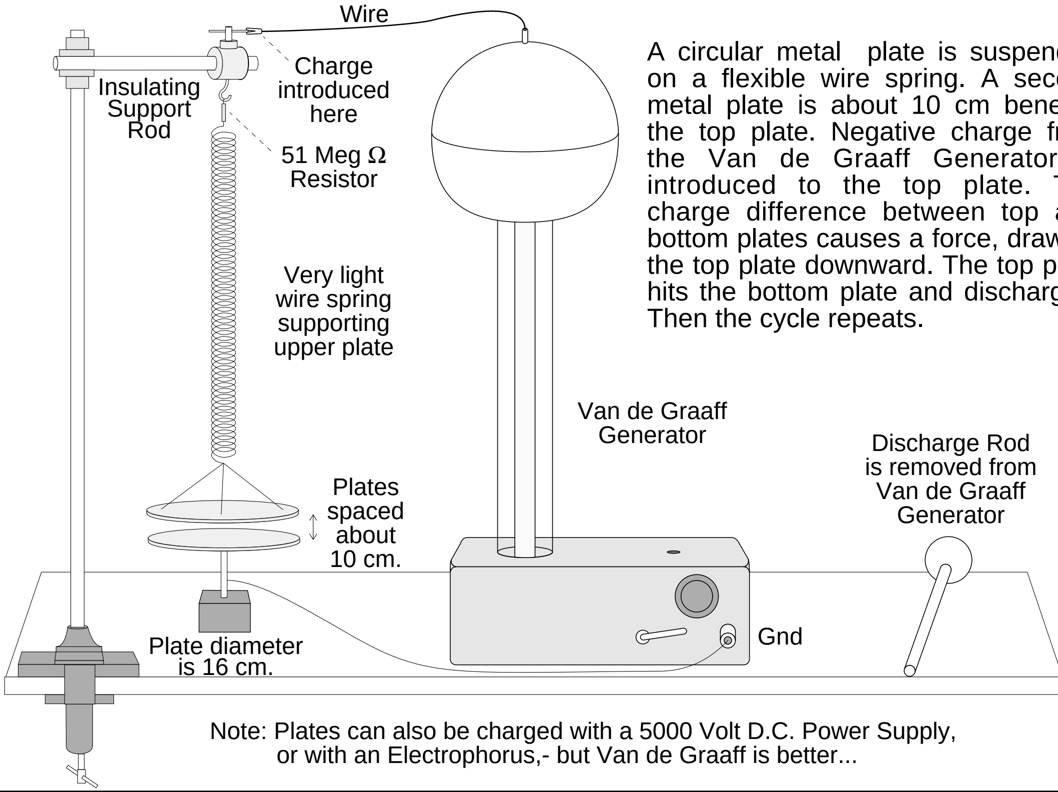
Levitator


Van de Graaff

CAPACITANCE. D+0+0

Attraction between horizontal plates of a charged capacitor.

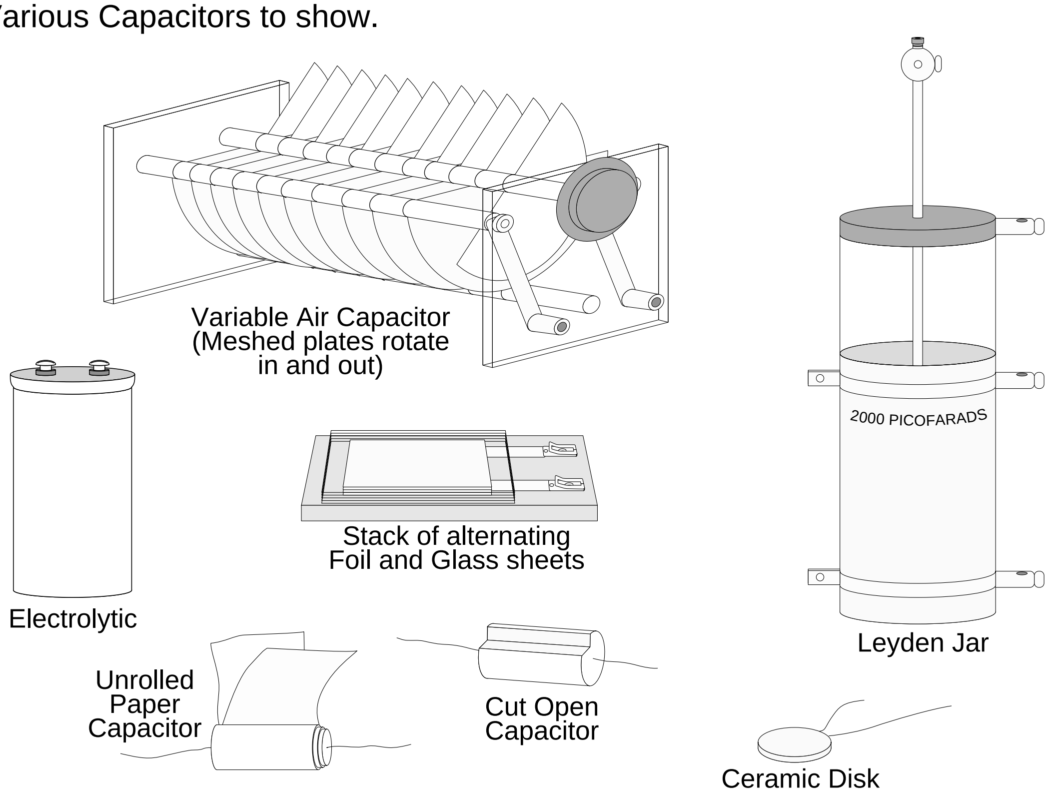
A circular metal plate is suspended on a flexible wire spring. A second metal plate is about 10 cm beneath the top plate. Negative charge from the Van de Graaff Generator is introduced to the top plate. The charge difference between top and bottom plates causes a force, drawing the top plate downward. The top plate hits the bottom plate and discharges. Then the cycle repeats.



Note: Plates can also be charged with a 5000 Volt D.C. Power Supply, or with an Electrophorus,- but Van de Graaff is better...

CAPACITANCE. D+0+2

Various Capacitors to show.



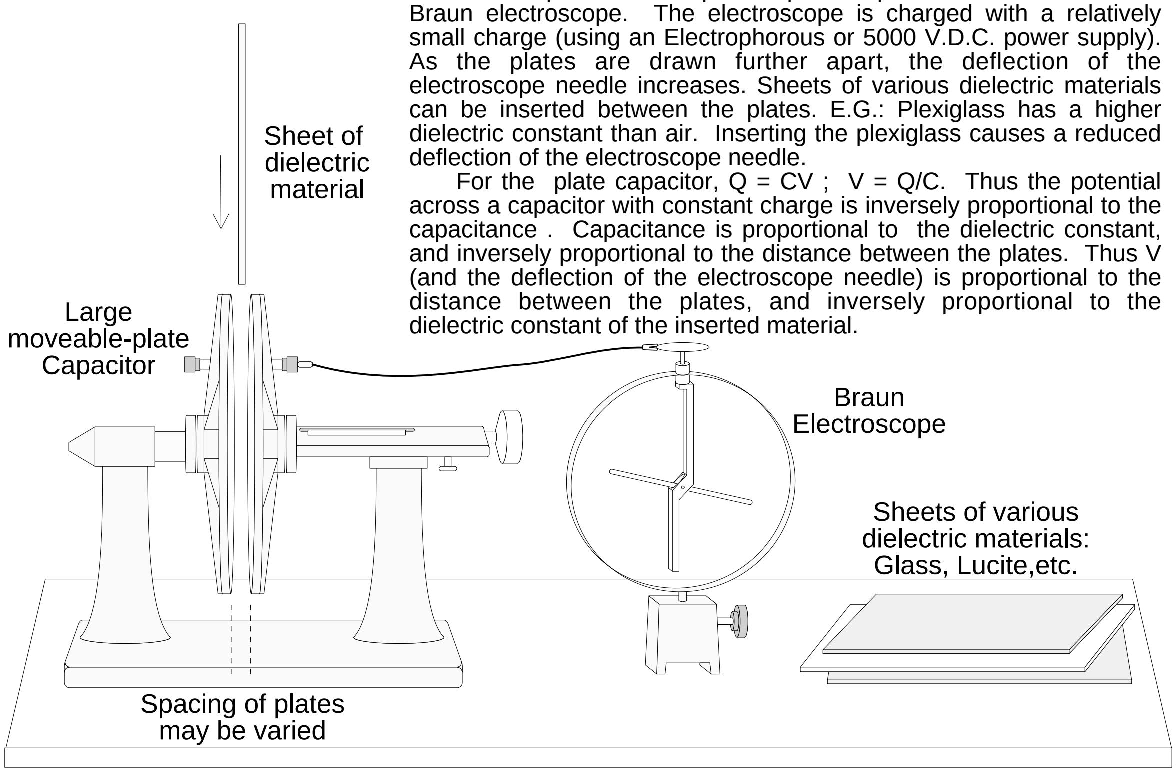
NOTE: There are many other capacitors not shown here...

CAPACITANCE. D+0+4

Parallel plate capacitor with dielectric materials and electroscope.

One of the plates of the parallel-plate capacitor is connected to a Braun electroscope. The electroscope is charged with a relatively small charge (using an Electrophorous or 5000 V.D.C. power supply). As the plates are drawn further apart, the deflection of the electroscope needle increases. Sheets of various dielectric materials can be inserted between the plates. E.G.: Plexiglass has a higher dielectric constant than air. Inserting the plexiglass causes a reduced deflection of the electroscope needle.

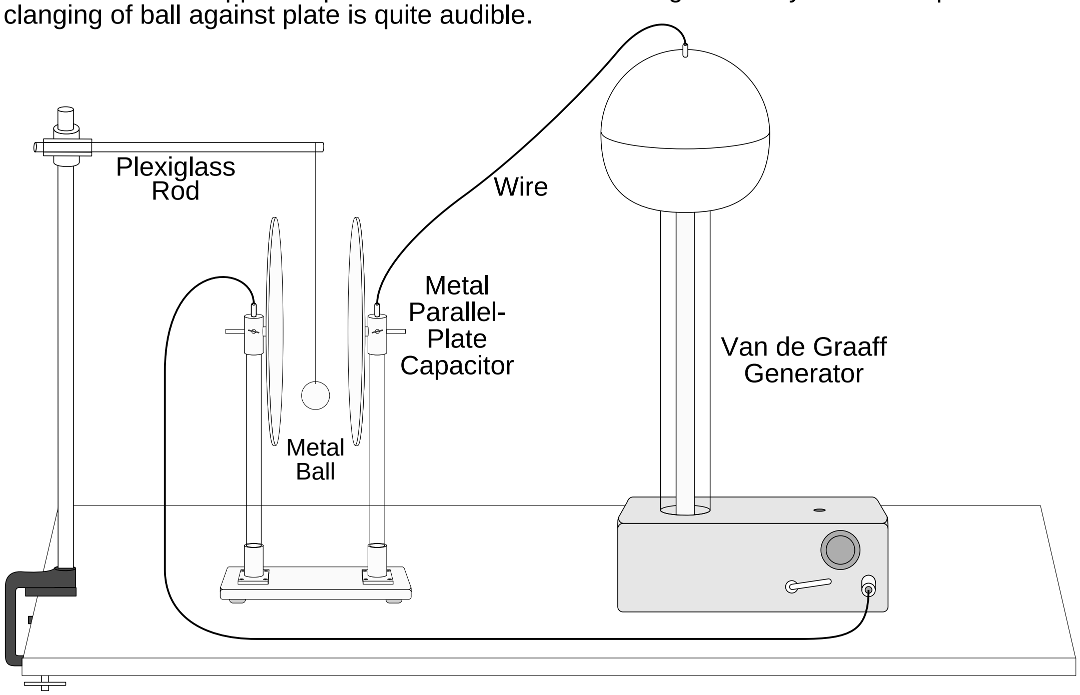
For the plate capacitor, $Q = CV$; $V = Q/C$. Thus the potential across a capacitor with constant charge is inversely proportional to the capacitance . Capacitance is proportional to the dielectric constant, and inversely proportional to the distance between the plates. Thus V (and the deflection of the electroscope needle) is proportional to the distance between the plates, and inversely proportional to the dielectric constant of the inserted material.



CAPACITANCE. D+0+6

Capacitor doorbell driven by Van de Graaff generator.

Negative charge from the Van de Graaf generator builds up on one plate. The metal ball, initially uncharged, is attracted to the negative plate and hits it, becoming negative also. It rebounds to the opposite plate where it loses its charge. The cycle then repeats. The clanging of ball against plate is quite audible.

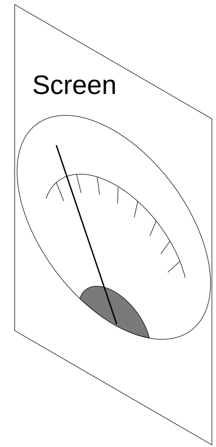


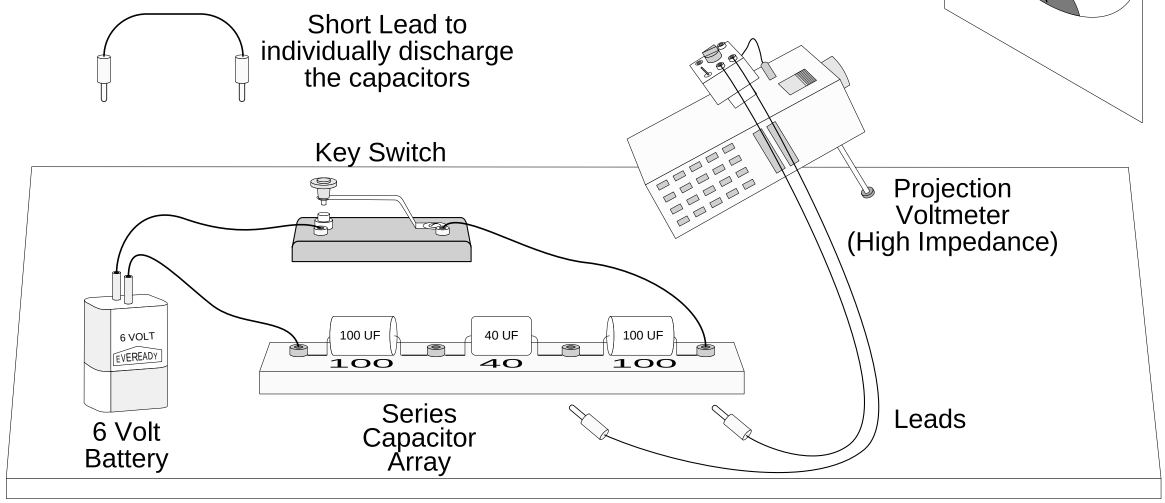
CAPACITANCE. D+0+8

Series capacitor array.

Close the key switch briefly (about a second) to establish a charge. Once charged, the voltages on each capacitor may be read using a high impedance (about 10 megohms) voltmeter. A voltage reading must be done quickly or else the charge on the capacitor will drain away.

This array is 100-40-100 microfarads. High-quality electrolytic capacitors are used.

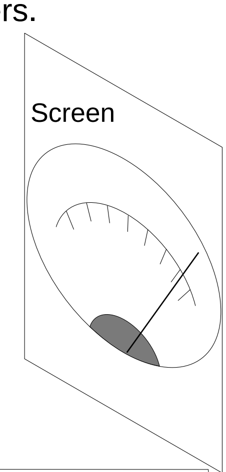


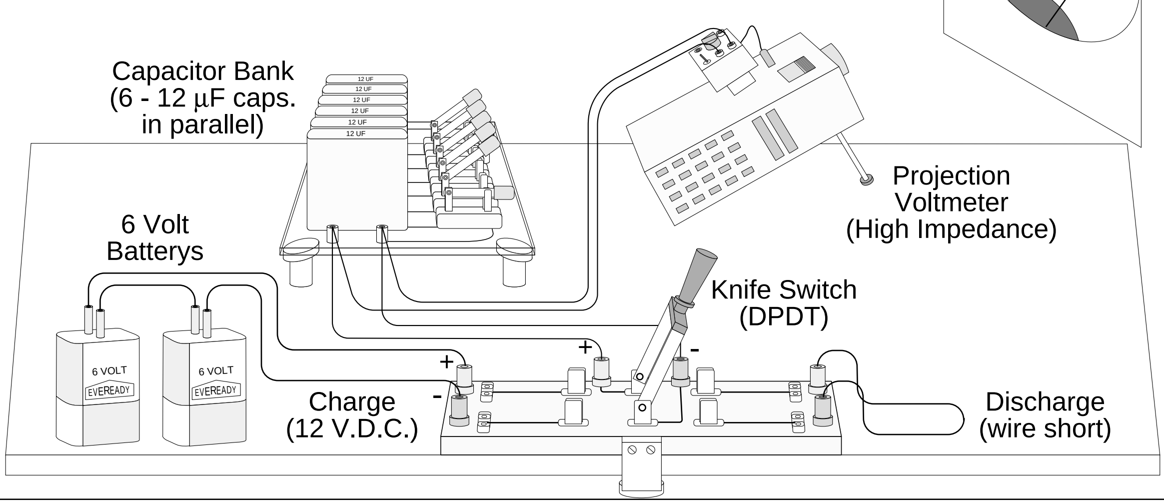


CAPACITANCE. D+0+10

Parallel capacitor array: A charged capacitor charges the others.

Discharge the circuit by closing all capacitor switches and placing the knife switch in the discharge position. Open all capacitor switches but one, then close the knife switch in the charge position. Now open the knife switch and notice the voltage on the projection voltmeter. At this point, throw the switches on the capacitor array, one at a time. Notice that the voltage decreases as you add more capacitance. The voltage should decrease fairly proportionally, because the capacitors have the same value.

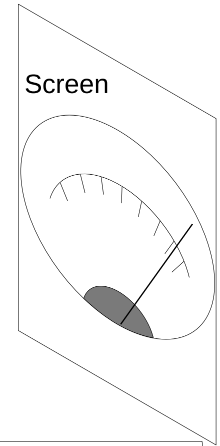


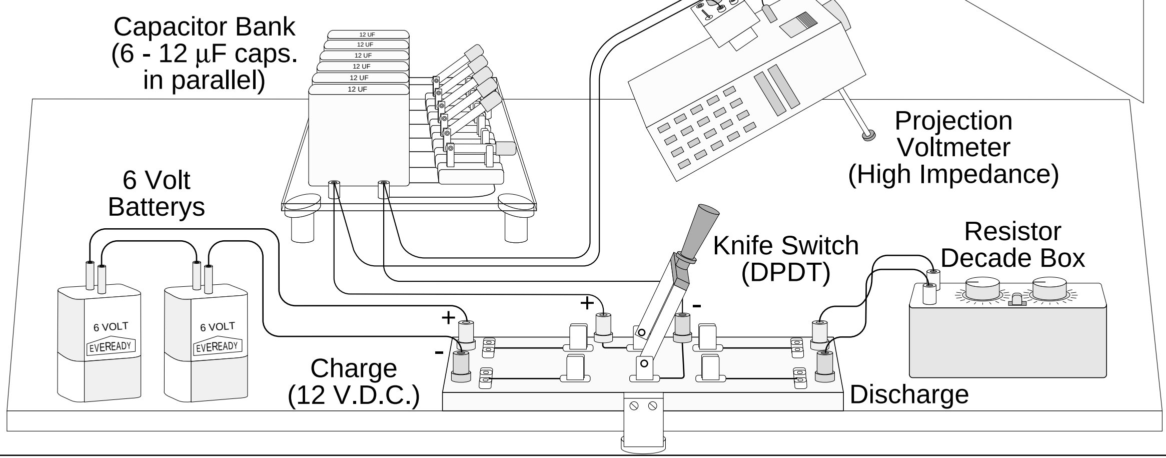


CAPACITANCE. D+0+12

Visual charge/discharge of a capacitor through a load.

The capacitors in the capacitor bank are in parallel. Closing or opening the capacitor switches selects a desired capacitance. Throw the large knife switch to the 'charge' position to charge the capacitors. Select a resistor value on the resistor box, then throw the knife switch to the 'discharge' position to discharge the capacitors through the resistance. The high impedance voltmeter shows both the exponential charging and discharging of the capacitors.

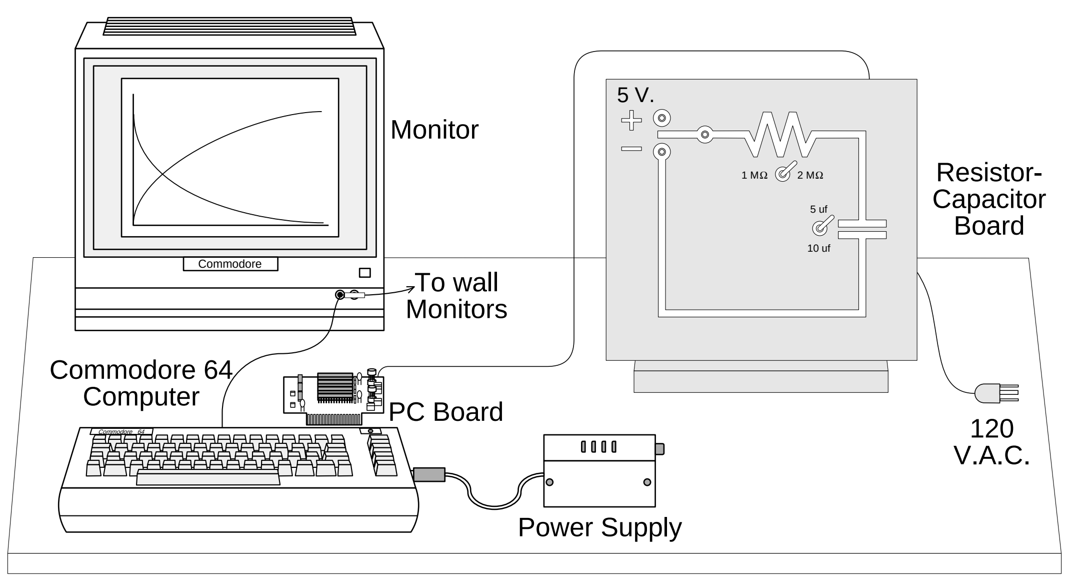




CAPACITANCE. D+0+14

Computer Demo: Charge/discharge of a capacitor, runs 3 minutes.

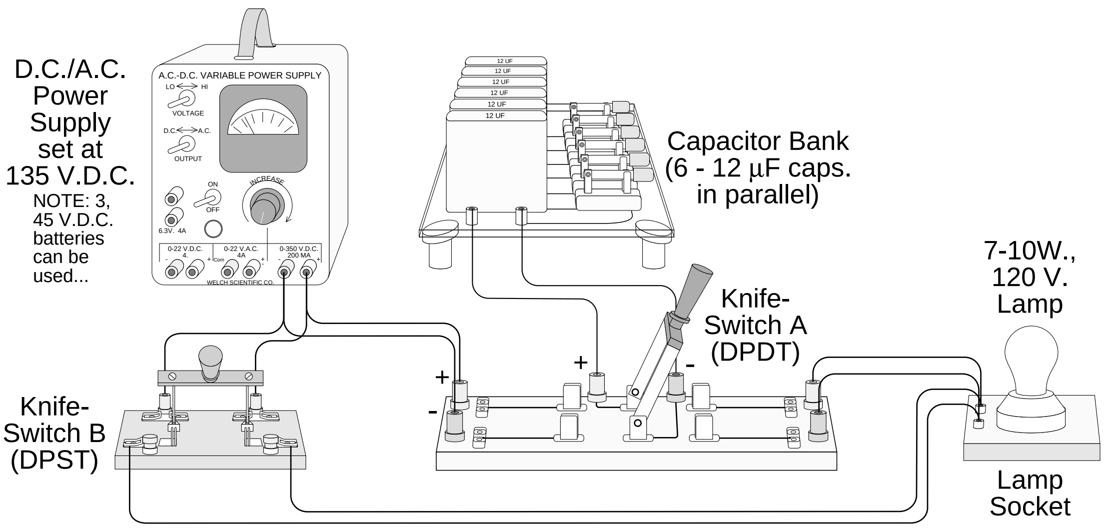
This program plots voltage versus time for the charging and discharging of a capacitor through a series resistor. Two values of resistor (1 Meg Ω or 2 Meg Ω) and 2 values of capacitor (5 µf or 10 µf) can be chosen. After the plot is finished (3 min.) , you can input the values of the resistor and capacitor used, and the computer will calculate the value of the time constant and compare it with the measured value.
NOTE: Switches on the back of the resistor-capacitor board allow one to manually charge and discharge the capacitor. Output can be sent to an oscilloscope.



CAPACITANCE. **D+0+16**

Discharging a capacitor through a lamp.

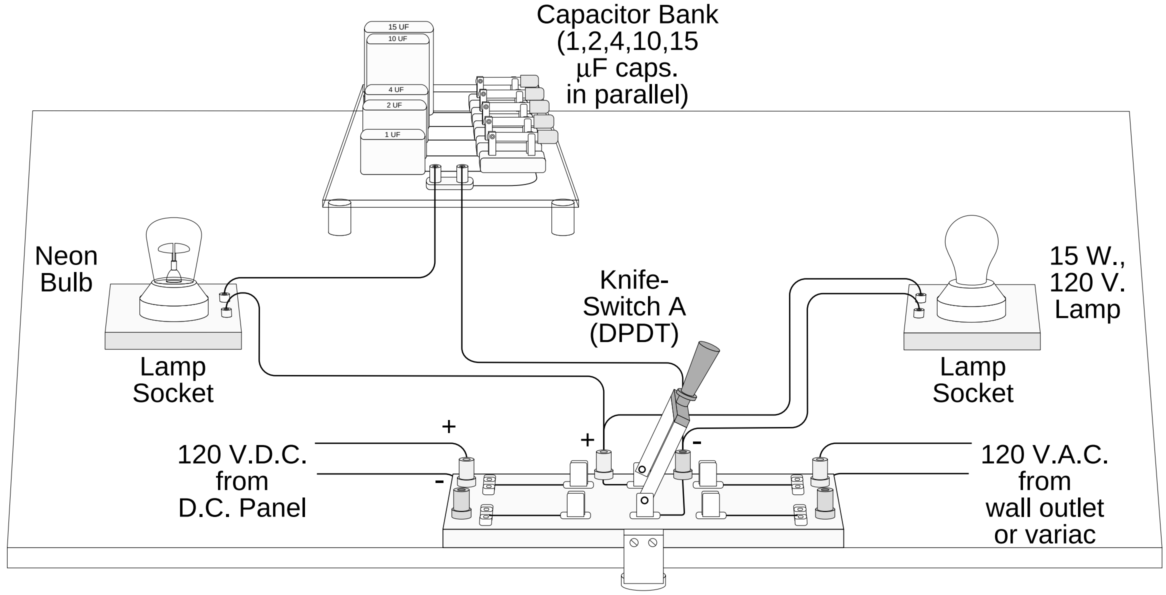
Throw knife-switch A to the left to charge the capacitor bank with 135 V.D.C. Throw Switch A to the right to discharge the capacitor bank through the lamp, causing a flash. Close knife-switch B to put 135 V.D.C. across the lamp, causing it to glow continuously.



CAPACITANCE. **D+0+18**

Capacitors with a series neon bulb on A.C. and D.C..

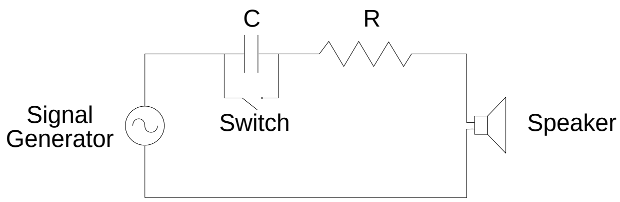
Throw knife-switch A to the left to put 120 V.D.C. across the series capacitor and neon bulb circuit. The breakdown voltage of the neon in the neon bulb is about 70 volts, but only one of the two semi-circular electrodes in the bulb glows briefly. Throw Switch A to the right to put 120 V.A.C. across the capacitor and neon bulb circuit. Now both electrodes of the neon bulb glow. In both the D.C. and A.C. cases, the regular 15 watt tungsten filament lamp glows continuously.

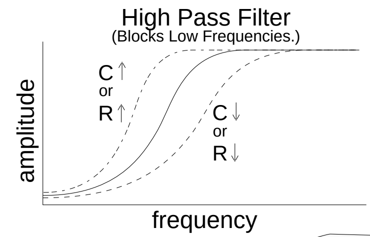


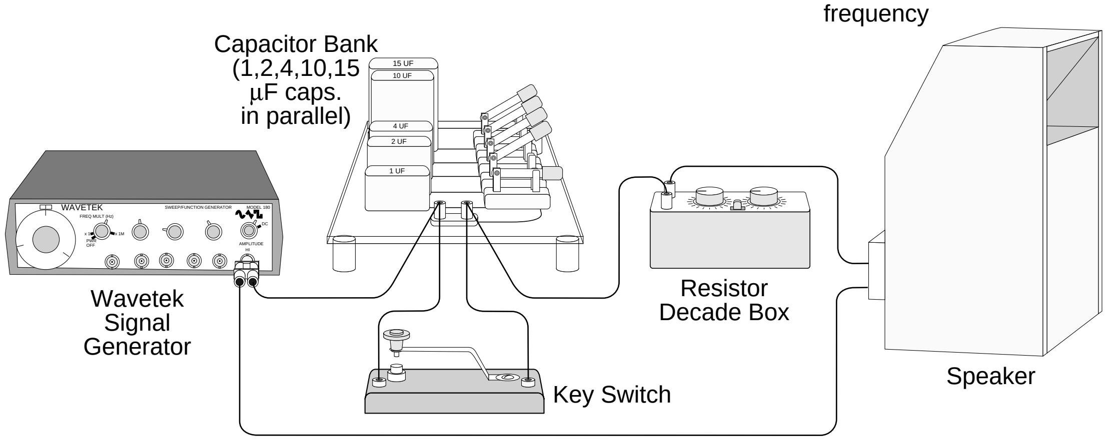
CAPACITANCE. D+0+20

Capacitor in series in an audio circuit: High pass filter.

A variable audio oscillator is hooked to a capacitor and resistor in series. The circuit passes high frequencies and blocks low frequencies, as can be heard with the speaker. Capacitance and resistance can be varied. A good set of starting values is 1 µf capacitance, and 15 Ω resistance. Maximum signal is at 20 KHz; signal is attenuated by 50% at 760 Hz (6 db down); and by 90% at 260 Hz (20 db down). Closing or opening the key-switch allows one to check the frequency attenuation.







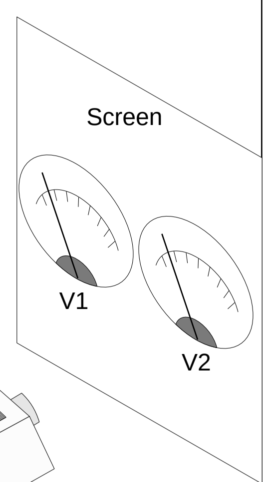
CAPACITANCE. D+0+22

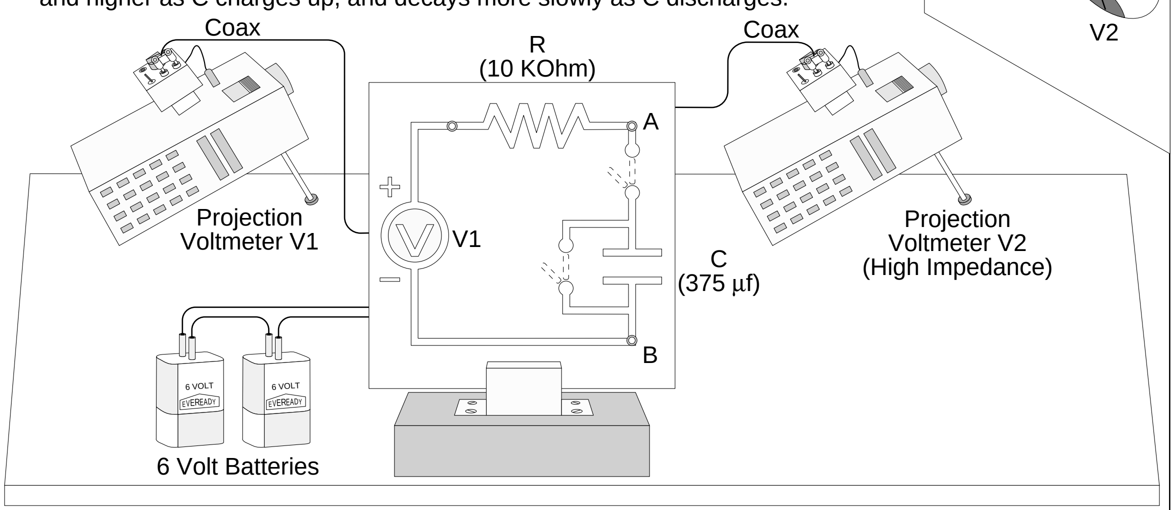
Effects of changing a D.C. voltage in a series RC circuit.

On the back of this RC board is a variable potentiometer that can vary the voltage V1 across the series RC circuit quickly from 0 to 12 volts D.C. Voltmeter V2 swings to show voltage fluctuations across C (or across R) when V1 is varied. There are actually 4 possible configurations of this circuit, determined by a mult-step switch on the back of the board:

1: The capacitor is replaced with a wire. V2 is measured across R.
2: The capacitor is in the circuit. V2 is measured across R.
3: The capacitor is taken out of the circuit. V2 is measured across A & B.
4. The capacitor is in the circuit. V2 is measured across Capacitor C.

In cases 1 and 3 , variations in V2 match variations in V1. In case 2, V2 tries to follow V1, but sluggishly. In case 4, V2 tries to follow V1, but rises higher and higher as C charges up, and decays more slowly as C discharges.

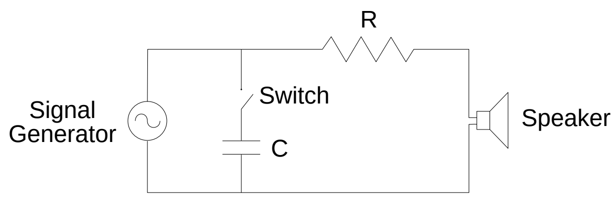


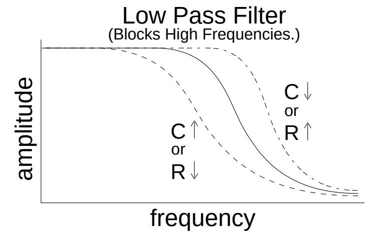


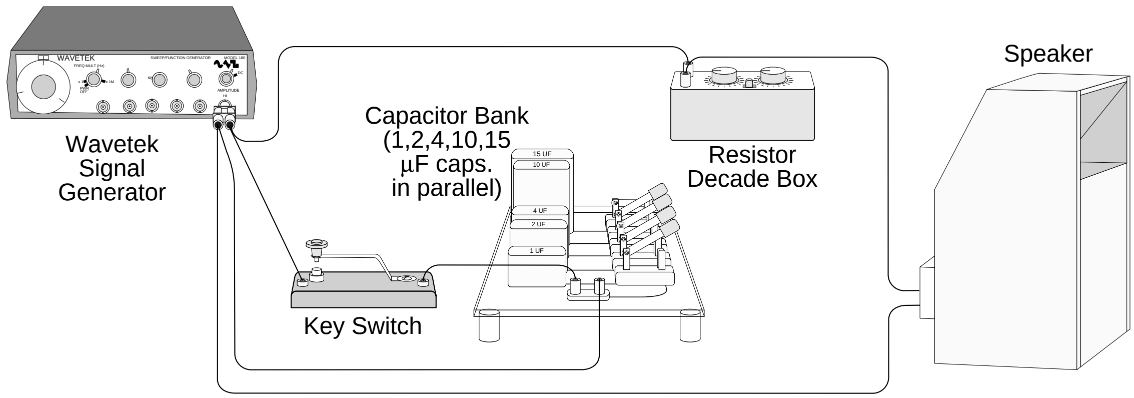
CAPACITANCE. D+0+24

Capacitor in parallel in an audio circuit: Low pass filter.

A variable audio oscillator is hooked to a capacitor and resistor in parallel. The circuit passes low frequencies and blocks high frequencies, as can be heard with the speaker. Capacitance and resistance can be varied. A good set of starting values is 15 μf capacitance, and 100 Ω resistance. Maximum signal is at 20 Hz; signal is attenuated by 50% at 1800 Hz (6 db down); and by 90% at 5400 Hz (20 db down). Closing or opening the key-switch allows one to check the frequency attenuation.

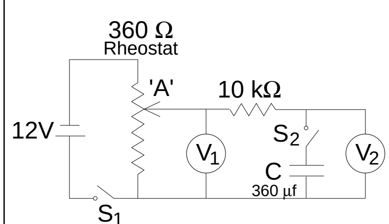




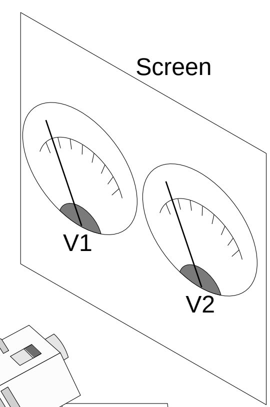


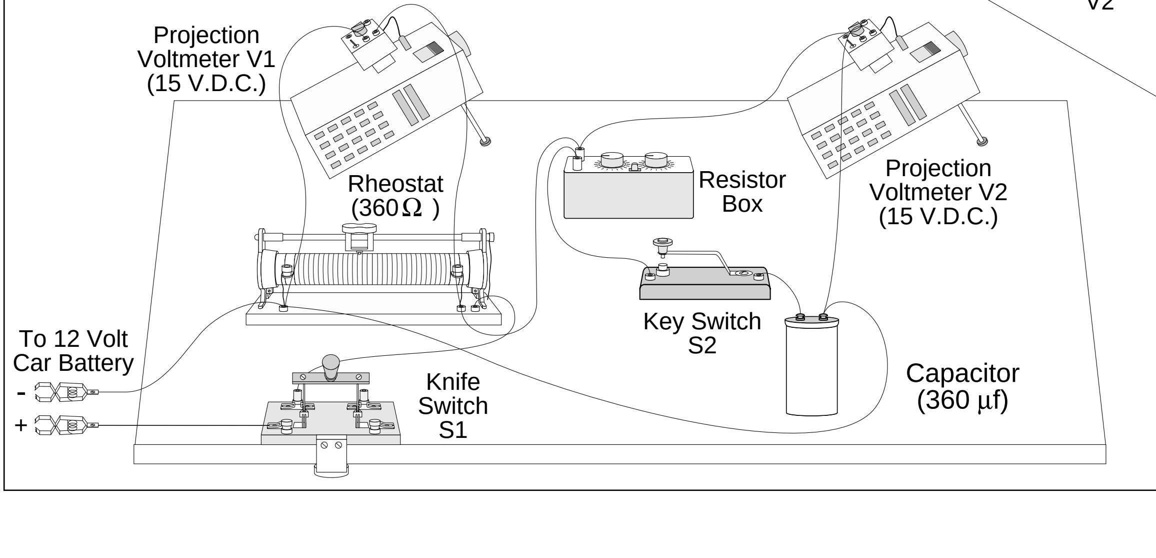
CAPACITANCE. D+0+26

Capacitor in parallel in a D.C. circuit.



When switch S1 is closed, 12 V.D.C. is put across a 360 ohm slidewire rheostat. Moving the slider on the rheostat varies the voltage at 'A' from 0 to 12 V. When capacitor C (360 μf) is not in the circuit (switch S2 open), rapidly moving the rheostat slider causes voltmeters 1 and 2 to swing quickly and equally to read voltage changes. When C is in the circuit (S2 closed), voltmeter 1 swings quickly to read voltage changes, but voltmeter 2 responds slowly. Thus, when C is in the circuit, time variations are smoothed out.



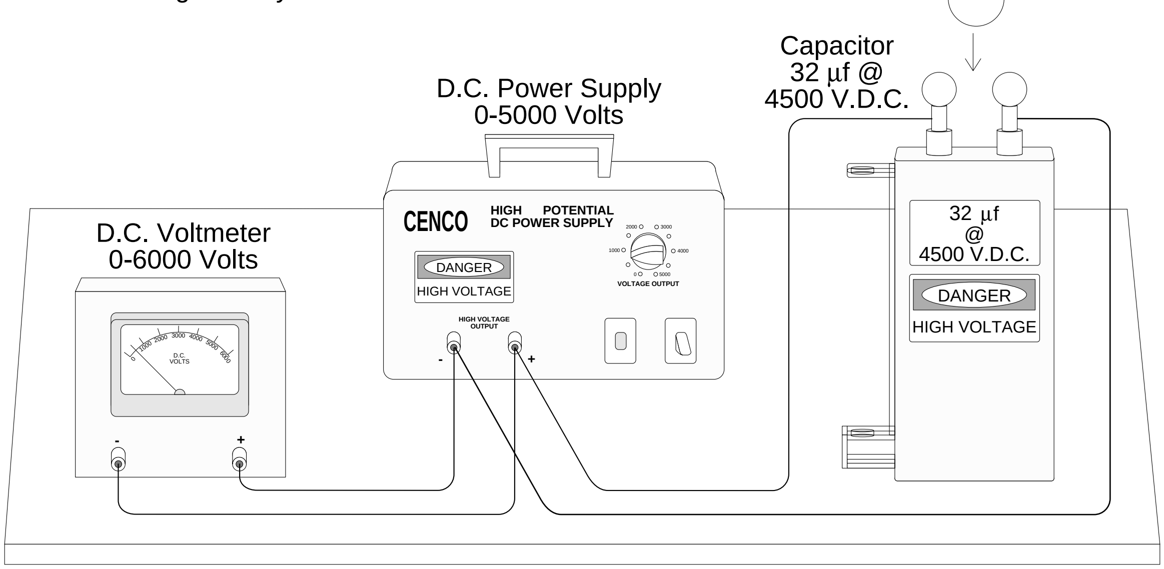


CAPACITANCE. **D+0+28**

Energy storage in a commercial capacitor. Loud bang!

A high voltage D.C. power supply is used to charge a large commercial capacitor. The power supply is set at about 2500 volts, and the capacitor is allowed to charge for a minute or so. The power supply is then turned off, and the capacitor is discharged with a metal ball on an insulating rod. The sound of the discharge is very loud!

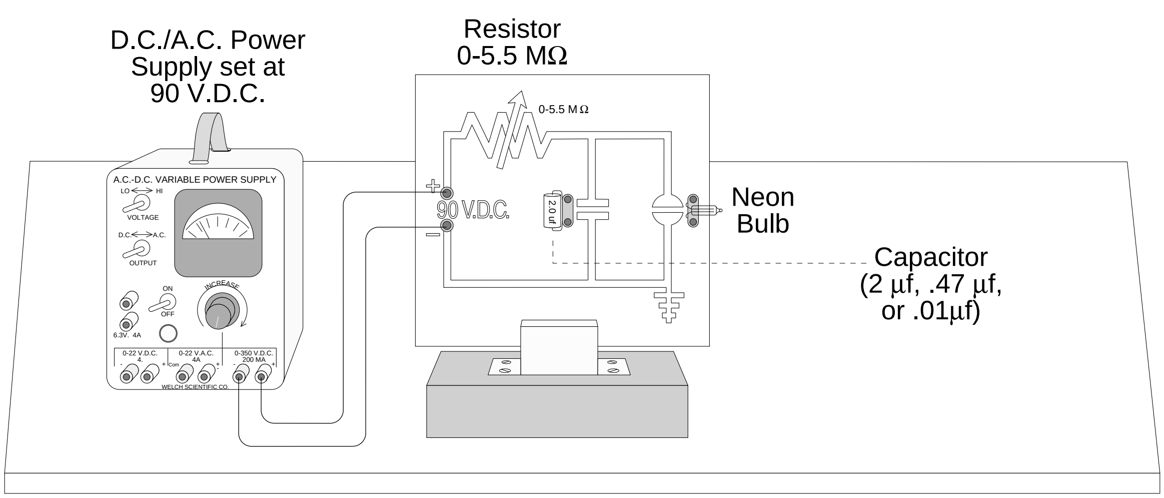
Brass Ball with insulated handle to discharge capacitor.



CAPACITANCE. **D+0+30**

Oscillator made with resistor, capacitor and neon lamp.

90 Volts D.C. is put across a series RC circuit. A neon bulb is in parallel with the capacitor. When the capacitor charges up to 80 volts, the neon bulb flashes (breakdown voltage for this neon bulb is about 80 volts), draining the capacitor charge. The capacitor then begins to charge again, and the cycle repeats. The period T of the flashes of the bulb is the product of the Resistance and Capacitance (RxC). The resistance can be varied from 0 to 5.5 M Ω, and three different capacitors can be plugged in: 2 µf, .47 µf, and .01 µf.

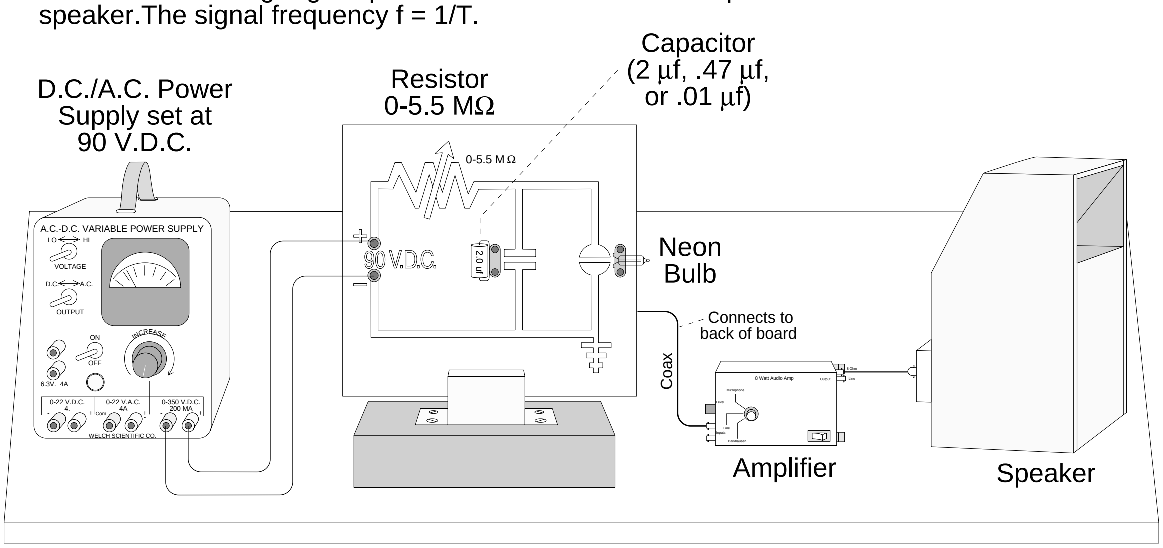


CAPACITANCE. D+0+32

Same as D+0+30 using speaker for audio tone generation.

90 Volts D.C. is put across a series RC circuit. A neon bulb is in parallel with the capacitor. When the capacitor charges up to 80 volts, the neon bulb flashes (breakdown voltage for this neon bulb is about 80 volts), draining the capacitor charge. The capacitor then begins to charge again, and the cycle repeats. The period T of the flashes of the bulb is the product of the Resistance and Capacitance (RxC). The resistance can be varied from 0 to 5.5 M Ω, and three different capacitors can be plugged in: 2 μf, .47 μf, and .01 μf.

The oscillating signal produced in this demo is amplified and made audible with a speaker.The signal frequency f = 1/T.

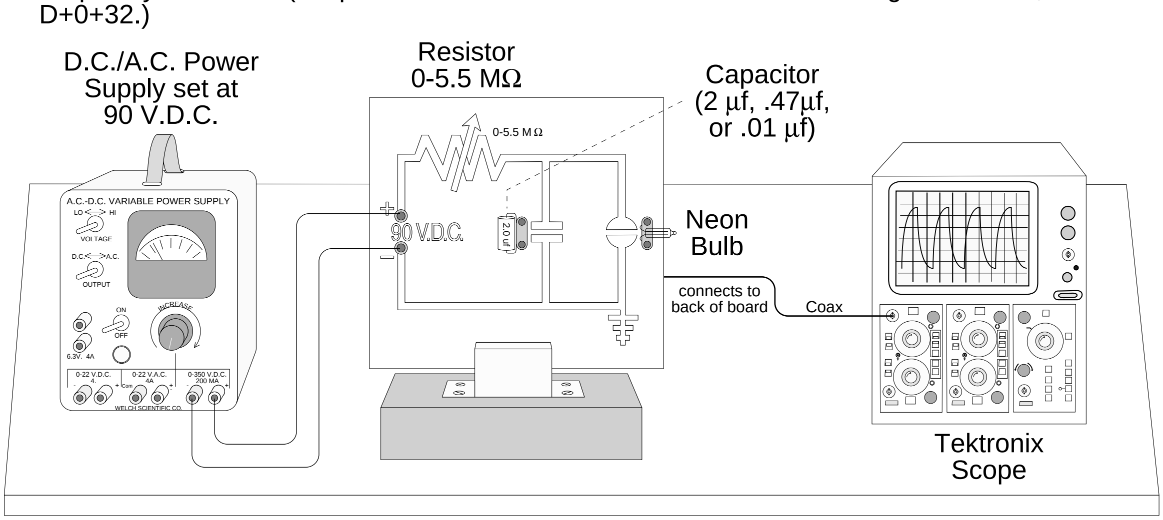


CAPACITANCE. D+0+34

Same as D+0+30 using oscilloscope to display waveform.

90 Volts D.C. is put across a series RC circuit. A neon bulb is in parallel with the capacitor. When the capacitor charges up to 80 volts, the neon bulb flashes (breakdown voltage for this neon bulb is about 80 volts), draining the capacitor charge. The capacitor then begins to charge again, and the cycle repeats. The period T of the flashes of the bulb is the product of the Resistance and Capacitance (RxC). The resistance can be varied from 0 to 5.5 M Ω, and three different capacitors can be plugged in: 2 μf, .47 μf, and .01 μf.

The oscillating signal produced in this demo is displayed on an oscilloscope. The signal frequency f = 1/T. (A speaker can also be attached to make the signal audible, as in D+0+32.)

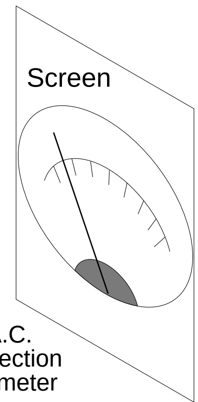


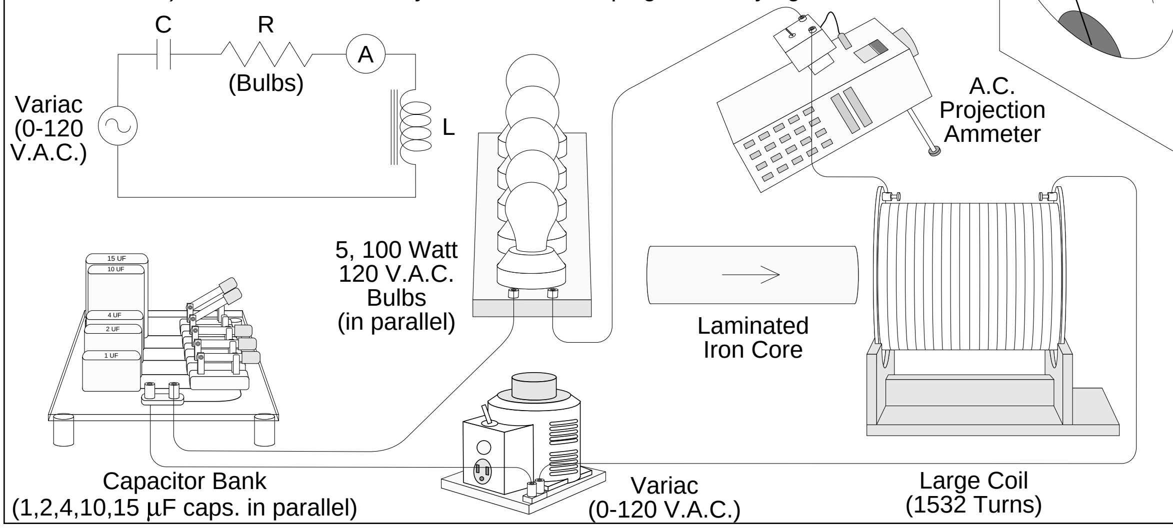
ELECTROMAGNETIC OSCILLATIONS. D+5+0

Resonance in a series LCR circuit using 120 v.a.c.

This is a series LRC circuit. 0-120 V.A.C. is supplied with a Variac. The light bulbs are the resistance; the large coil is the inductance, and the capacitance is a bank of capacitors in parallel. Resistance can be changed by removing or adding light bulbs. The inductance of the coil can be changed by moving a laminated iron core into or out of the center of the coil. Capacitance can be changed by throwing switches on the capacitor bank.

A good set of values to start with is 20 μf capacitance, and the bank of five 100 watt bulbs. When the variac is turned to 120 volts a.c., the bulbs glows dimly. When the laminated iron core is inserted half-way into the coil, the lamps glow brightly (LCR resonance). When the core is fully inserted, the lamps glows dimly again.



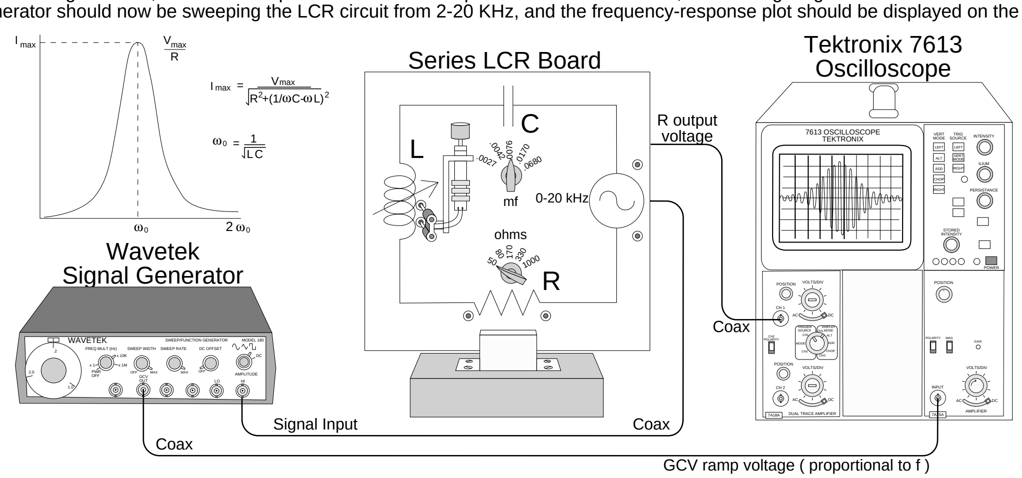


ELECTROMAGNETIC OSCILLATIONS. D+5+2

LCR series resonance curve of V vs. F (2-20 kHz) on an oscilloscope.

In this series LCR circuit, a signal generator sweeps from 2 kHz to 20 kHz, and the amplitude of the circuit current (measured as voltage across the resistor) is displayed versus frequency on the oscilloscope screen. Using the variable inductor (16-36 mh) and the .0076 μf capacitor, peak resonance is from 8-13 kHz, approximately in the center of the screen. Inductance, resistance and capacitance can all be varied. To move the resonance peak left or right on the screen, vary either the inductance or capacitance. To change the 'Q' (or sharpness) of the resonance peak, change the resistance.

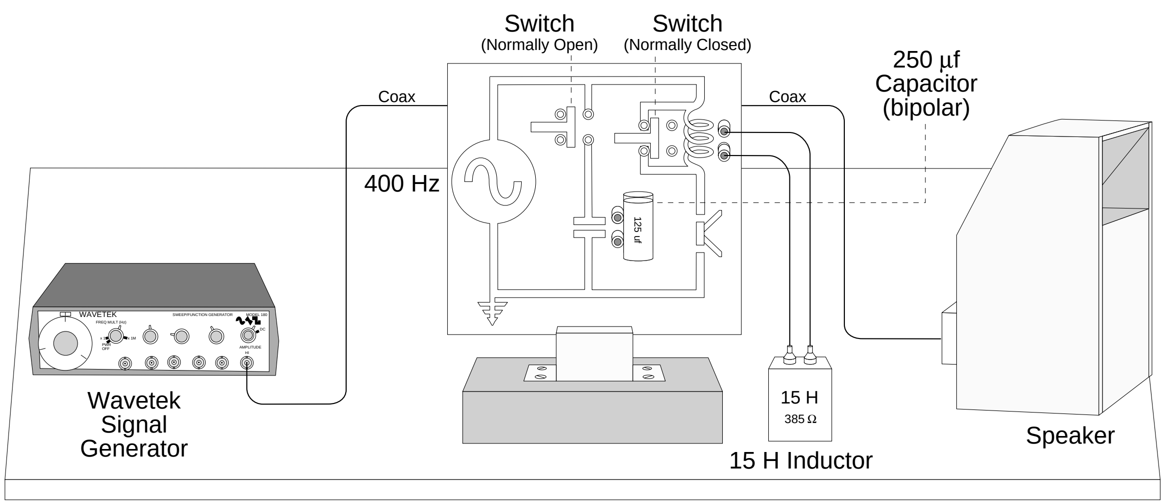
Set-up Notes: The time base of the scope is replaced with a plug-in amp, controlling the horizontal motion of the beam. This amp is driven by the GCV output of the signal generator (a ramp proportional to the frequency). The signal generator drives the LCR circuit (co-ax connection on back of board). The voltage across the resistor (coax-connector, back of board) is the input to the vertical amp on the scope. Use .1 V/Div for both the vertical and horizontal amp plug-ins. Use the 10 KHz scale for the signal generator. To adjust the screen display: place horizontal and vertical amps on 'DC' setting. Zero the DC Offset knob, and the Sweep Width and the Sweep Rate knobs of the signal generator. First, set the frequency to 2 KHz and use the position knob on the right plug-in (horizontal sweep) to locate the vertical line at screen left. Then, set the frequency to 20 KHz, and use the 'cal' volts/div knob on the right plug-in to locate the vertical line at screen right. Then, turn the Sweep Width and the Sweep Rate knobs to full scale, with the signal generator set to 2 KHz. The signal generator should now be sweeping the LCR circuit from 2-20 KHz, and the frequency-response plot should be displayed on the scope.



ELECTROMAGNETIC OSCILLATIONS. D+5+4

Low frequency filtering using a capacitor and inductor.

This demonstration shows how low frequency A.C. signals (400 Hz) are affected by a series inductor or a capacitor in parallel. A variable audio oscillator is connected via coax cable to the back of the demo board. The board is set up with switches on back so that an inductor can be placed in series with the speaker, or a capacitor can be placed in parallel with the speaker. When no switch is pressed, neither the capacitor nor inductor is in the circuit. When either the 250 μf capacitor or 15H inductor is in the circuit, the audio signal to the speaker is drastically reduced.

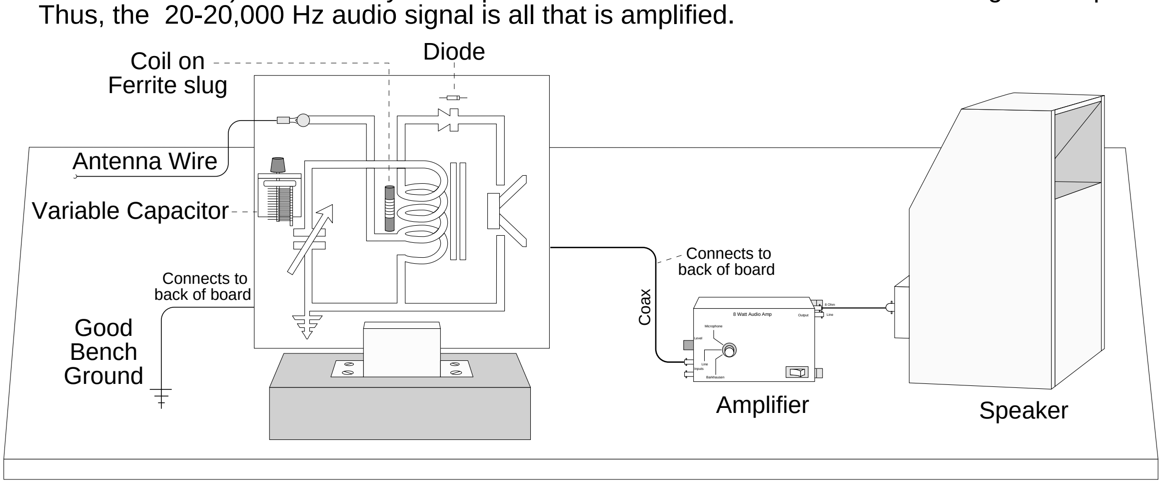


ELECTROMAGNETIC OSCILLATIONS. D+5+6

Crystal radio circuit for AM reception.

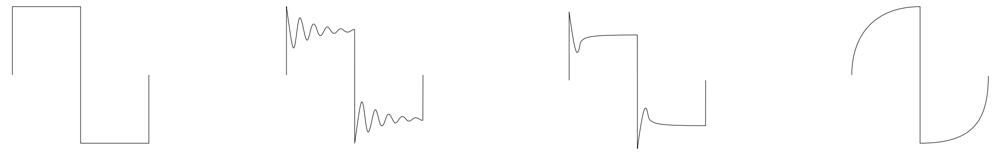
This is a simple crystal-radio receiver circuit. An antenna wire from the roof of LeConte Hall connects to a coil wrapped on a ferrite slug which is in parallel with a variable capacitor (a 'tank' circuit). The antenna receives e-m radiation of all frequencies, giving rise to currents in the coil. The variable capacitor 'tunes' the tank circuit to resonate with the carrier frequency of any AM radio station (45-160 KHz). The signal is picked off the coil, rectified by the diode (made into an D.C. audio signal), amplified, then made audible with the speaker. To change the channel, just turn the tuning capacitor.

The capacitor is in the 45 -157 pf range. The inductor should be in the low milli-henry range (.05 to 1.3 mH). The high-frequency part of the detected audio signal (45-160 KHz = the carrier wave) is bled off by the capacitance of the coax cable before reaching the amp. Thus, the 20-20,000 Hz audio signal is all that is amplified.

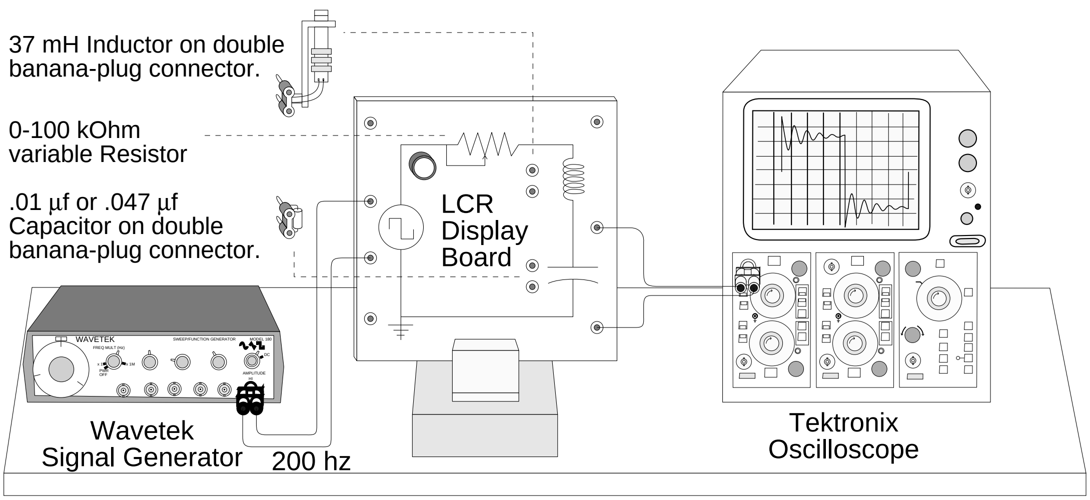


ELECTROMAGNETIC OSCILLATIONS. D+5+8

Damped Oscillations in a resonant LCR circuit on an oscilloscope.



The various different waveforms are created by adjusting the 100k potentiometer on the LCR display board.

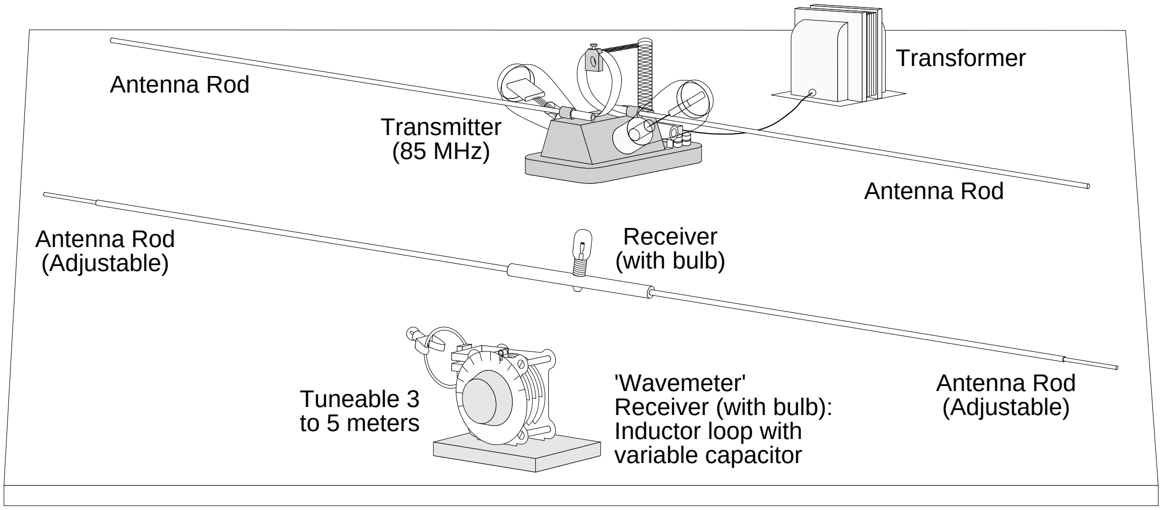


ELECTROMAGNETIC OSCILLATIONS. D+5+10

85 MHz radio transmitter, with indicating lamp on dipole antenna.

This is a simple radio transmitter and receiver demonstration apparatus. The transmitter is a high frequency vacuum tube oscillator with a fixed frequency of 85 MHz (3.5 M wavelength), powered by a transformer. Mica capacitors are mounted within the bakelite case, and the simple loop (7 cm. diameter) on top is the inductance. Horizontal copper 'sending' antennas are plugged into the ends of the inductance loop.

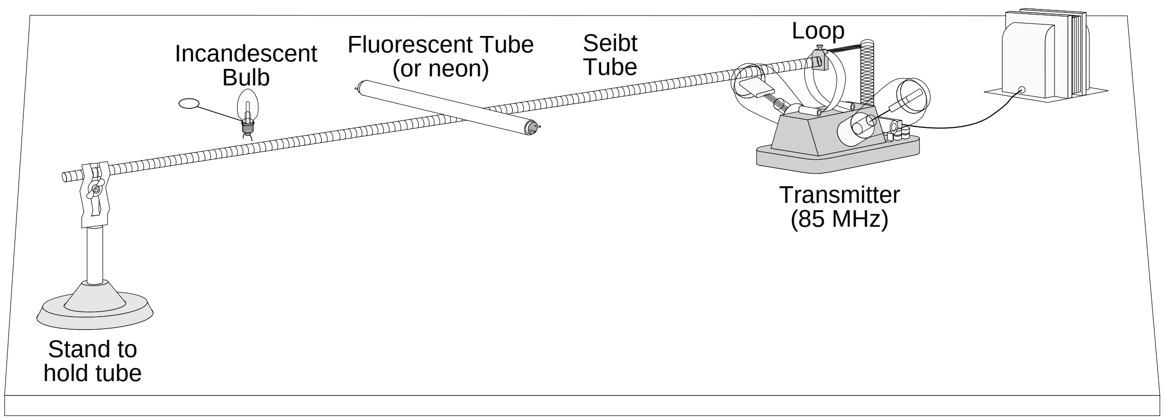
The first receiver is a simple linear oscillator which is a straight copper conductor connected at its middle through a small incandescent (or neon) lamp. Its length can be adjusted by means of copper rods telescoping into its ends. When the length is properly adjusted so that it oscillates at the frequency of the transmitter, the lamp glows brilliantly within a meter of the transmitter, and continues to glow at several meters. The second type of receiver ('wavemeter')consists of an inductance loop, and a variable capacitor. The receiver can be tuned from 3 to 5 meters wavelength, lighting the pilot lamp.



ELECTROMAGNETIC OSCILLATIONS. D+5+12

Seibt effect: Wire wound glass tube with D+5+10 transmitter. Standing waves.

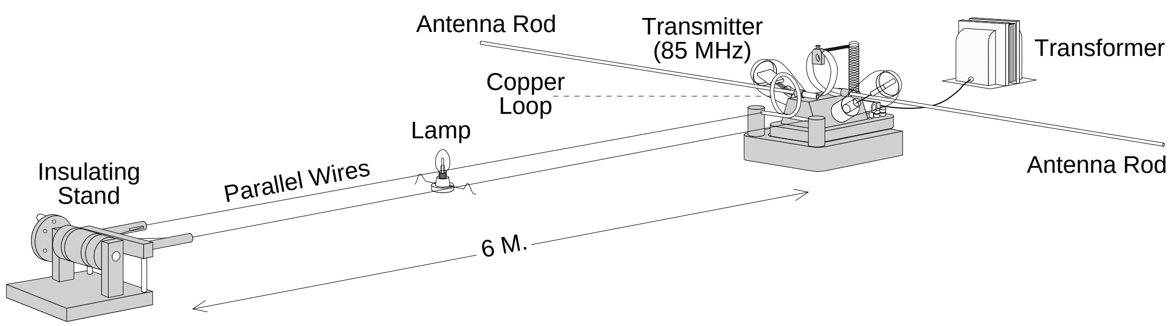
The radio transmitter is a high frequency vacuum tube oscillator with a fixed frequency of 85 MHz (3.5 meter wavelength), powered by a transformer. (See D+5+10). The 'Seibt Tube' demonstrates standing radio waves, on what is effectively a transmission delay line (speed of propagation is less than C). The tube consists of a glass tube wound with a fine, evenly spaced copper helix. The helix is designed so that its natural frequency is in resonance with the loop of the transmitter. The tube is coupled with the transmitter when it is placed in close proximity with the transmitter loop. Powerful resonant waves are set up on the standing wave tube. The waves consist of a series of voltage and current nodes and anti-nodes. (Current antinodes are approximately at voltage nodes, and vice versus). The distance between a pair of anti-nodes (about 11 cm) is 1/2 the wavelength. The waves are exactly similar to the stationary waves in an open-ended organ pipe. Eight to ten stationary waves can be detected with a fluorescent (or neon) tube, or with an incandescent bulb. Moving the fluorescent tube along the length of the Seibt Tube will cause the fluorescent tube to glow at current nodes (current is minimum; voltage is maximum). Moving the incandescent bulb will cause the lamp to glow at voltage nodes (current is maximum; voltage is minimum). In this case, the person holding the bulb is grounded, and a significant high-frequency current passes through both the lamp and the person to ground. (The fluorescent or neon tubes are more visible than the incancescent bulb).



ELECTROMAGNETIC OSCILLATIONS. D+5+14

Standing waves on two parallel wires, with D+5+10 transmitter.

This is the 'Lecher ' wire method of measuring wavelength.The radio transmitter is a high frequency vacuum tube oscillator with a fixed frequency of 85 MHz, powered by a transformer. (See D+5+10,D+5+12). The transmitter loop is placed close to a second loop of copper rod. On either end of the second loop are attached two long (6M.) parallel wires which stretch out across the lecture table and are secured at the end by an insulating stand. The transmitter loop couples with the second loop, inducing standing radio waves on the long wires. The waves become very pronounced if the length of the wires bears a definite relation to the wavelength. When the ends of the wires are 'open' (held by an insulator), a reversal in phase takes place on reflection, as in an open organ pipe; the open ends become points of maximum potential variation (and minimum current). If the ends are 'closed', or connected by a wire, the potential variation at the ends becomes zero; thus they are potential nodes (and current is maximum.). A small incandescent bulb with wires attached is used to 'tune' the system to resonance. The lamp glows brightly when at the potential antinodes (large potential difference; zero current), and dims when at the potential nodes (regions of zero potential difference; large current). The other potential nodal points on the wires can be located by moving the lamp down the wires. The distance between nodes is half the wavelength. Note: The distance between nodes, when last measured, was .93 M., which is half what it should be. Thus it appears that the oscillator is operating at both 85 and 170 MHz (a harmonic). C = wavelength x frequency.

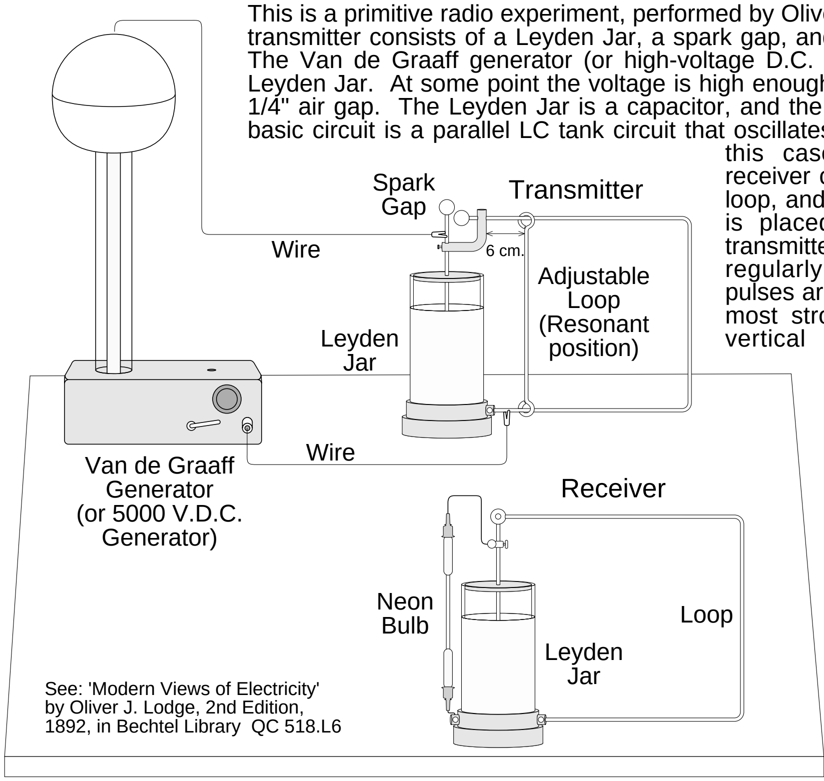


ELECTROMAGNETIC OSCILLATIONS. D+5+16

Lodge's experiment: Spark gap radio transmitter and receiver.

This is a primitive radio experiment, performed by Oliver Lodge in the 1890's. The transmitter consists of a Leyden Jar, a spark gap, and a tuneable loop of metal. The Van de Graaff generator (or high-voltage D.C. generator) charges up the Leyden Jar. At some point the voltage is high enough so that a spark jumps the 1/4" air gap. The Leyden Jar is a capacitor, and the loop is an inductor,-so the basic circuit is a parallel LC tank circuit that oscillates at a certain frequency (in this case about 2.5 MHz). The receiver consists of a Leyden Jar, a loop, and a neon tube. The receiver is placed about a foot from the transmitter. When the transmitter is regularly sparking, radio wave pulses are picked up by the receiver most strongly when the moveable vertical bar of metal on the transmitter loop is moved to the 'resonant' position. At this point, the neon bulb on the receiver flashes with each spark of the transmitter.

The capacitance of the Leyden Jar is about 2.6 nf. The inductance of the loop is about 1.6 µH. Each spark oscillates at about 2.5 MHz and rapidly decays in about 6 microseconds. The wavelength is about 120 M.

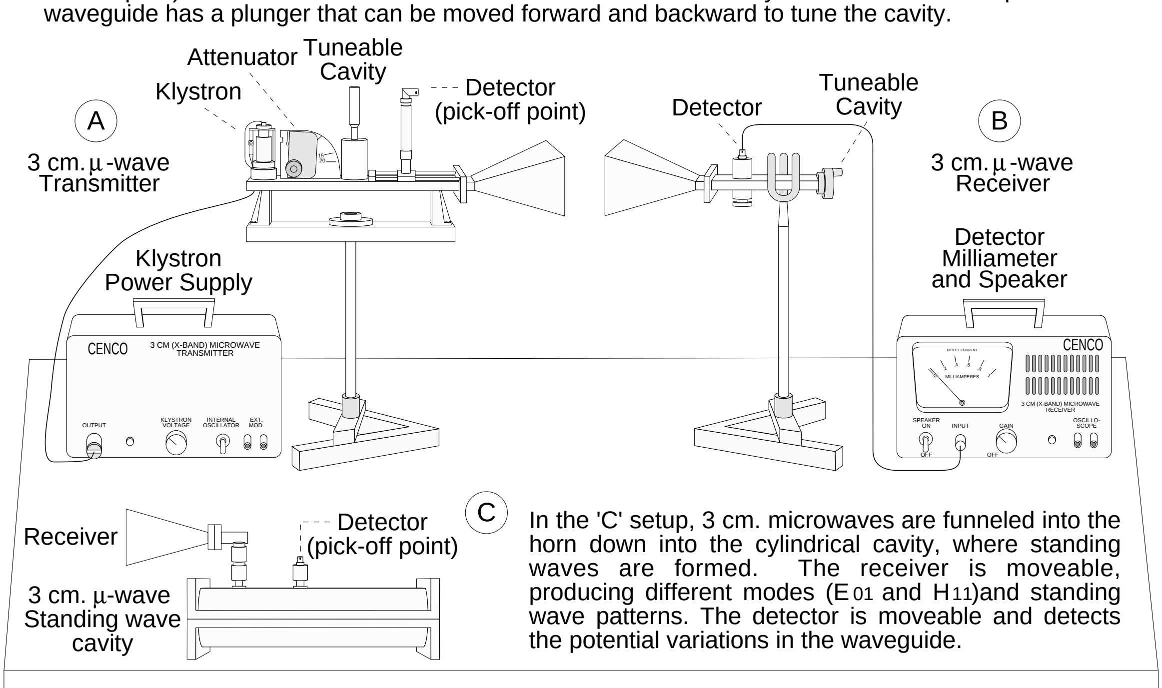


See: 'Modern Views of Electricity' by Oliver J. Lodge, 2nd Edition, 1892, in Bechtel Library QC 518.L6

ELECTROMAGNETIC OSCILLATIONS. D+5+18

3 cm. microwave klystron oscillator with cavity and waveguides.

In the 'A' transmitter setup , a klystron produces 3 cm. microwaves. There is a tuneable cavity which adjusts the position of the potential nodes and antinodes in the waveguide. A moveable detector on the waveguide can detect the waveguide potential variations (using a milliameter, or the Speaker unit in set-up 'B'). Microwaves from 'A' radiate out and are detected by the receiver of set-up 'B'. The waveguide has a plunger that can be moved forward and backward to tune the cavity.

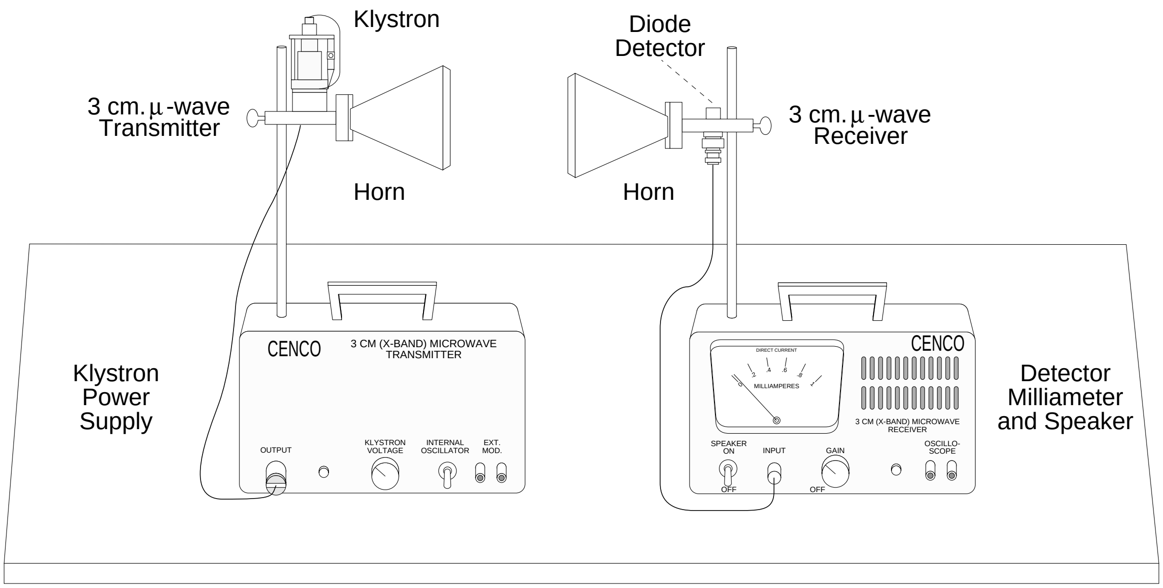


In the 'C' setup, 3 cm. microwaves are funneled into the horn down into the cylindrical cavity, where standing waves are formed. The receiver is moveable, producing different modes (E_{01} and H_{11})and standing wave patterns. The detector is moveable and detects the potential variations in the waveguide.

ELECTROMAGNETIC OSCILLATIONS. D+5+19

3 cm. microwave transmitter and receiver.

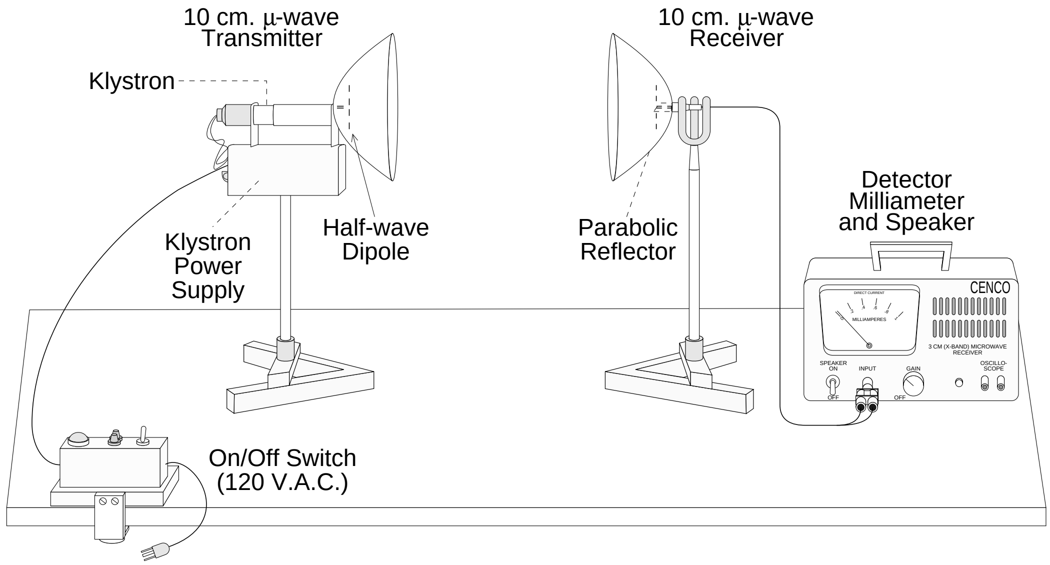
This is a simpler setup than in D+5+18. In the transmitter, power is supplied to a klystron that produces 3 cm. microwaves (polarized) which are radiated out from the horn. In the receiver, microwaves are funnelled into the horn and down the waveguide. The microwaves are detected by a diode, and the signal amplitude can be displayed on the milliammeter, or can be heard as a tone emitted from the speaker.



ELECTROMAGNETIC OSCILLATIONS. D+5+20

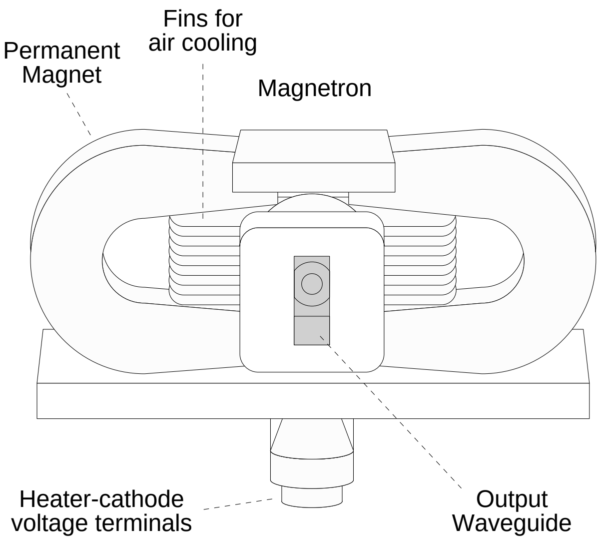
10 cm. microwave transmitter and receiver.

This setup is much like D+5+19, except that the transmitter emits microwaves of 10 cm. wavelength. In the transmitter, power is supplied to the klystron which is a cavity oscillator (the cylindrical tube). A wire loop couples the inner cavity directly to the half-wave antenna at the focus of the parabolic reflector. The paraboloid is a quarter-wave in focal length. The microwaves are sent in a collimated beam to the receiver. The half-wave antenna of the receiver is coupled to a diode, and the signal amplitude can be displayed on the milliameter, or can be heard as a tone emitted from the speaker.



ELECTROMAGNETIC OSCILLATIONS. D+5+22

Magnetron assembly to show.



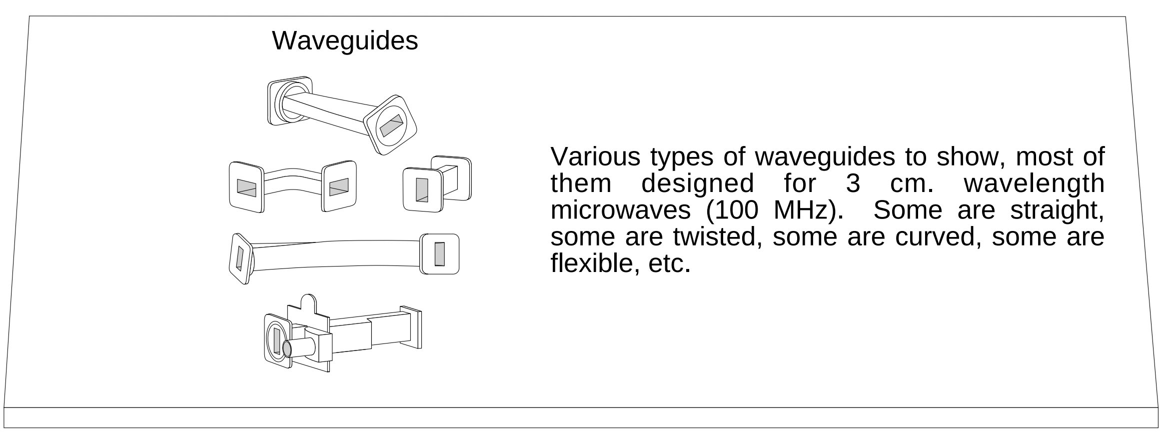
Reference: Mac Graw Hill Encyclopedia of Science and Technology, Vol.10, p 340-343, Physics Library

A magnetron is a 'crossed-field' microwave electron tube capable of efficiently generating high-power microwaves (1-100 kW, up to 10 mW for short pulses) in the frequency range of 1-40 GHz. Magnetrons have been used since the 1940s as pulsed microwave radiation sources for radar tracking, for both ground radar stations and aircraft. More recently, they have been used for rapid microwave cooking.

The central portion of the magnetron is cylindrical, with a hollow central cylindrical cathode, and a larger concentric anode. The anode consists of a series of quarter-wavelength cavity resonators placed symmetrically about the axis. Fixed permanent magnets provide a magnetic field parallel to and coaxial with the cathode. A radial DC electric field (perpendicular to the cathode) is applied between anode and cathode. When the cathode is heated, electrons are emitted. The combination of electric and magnetic fields ('crossed-field') causes the electrons to orbit the cathode (moving in a direction perpendicular to both e and b fields). The motion of the swarm of circulating electrons generates electrical noise currents in the surface of the anode, exciting the resonators in the anode so that microwave fields build up at the resonant frequency. The parameters of the tube, especially the velocity of the electrons, have been chosen so that the microwave fields are maximized (by a process called 'electron-bunching'). Thus a relatively small tube can be very efficient. The microwaves exit the magnetron through the output waveguide.

ELECTROMAGNETIC OSCILLATIONS. D+5+24

Waveguide pieces to show.



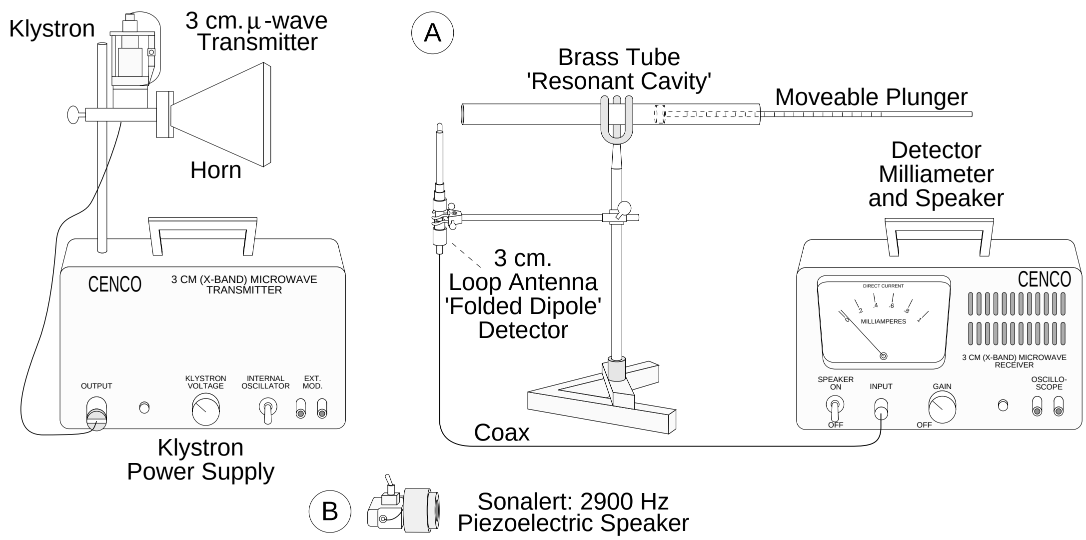
Various types of waveguides to show, most of them designed for 3 cm. wavelength microwaves (100 MHz). Some are straight, some are twisted, some are curved, some are flexible, etc.

ELECTROMAGNETIC OSCILLATIONS. D+5+26

Standing Waves (microwaves or sound waves) in an adjustable cavity.

This is a comparison between standing microwaves and standing sound waves, using the same cavity. In setup 'A', a 3 cm. wavelength microwave transmitter sends 100 MHz microwaves to a 'resonant cavity' brass tube that has a moveable plunger. A 3 cm. loop antenna 'folded dipole', with a detector diode in the base of the handle, is placed near the mouth of the tube. This antenna detects the signal amplitude of the standing wave which can be displayed on the milliameter, or can be heard as a tone emitted from the speaker. As the plunger is moved in and out of the tube, the antenna detects maximums and minimums of the standing microwave.

In setup 'B', most of the equipment is removed. Only the 2900 Hz Sonalert sound source is held by hand in front of the brass tube. The plunger is moved in and out of the tube, and nodes and antinodes can be clearly heard. The wavelength of the Sonalert is about 12 cm.



ELECTROMAGNETIC OSCILLATIONS. D+5+28

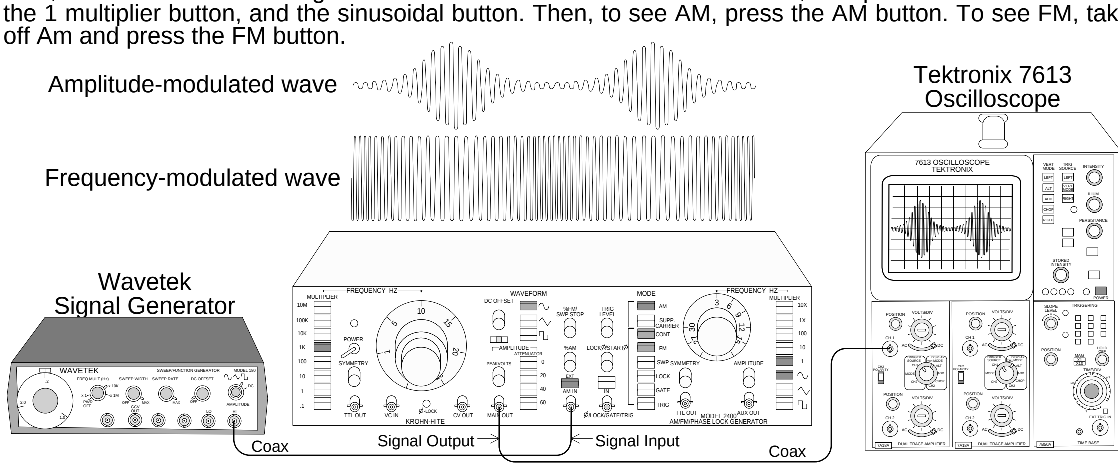
AM and FM Demonstration (minimum 24 hr notice required).

This setup allows one to modify an electronic signal with another. A signal generator feeds a 1 kHz signal into a piece of equipment called an AM/FM/Phase Lock Generator (KH Model 2400). AM or FM modulation options are chosen, and the AM or FM signal is shown on the scope.

Amplitude Modulation (AM) occurs when a varying signal (say from a microphone or signal generator) is used to modulate the amplitude of a carrier wave. The frequency of the carrier wave is much higher than the modulating signal. The amplitude of the carrier wave is made to vary in accordance with the signal wave amplitude, while the frequency of the carrier wave remains unchanged.

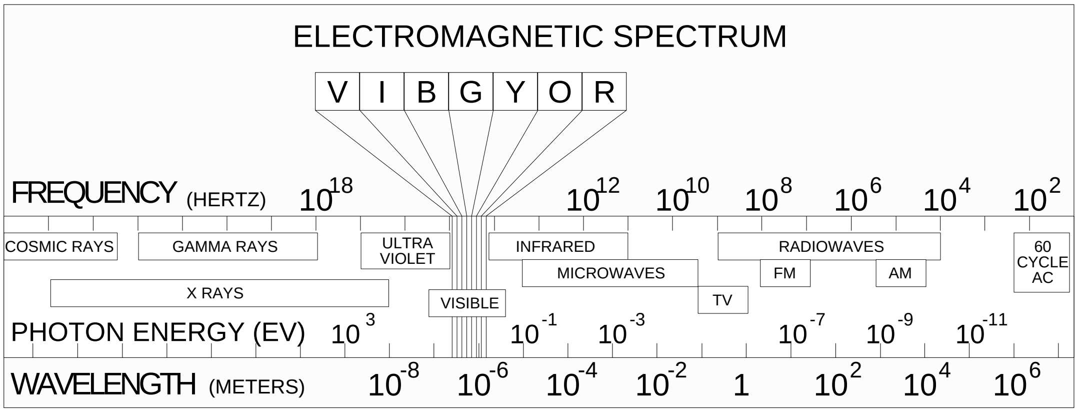
Frequency Modulation (FM) occurs when a varying signal is used to modulate the frequency of a carrier wave. The frequency of the carrier wave is made to vary in accordance with the signal wave frequency, while the amplitude of the carrier wave remains unchanged.

For Setup People: Use Wavetek signal generator 'HI' output, 1 kHz. On the scope, use .5 volts/div., and .1ms time sweep, with external trigger. On the left half of the KH 2400, push the1k multiplier button, choose10 on the dial, and press the sinusoidal waveform button. In the middle of the KH 2400, press the EXT,AM IN button. On the right half of the KH 2400 choose 3 on the dial, and press the 'CONT' button, the 1 multiplier button, and the sinusoidal button. Then, to see AM, press the AM button. To see FM, take off Am and press the FM button.



ELECTROMAGNETIC OSCILLATIONS. **D+5+30**

Wall chart of the electromagnetic spectrum.



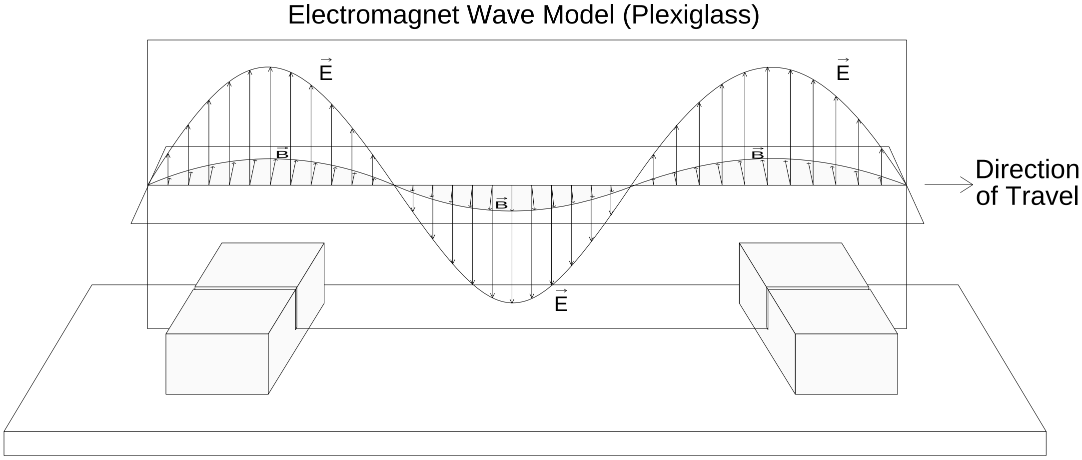
This is a large chart, about 2'x6'

ELECTROMAGNETIC OSCILLATIONS. **D+5+32**

Plexiglass model of electromagnetic wave.

This model shows electric and magnetic field strengths in an electromagnetic wave. 'E' and 'B' are at right angles to each other. The entire pattern moves in a direction perpendicular to both E and B.

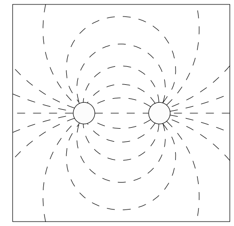
Electromagnet Wave Model (Plexiglass)

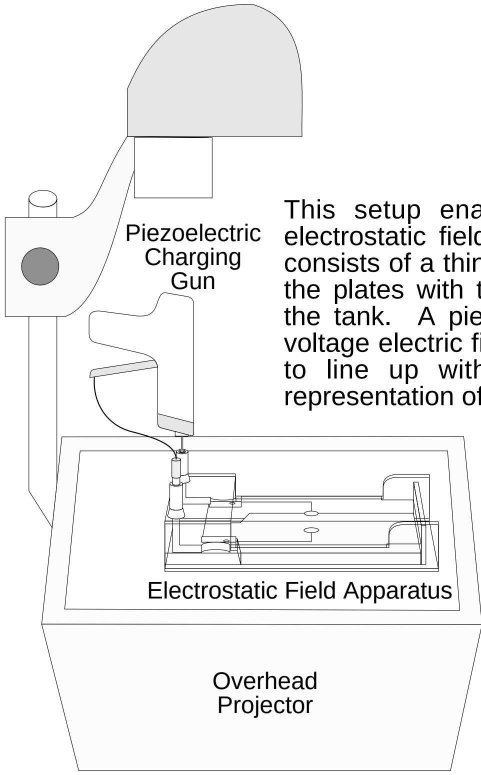


ELECTROSTATICS. D+10+0

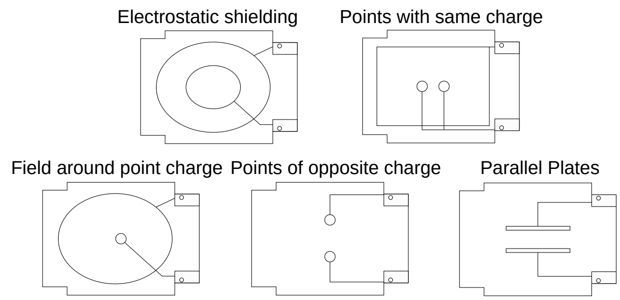
Electric fields: Lines of force shown on an OHP.

Projected Image





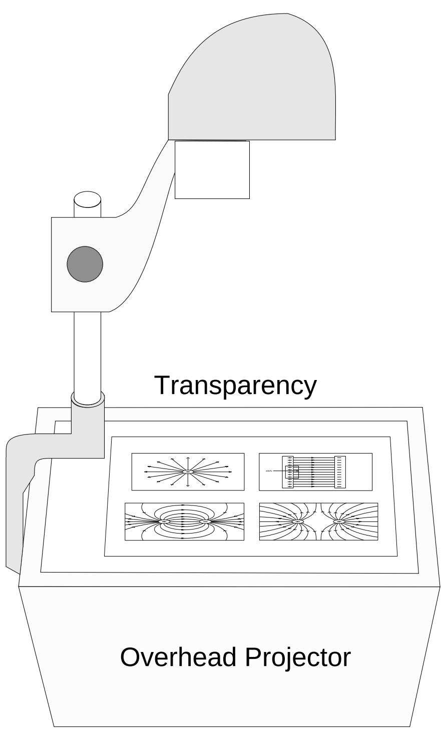
This setup enables one to see the lines of force in various electrostatic field configurations. The bottom part of the apparatus consists of a thin tank of silicon oil, glycerol, and wood chips. One of the plates with the desired electrode configuration is inserted over the tank. A piezoelectric charging gun creates a temporary high-voltage electric field between the electrodes, causing the wood chips to line up with the electric field vectors. (This is a visual representation of the Teledeltos experiment performed in the labs.)

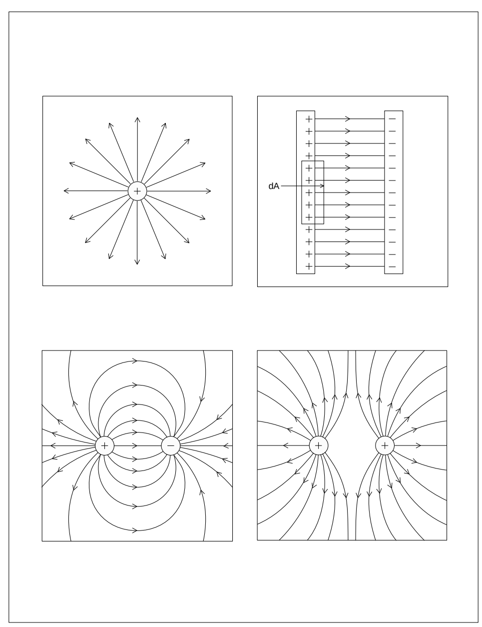


Plexiglass plates with metal electrodes in various configurations

ELECTROSTATICS. D+10+2

Transparency: Mapping of an electric field.





A transparency showing the mapping of the electric fields for four different situations:

1. A single positive charge.
2. A positive plate and a negative plate.
3. A positive charge and a negative charge.
4. Two positive charges.

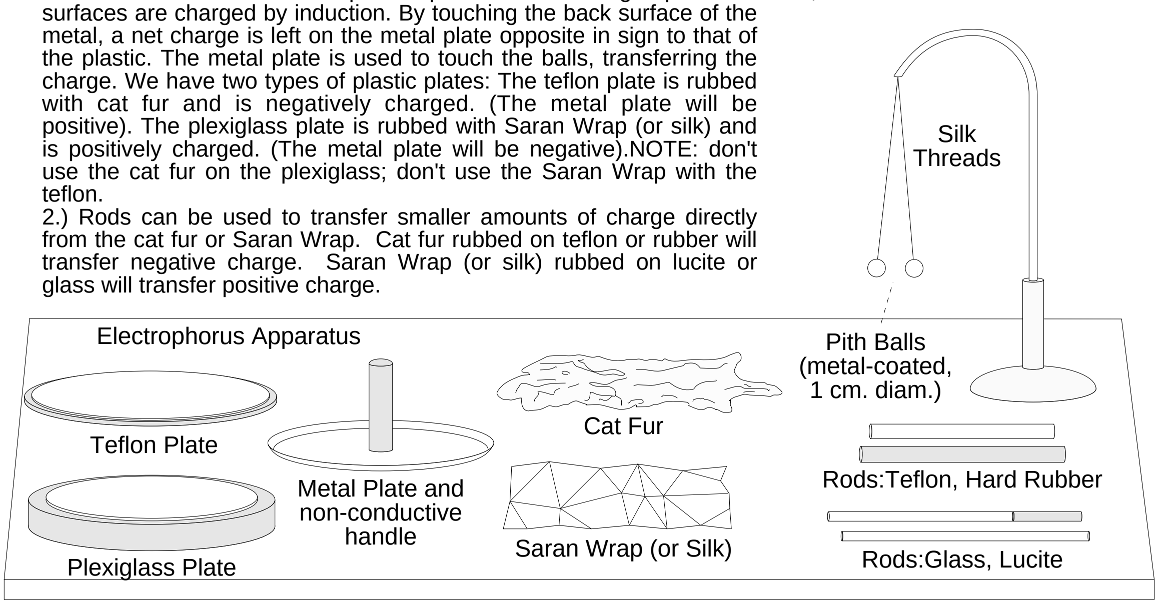
ELECTROSTATICS. D+10+4

Pith balls on thread, with positive and negative charged rods.

In this setup, two metal-coated pith balls (1 cm. diam.) are suspended on non-conducting silk threads. The balls can be charged with positive or negative charge. When both balls have the same charge, they repel each other. The balls can be charged up in several different ways:

1.) A large charge can be delivered to both balls using the 'electrophorous'. This consists of two parts: a piece of plastic that can be charged by friction; and a round metal plate with curved edges and a non-conductive handle. The metal plate is placed on the charged plastic surface, and the front and back metal surfaces are charged by induction. By touching the back surface of the metal, a net charge is left on the metal plate opposite in sign to that of the plastic. The metal plate is used to touch the balls, transferring the charge. We have two types of plastic plates: The teflon plate is rubbed with cat fur and is negatively charged. (The metal plate will be positive). The plexiglass plate is rubbed with Saran Wrap (or silk) and is positively charged. (The metal plate will be negative).NOTE: don't use the cat fur on the plexiglass; don't use the Saran Wrap with the teflon.

2.) Rods can be used to transfer smaller amounts of charge directly from the cat fur or Saran Wrap. Cat fur rubbed on teflon or rubber will transfer negative charge. Saran Wrap (or silk) rubbed on lucite or glass will transfer positive charge.

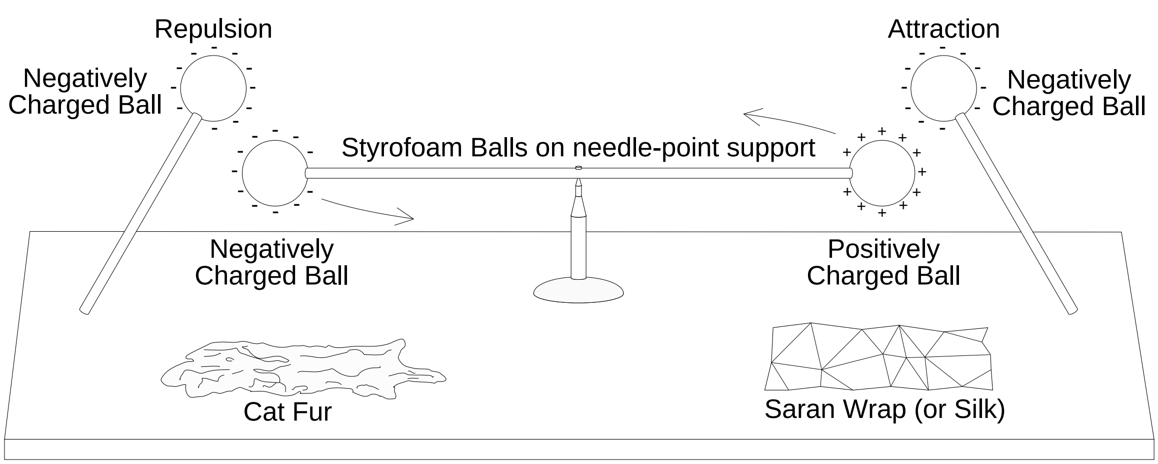


NOTE: A T.V. camera and monitor can be used to show more clearly the separation of the pith balls. Also, a point source light can be used to cast an enlarged shadow of the pith balls on a screen.

ELECTROSTATICS. D+10+6

Attraction and repulsion of charged styrofoam balls.

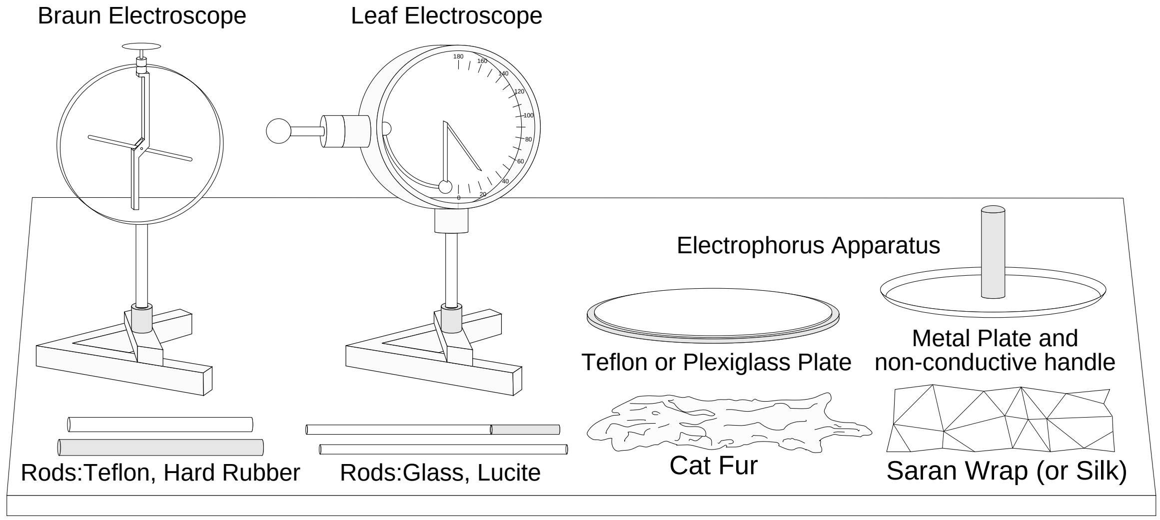
Two Styrofoam balls are balanced on a needle-point support. Cat fur rubbed on one ball will impart a negative charge. Saran Wrap rubbed on the other ball will impart a positive charge. Two other Styrofoam balls on sticks can be charged positively or negatively. A ball-on-stick charged negatively will repulse a negatively charged ball on the needle-point support, causing the support to rotate away. A negative ball-on-stick will attract the positively charged ball on the needle-point support, rotating the assembly toward it.



ELECTROSTATICS. D+10+8

Braun and Leaf electroscopes.

There are two types of electroscopes to show. The Braun electroscope has a light-weight metal pointer on a needle-point suspension. Touching the top metal disk with a charged object causes the pointer to move to a position proportional to the amount of charge applied. The Leaf electroscope has a delicate metallic leaf on a hinge, enclosed in a glass-sided metal housing. Touching the ball of the electroscope with a charged object causes the leaf to rise. The Braun electroscope is adequate for most situations, but is somewhat less sensitive than the leaf electroscope. Charged rods or the electrophorus apparatus can be used to charge either electroscope. See D+10+4 for more information.

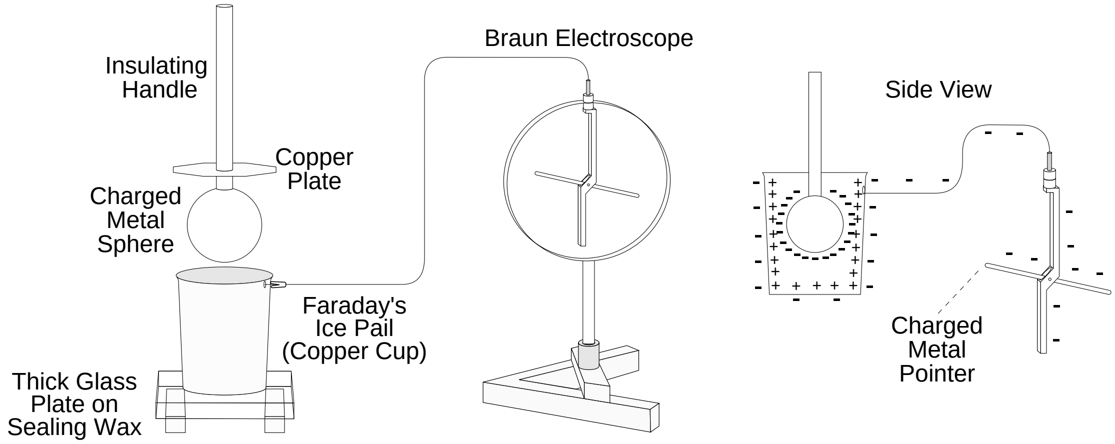


ELECTROSTATICS. D+10+10

Reference: The below was paraphrased from MODERN COLLEGE PHYSICS, p.343 by Harvey E. White, 6th edition

Faraday's ice pail: Charge induced on the outside of a pail.

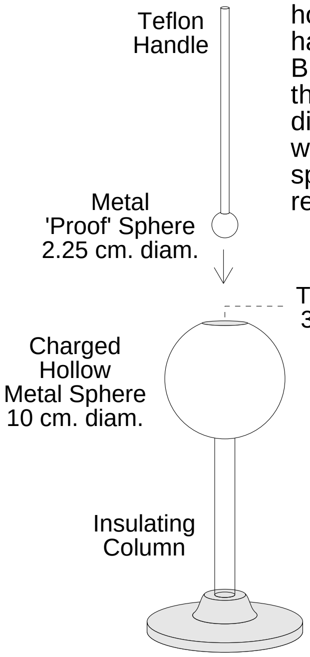
The distribution of charge over a metal conductor can be demonstrated by Faraday's Ice Pail. A metal sphere is electrostatically charged. (The Wimshurst machine gives a good charge. The electrophorous works less well. See D+10+18-22) Say the sphere is charged negatively. The metal sphere is then lowered into a metal cup, without actually touching the sides of the cup. Free electrons in the metal pail are repelled to the to the outer surface. The net charge on the outer surface is negative, and the electroscope leaf rises. The charge on the inner surface of the cup is positive. If the ball is now removed, the electroscope leaf falls, and the pail is uncharged. If, however, the ball touches the pail, all negatives leave the ball and neutralize an equal number of pail positives. The electroscope leaf remains fixed in its raised position, showing there is no redistribution of the negative charges on the outer pail surface; and also the number of induced positive charges within the pail equals the number of negative charges on the ball.

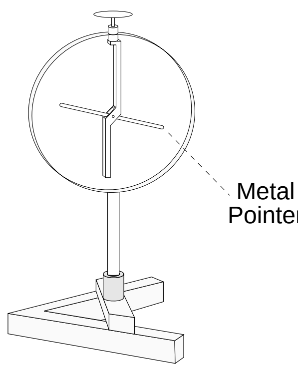


ELECTROSTATICS. D+10+12

Charge resides on the outside of a conductor.

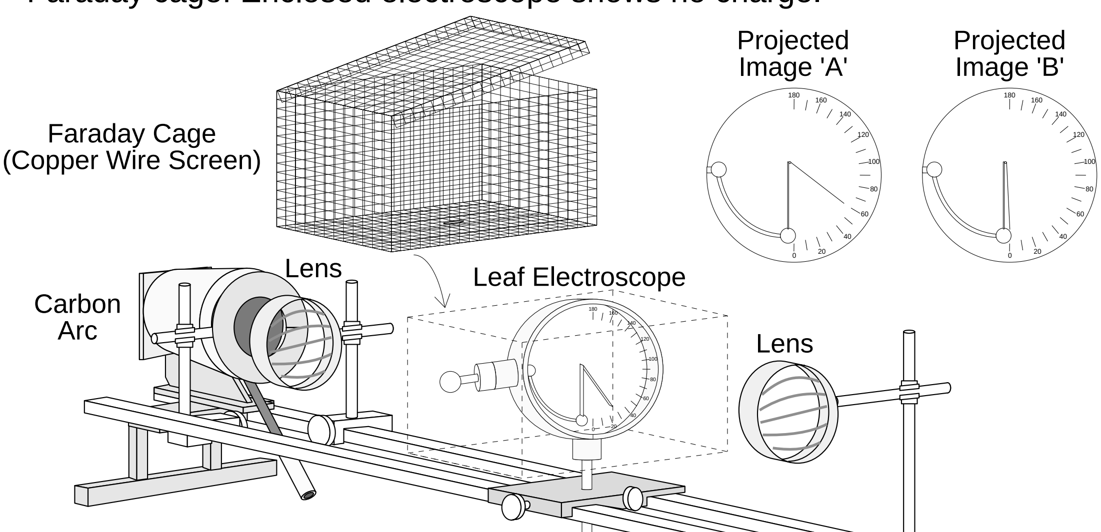
The large hollow metal sphere is electrostatically charged. (The Wimshurst machine gives a good charge. The electrophorous works less well. See D+10+18-22) Touch the outer surface of the hollow sphere with the small 'proof' sphere mounted on the Teflon handle. Move the small sphere to touch the top metal plate of the Braun electroscope. The metal pointer will move, indicating that there is charge on the outside of the hollow sphere. Now, discharge the electroscope. Touch the inside of the hollow sphere with the 'proof' sphere, then touch the electroscope with the 'proof' sphere. The metal pointer does not move, indicating that charge resides only on the outside of a conductor.





ELECTROSTATICS. D+10+13

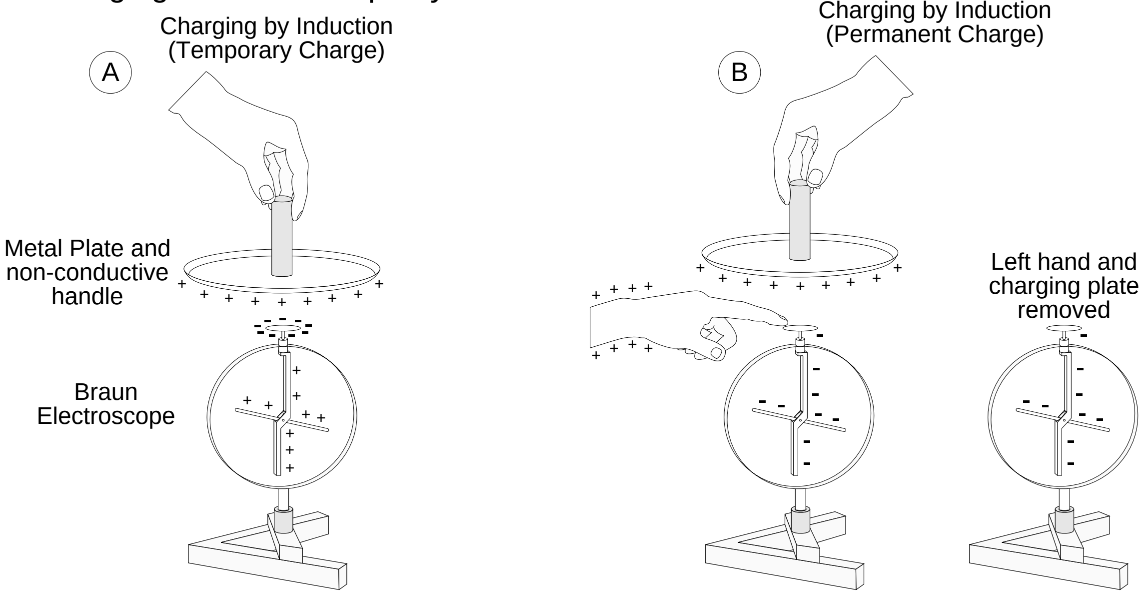
Faraday cage: Enclosed electroscope shows no charge.



The Leaf Electroscope is mounted on an optical bench so that the class can see the movements of the leaf. First, a charge is placed on the electroscope (with charged rod or electrophorus), to show that it is working (Image 'A'). The electroscope is then discharged, and placed in a Faraday Cage of copper screen. The ball of the electroscope is in direct contact with the screen. Now a charge is applied to the screen. However, no matter how much charge is applied, the electroscope leaf does not register any charge (Image 'B'). Thus, all charge stays on the outside of the Faraday Cage; no charge resides within.

ELECTROSTATICS. D+10+14

Charging an electroscope by induction.



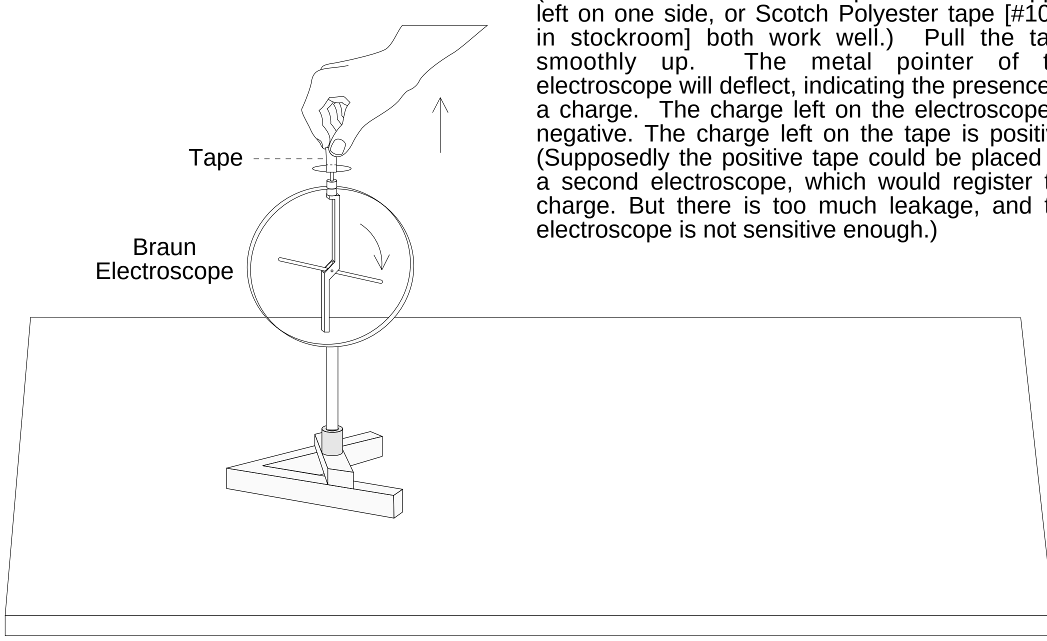
A charged plate (see D+10+18) is brought close to, but not touching, the top plate of the electroscope. The metal pointer deflects. Remove the plate, and the pointer returns to its discharged position. The charged plate displaces free electrons in the electroscope. If the plate is positive, electrons are temporarily drawn from the pointer into the top disk, and a positive charge temporarily results in the pointer, as long as the charged plate is in position.

The top disk of the electroscope is touched by a finger. At the same time a charged plate is brought nearby (but not touching). The finger is withdrawn, then the charged plate is withdrawn. The electroscope will be left with a charge whose sign is opposite that of the charged plate. If the plate is positive, positive charges are repelled into the hand touching the top disk, and negative charges are drawn into the pointer and top disk. Removing the hand leaves the pointer negatively charged.

ELECTROSTATICS. D+10+16

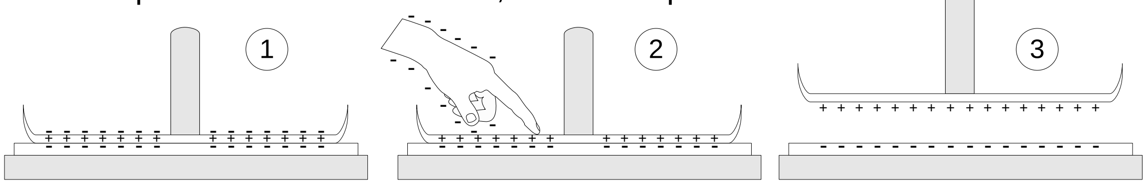
Separation of charge in electrical tape.

Press a short piece of tape onto the top disk of the Braun Electroscope so that it is very well stuck. (Scotch double-stick foam tape with the wrapper left on one side, or Scotch Polyester tape [#1022 in stockroom] both work well.) Pull the tape smoothly up. The metal pointer of the electroscope will deflect, indicating the presence of a charge. The charge left on the electroscope is negative. The charge left on the tape is positive. (Supposedly the positive tape could be placed on a second electroscope, which would register the charge. But there is too much leakage, and the electroscope is not sensitive enough.)

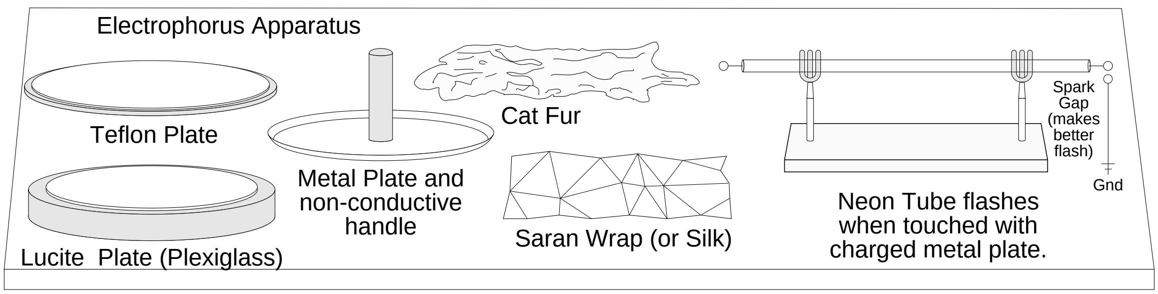


ELECTROSTATICS. D+10+18

Electrophorous: Cat fur on teflon, Saran Wrap on lucite.

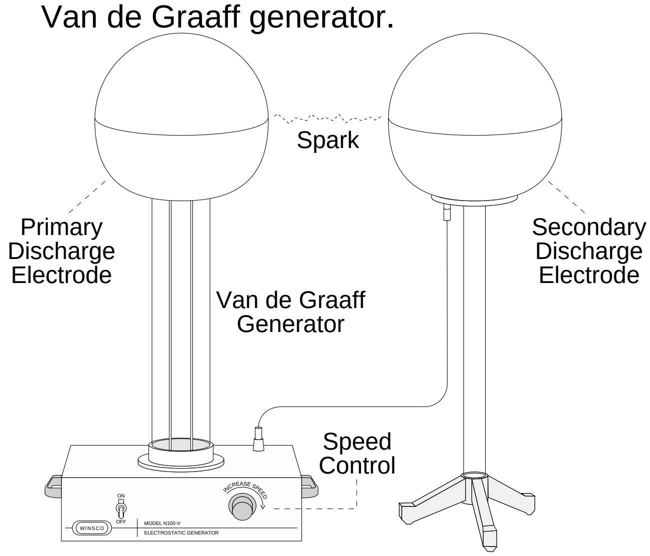


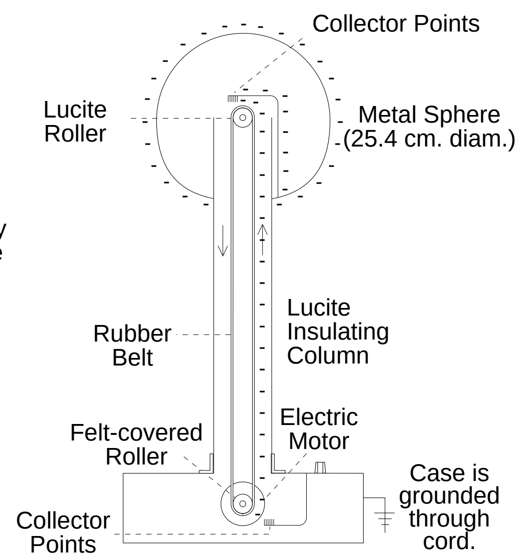
The 'electrophorous' consists of two parts: a piece of non-conductive plastic that can be charged by friction; and a round metal plate with curved edges and a non-conductive handle. We have two types of plastic plates: The teflon plate is rubbed with cat fur and becomes negatively charged. The lucite plate (plexiglass) is rubbed with Saran Wrap (or silk) and becomes positively charged. The metal plate is then placed on the charged plastic insulating surface, and the top and bottom metal surfaces are charged by induction. By touching the top surface of the metal, a net charge is left on the metal plate opposite in sign to that of the plastic. The metal plate can now be used to transfer charge. The charge can be discharged into an electroscope, or into a neon tube (causing a brief flash). For example, when cat fur is rubbed on the teflon, the top surface of the teflon becomes negatively charged. Placing the metal plate on the charged teflon causes electrons in the metal to be repelled by induction to the top of the metal plate; and the bottom of the metal becomes positive. Touching the top surface of the metal plate drains off electrons, and the plate, when lifted, has a net positive charge. NOTE: don't use the cat fur on the plexiglass; don't use the Saran Wrap with the teflon.



ELECTROSTATICS. D+10+20

Van de Graaff generator.





This Van de Graaff apparatus is an electrostatic generator capable of throwing sparks 25 to 38 cm. long from the primary electrode to a secondary discharge electrode (depending on humidity, motor speed,etc.) The apparatus is safe, delivering at most a 10 microamp current.

A large hollow conducting aluminum sphere is supported on top of a tall insulating lucite column above a metal base. The sphere is charged to a high potential (250K-400K volts) by a moving nonconducting rubber belt. In the base, the felt-covered roller, pressing against and separating from the rubber belt, causes negative charge to be left on the rubber belt as it travels upward. When the belt reaches the top and rolls over the lucite roller, the negative charge jumps to sharp collector points and is transferred immediately to the outer surface of the metal sphere. As more charge is brought upward, the sphere becomes more highly charged and reaches greater voltage. The process requires energy, since the upward moving charged belt is repelled by the charged sphere. The energy is supplied by the motor driving the belt.

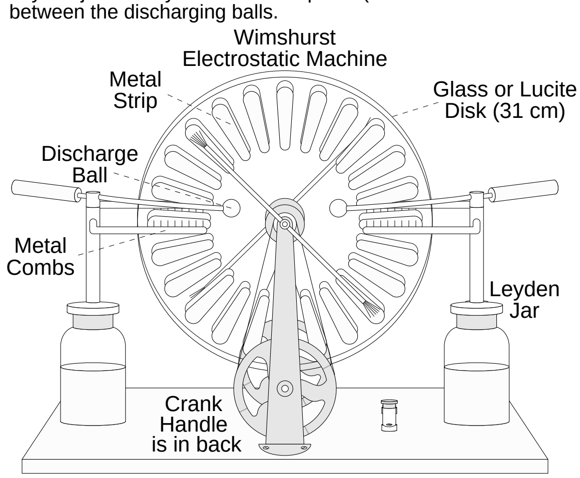
ELECTROSTATICS. D+10+22

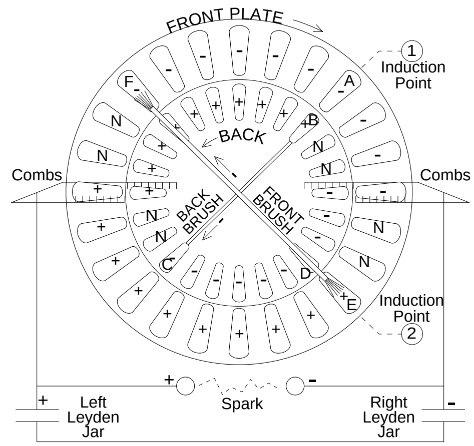
Wimshurst machine, large or small.

The Wimshurst machine is an electrostatic generator capable of throwing long sparks (10-12 cm, at low humidities) between two discharge balls mounted on swivel arms, when both Leyden jars are connected in the circuit. This generator is different from the Van de Graaff demo in that the electrical charge is generated by induction rather than friction.

The Wimshurst machine consists of two parallel nonconductive plates (lucite or glass), hand driven so that they rotate in opposite directions. Each plate has narrow metal strips arranged radially, equal distances apart around the rim. Two brushes connected to metal rods, one in front and one in back, transfer charge. Metal combs pick up charge and store it in Leyden jars (high-voltage,non-leaky capacitors).

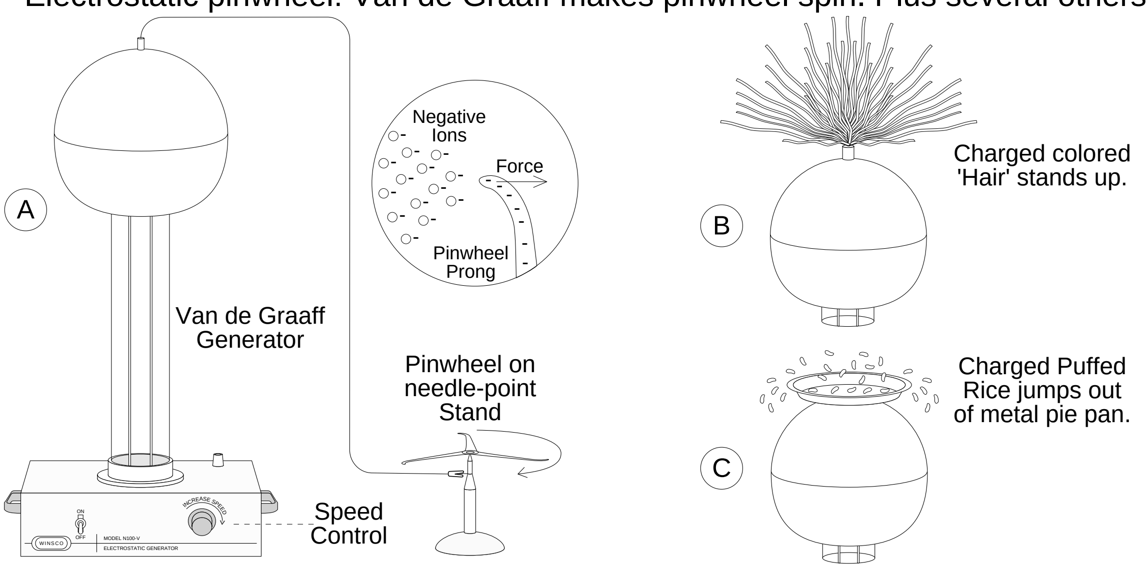
Suppose that metal strip 'A' on the front plate (FP) is negative and has moved clockwise to be opposite strip 'B' on the back plate (BP), at point '1'. 'A' is negative and induces a positive charge on the front side of strip 'B' and a negative charge on the back side of 'B'. The rear brush carries the negative charge from 'B' to strip 'C' on BP,leaving 'B' positive. As BP moves counter-clockwise to point '2', negative strip 'D' on BP induces a positive charge on the back of strip 'E' and a negative charge on the front of 'E' on FP. The front brush carries negative charge from 'E' to 'F' on FP, leaving 'E' positive. Negative charge from both plates is picked up by the 'combs' on the right Leyden jar; positive charge goes to the left Leyden jar. The cycle is now complete. (Points labelled 'N' are non-charged.) When voltage is sufficiently high, sparks jump between the discharging balls.





ELECTROSTATICS. D+10+24

Electrostatic pinwheel: Van de Graaff makes pinwheel spin. Plus several others.



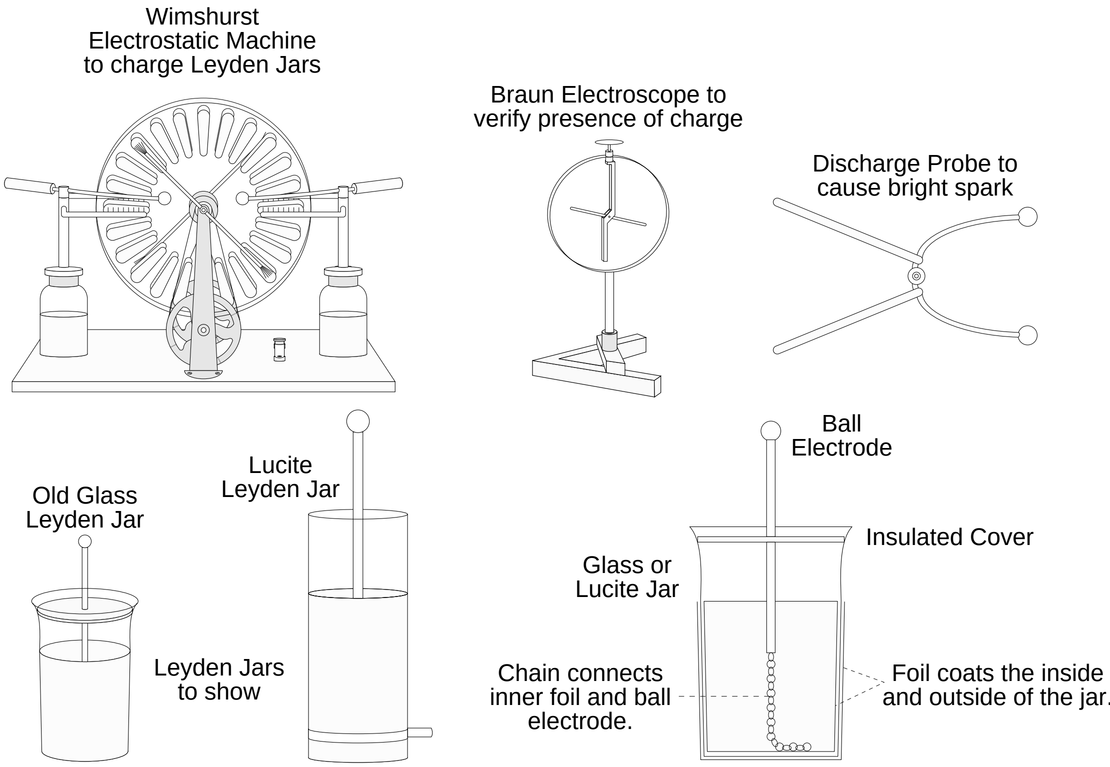
Pinwheel: In 'A', electric charge is transferred via wire from the top metal sphere of the Van de Graaff generator (which is at a high potential) to the metal needle-point stand. On top of the needle point is a three-pronged pinwheel. Charge flows from the stand, through the pinwheel, and is sprayed into the air near each pinwheel prong. The sprayed electrons form a cloud of ions in the air. Each negative pinwheel prong is repelled by its associated negative ion cloud, causing the pinwheel to rotate.

Hair: In 'B', colored strips of paper are fastened to the top metal sphere. (In the old days hair was used). When the Van de Graaff is fully charged, each strip of paper gets negatively charged and repells each other strip. The 'hair' stands up and spreads out.

Puffed Rice: In 'C', puffed rice is put in a metal pie pan that connects to the top of the metal sphere. When the Van de Graaff charges up, the negatively charged puffed rice jumps out of the negatively charged pan.

ELECTROSTATICS. D+10+26

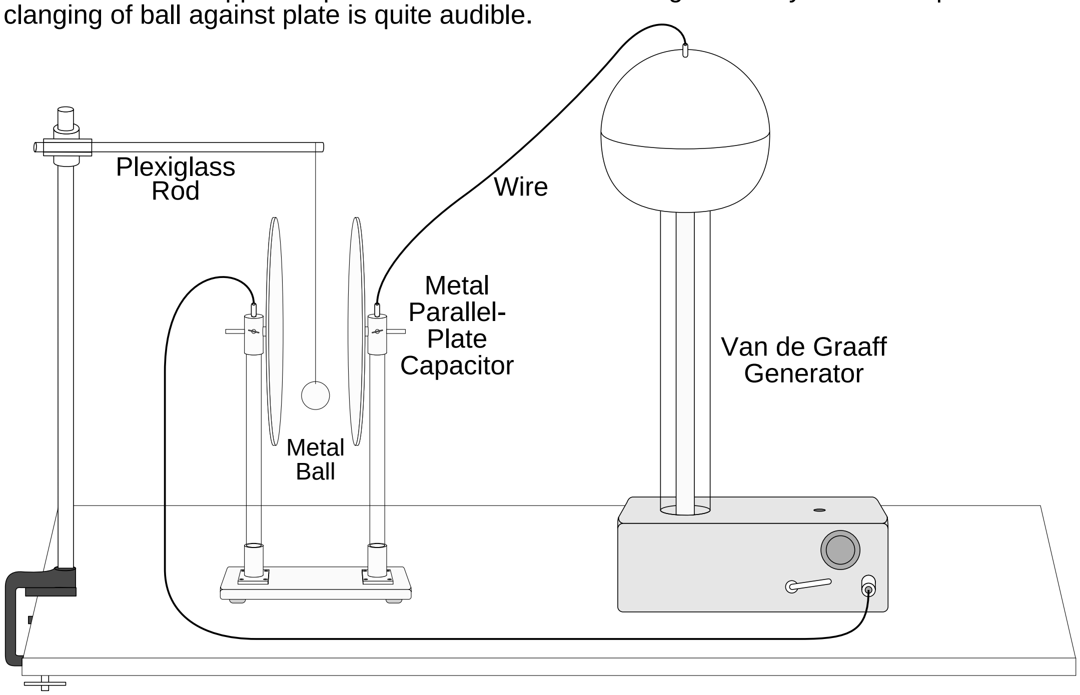
Various Leyden jars to show.



ELECTROSTATICS. D+10+28

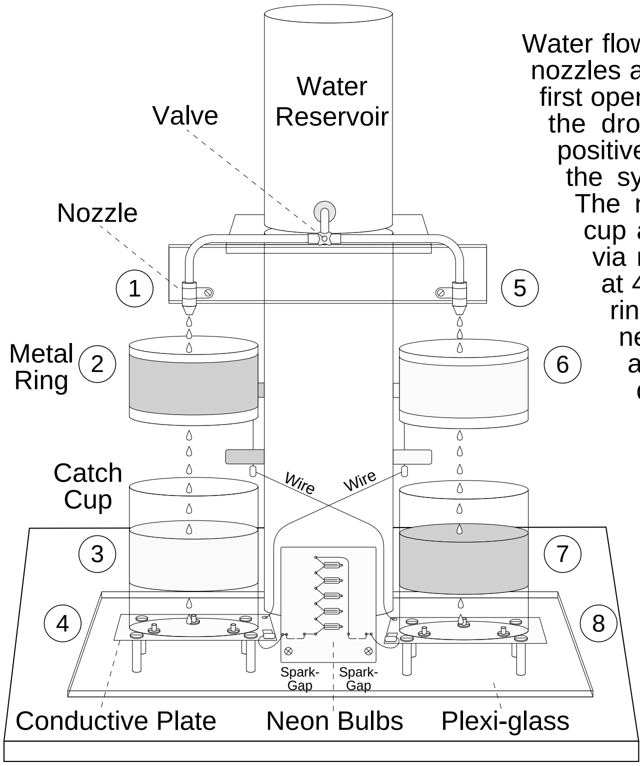
Electrostatic doorbell: Ball bangs between charged plates. (Same as D+0+6)

Negative charge from the Van de Graaf generator builds up on one plate. The metal ball, initially uncharged, is attracted to the negative plate and hits it, becoming negative also. It rebounds to the opposite plate where it loses its charge. The cycle then repeats. The clanging of ball against plate is quite audible.



ELECTROSTATICS. D+10+30

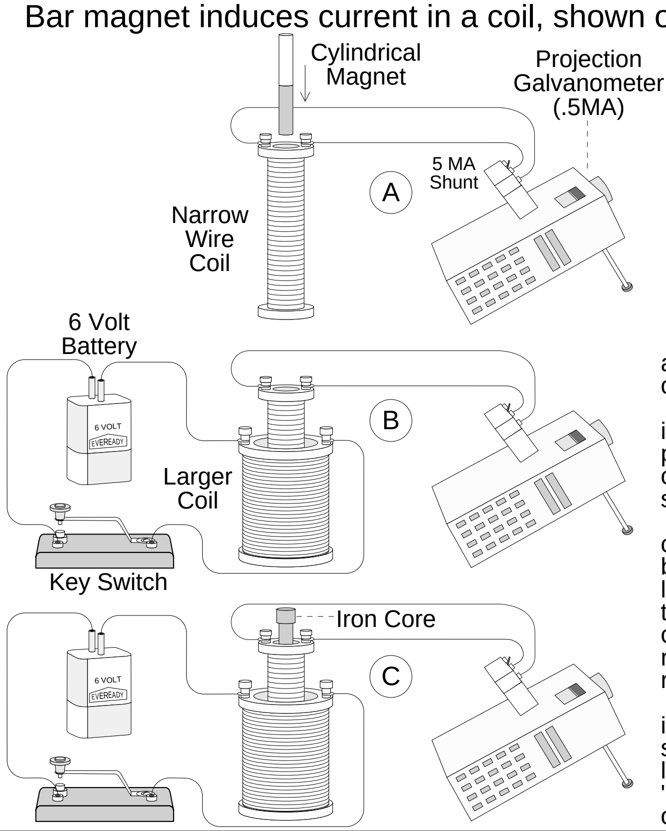
Kelvin water-drop generator: Falling charged water drops light neon bulbs.

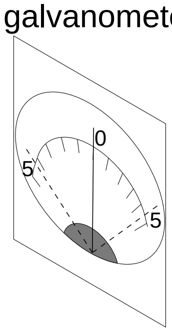


Water flows from a reservoir and drips through two nozzles at points 1 and 5. When the water valve is first opened, the water drop at 1, at the time when the drop separates from the nozzle, is either positive or negative. Say it is negative. To make the system neutral, the drop at 5 is positive. The negative drop lands in the plastic catch cup at 3. The bottom of the cup is connected via metal screws to a conductive metal plate at 4, which is connected by wire to the metal ring at 6. Thus, the ring at 6 becomes more negative, causing the next drop at 5 once again to be positive, by induction. The drops landing in catch cup 7 are positive, and make an electrical connection to the metal ring at 2, making the ring more positive. This causes the next drop at 1 to be negative, by induction. The cycle repeats until a large amount of negative charge is in cup 3, and a lot of positive charge is in cup 7. When enough charge is stored, sparks jump across the two spark gaps, and the bank of neon bulbs flash. There are a lot of flashes before the water reservoir is drained.

FARADAY'S LAW. D+15+0

Bar magnet induces current in a coil, shown on galvanometer.





Projected Image

A changing magnetic field cutting across a coil of wire induces an electric current.

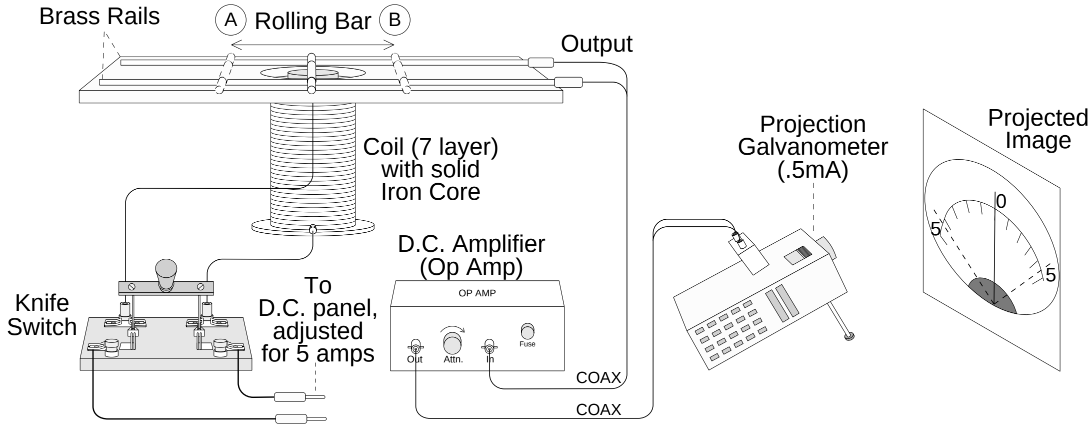
In 'A', a cylindrical bar magnet is thrust into a tall narrow coil which is hooked to a projection galvanometer. The induced current causes the needle to swing full scale in both directions.

In 'B', the narrow coil is placed inside a coil of larger diameter. A 6 volt D.C. battery and key switch are hooked to the larger coil. When the switch is pressed, the surge of magnetic field from the larger coil cuts the narrow coil. A current surge is registered when the switch is pressed or released, smaller than in 'A'.

In 'C', a soft iron cylindrical core is inserted into the narrow coil. When the switch is pressed or released, a much larger current swing is registered than in 'B'. Other cores can be inserted: a bundle of iron wires, a bronze core, and lucite.

FARADAY'S LAW. D+15+2

Elementary generator: Bar moved in magnetic field.

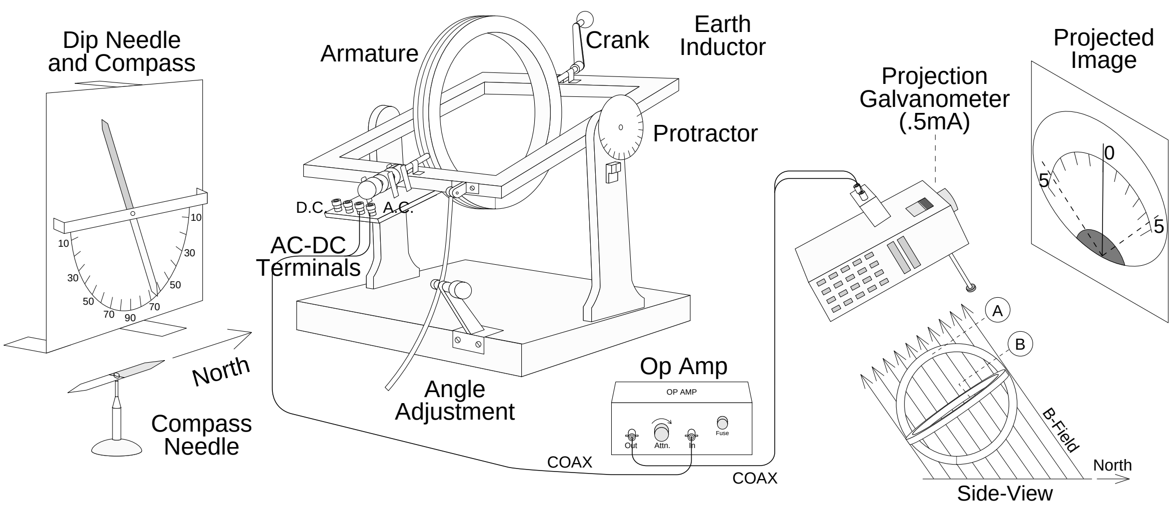


This is a simple generator, illustrating the principle that a changing magnetic field cutting across a loop of wire induces an electric current. Five amps of current (D.C.) are sent through a large coil of wire, with a soft iron core inserted within. A stationary magnetic field is generated, enhanced by the presence of the iron core. A board with two brass rails sits on top of the coil, and another independent brass bar can be moved manually along the rails. The brass bar and rails constitute a conducting 'loop' that cuts across the magnetic field. Even though the magnetic field is stationary, the magnetic field strengths vary at different locations, so essentially a changing magnetic field cuts the loop when the bar is moved. The current generated by moving the bar is amplified by a D.C. Amplifier (Op Amp) and the variations are shown with a projection galvanometer.

The two rails and bar must be polished to insure good conduction. The op amp is set so that a brisk sliding of the bar gives a moderate meter fluctuation. NOTE: whenever the knife switch is opened or closed, the meter will record a strong induced current spike from the building up or collapsing of the magnetic field. If the bar is at position 'A', more of the loop is cut by the flux than at 'B'. Thus a much larger spike (about10 times larger) is produced at 'A' than if the bar were at position 'B'. In order to avoid pegging the galvanometer needle, either have the bar off the rails while opening or closing the switch, or have the bar at 'B'.

FARADAY'S LAW. D+15+4

Earth inductor: Coil spun in Earth's field makes voltage.



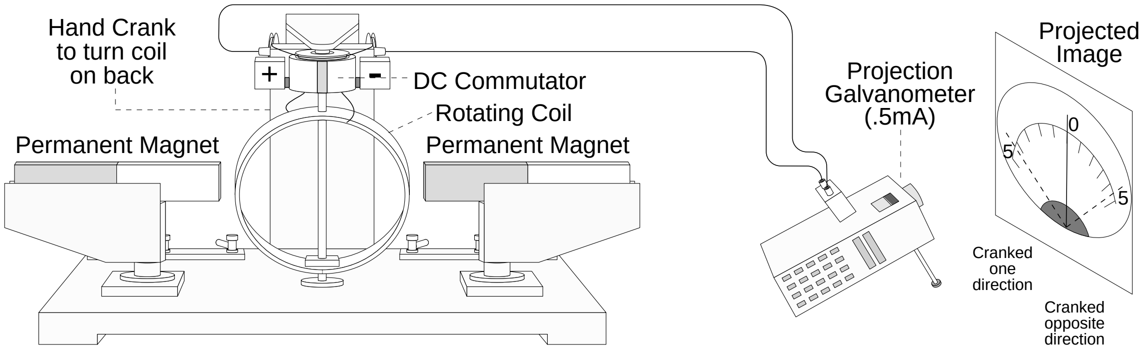
The 'Earth Inductor' is a simple generator, illustrating the principle that a changing magnetic field cutting across a loop of wire induces an electric current. In this case, the magnetic field is that of the earth. A coil of wire is rotated in the earth's magnetic field, generating an emf.

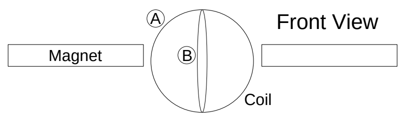
A simple magnetized needle on a stand finds north. Both the dip-needle and inductor apparatus are aligned with north. The dip-needle indicates the angle of the magnetic flux coming up through the earth. The inductor apparatus frame is tilted so that the coil-frame is perpendicular to the Earth's magnetic flux. (I.E.: The frame is rotated from the horizontal by an angle equal to the compliment of the dip-needle angle.) When the coil is rotated, maximum emf is generated at 'A' and min is at 'B' (in the side-view drawing). The apparatus has commutators so that either an AC sinusoidal signal or DC rectified signal can be amplified and visually represented by the projection galvonometer.

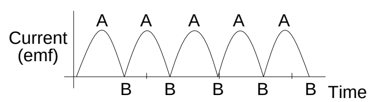
FARADAY'S LAW. D+15+6

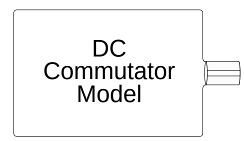
Generator: Coil with DC commutator rotates between magnets.

Simple D.C. Generator









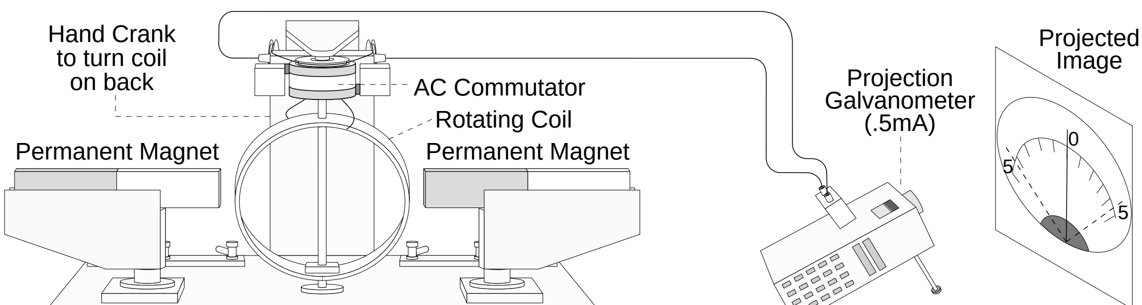
This is a simple generator illustrating the principle that a changing magnetic field cutting across a loop of wire induces an electric current. In this case, the magnetic field is produced by two strong permanent bar magnets mounted in line with each other, on opposite sides of the wire coil; close to the perimeter of the coil. The coil of wire is rotated in this magnetic field, generating an emf. The crank-handle/pulley system is on the back of the apparatus, not visible in this drawing.

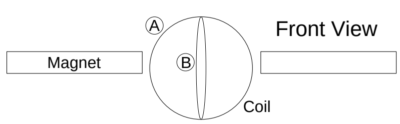
The 'split' commutator causes the output of the generator to be rectified D.C. current in the milliamp range. For example, crank the handle clockwise, and the current will go from 0 to +.5 ma to 0. Crank the handle counter-clockwise, and the current range will be 0 to -.5ma to 0. (Or vice versus.)

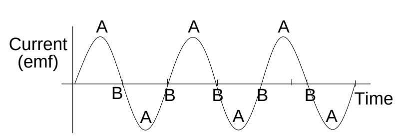
FARADAY'S LAW. D+15+8

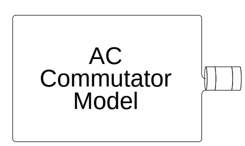
Alternator: Coil with AC commutator rotates between magnets.

Simple A.C. Alternator









This is a simple generator illustrating the principle that a changing magnetic field cutting across a loop of wire induces an electric current. In this case, the magnetic field is produced by two strong permanent bar magnets mounted in line with each other, on opposite sides of the wire coil; close to the perimeter of the coil. The coil of wire is rotated in this magnetic field, generating an emf. The crank-handle/pulley system is on the back of the apparatus, not visible in this drawing.

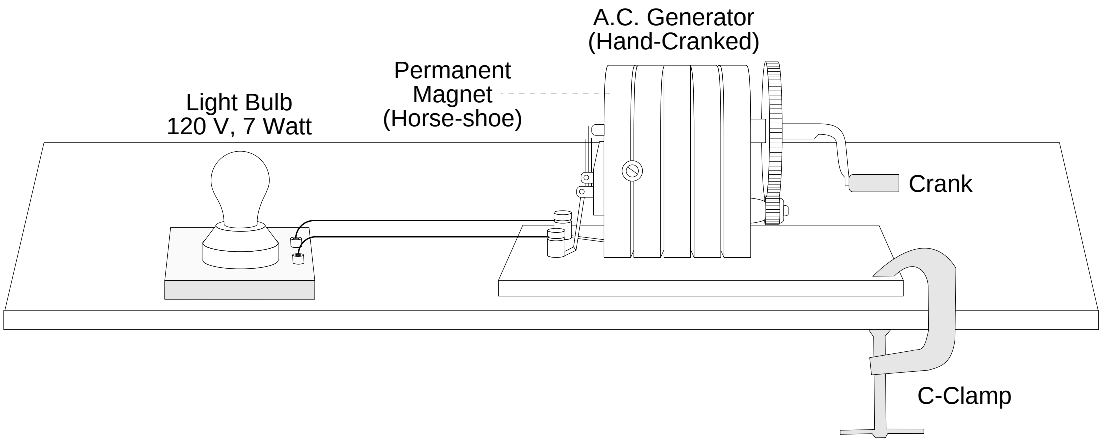
The 'slip-ring' commutator causes the output of the generator to be A.C. current in the milliamp range. For example, crank the handle clockwise or counterclockwise, and the current will go from 0 to +.5 ma to 0 to -.5 ma to 0, etc.

FARADAY'S LAW. D+15+10

Hand-cranked generator powers 12 volt lamp.

This A.C. generator consists of a cylindrical coil of wire that rotates within the stationary field of 5 permanent horse-shoe magnets. A geared hand-driven crank causes the coil to rotate. The rotating coil cuts across the magnetic flux of the horshoe magnets, inducing an emf. Depending on the speed that the generator is cranked, the A.C. voltage may be as high as 80 volts. The light bulb connected to the generator glows brightly.

NOTE: A larger, hand-cranked D.C. generator is also available. A projection voltmeter or ammeter may be introduced into the circuit if desired.

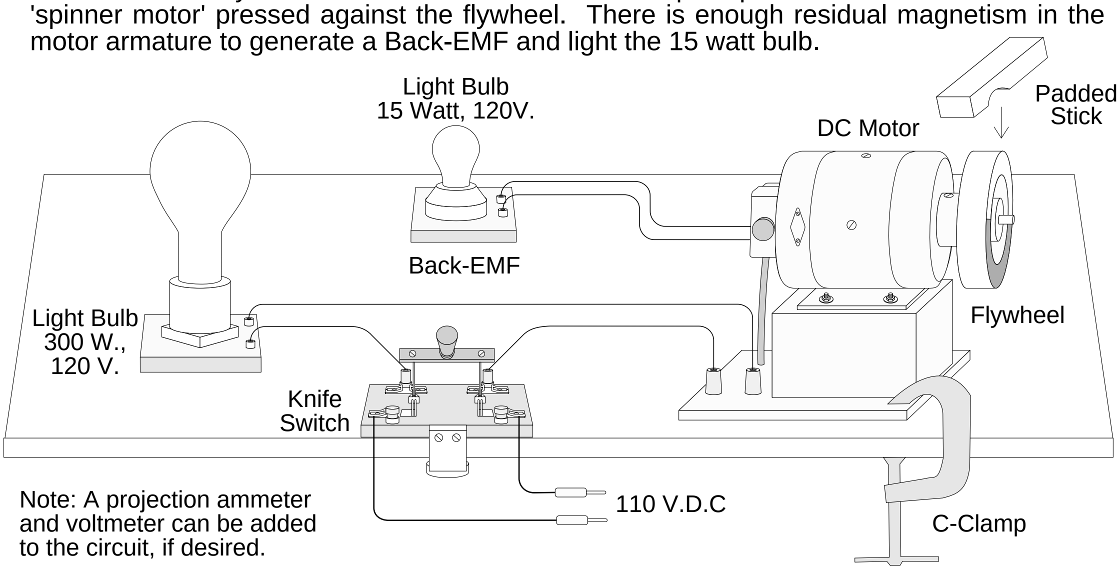


FARADAY'S LAW. D+15+12

Back EMF in a series DC motor with large flywheel.

The DC motor is series-compound, with a special connection to the inner armature coil to demonstrate 'Back-EMF'. When power is first applied, the 300 watt bulb glows brightly at first, then dims as the motor achieves speed. The 15 watt bulb is off at first, then glows brightly as the motor speeds up, indicating the production of Back-EMF. If a padded stick is pressed down on the spinning flywheel, the 300 watt bulb glows more brightly, and the 15 watt bulb dims. If power to the circuit is cut off, the 15 watt bulb continues to glow, becomming dimmer as motor speed drops, and the 300 watt bulb stays off.

Another way to demonstrate Back-EMF is to spin up the motor with a hand-held 'spinner motor' pressed against the flywheel. There is enough residual magnetism in the motor armature to generate a Back-EMF and light the 15 watt bulb.

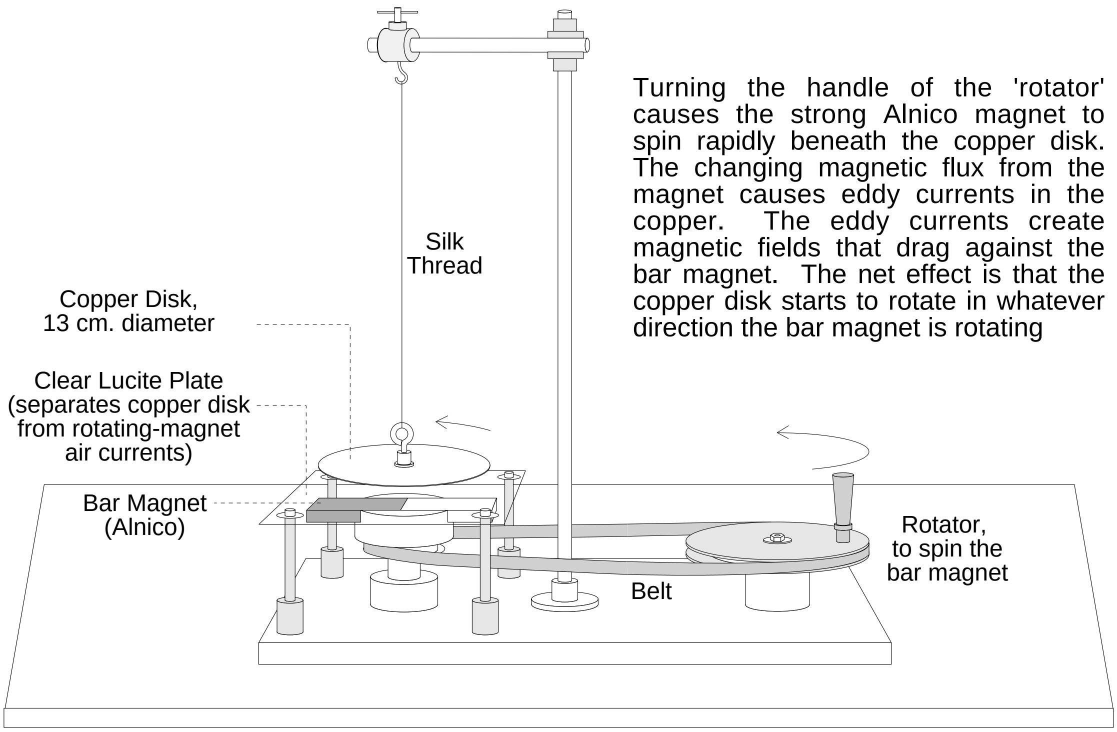


Note: A projection ammeter and voltmeter can be added to the circuit, if desired.

FARADAY'S LAW. **D+15+14**

Eddy currents: Copper disk rotates over a spinning bar magnet.

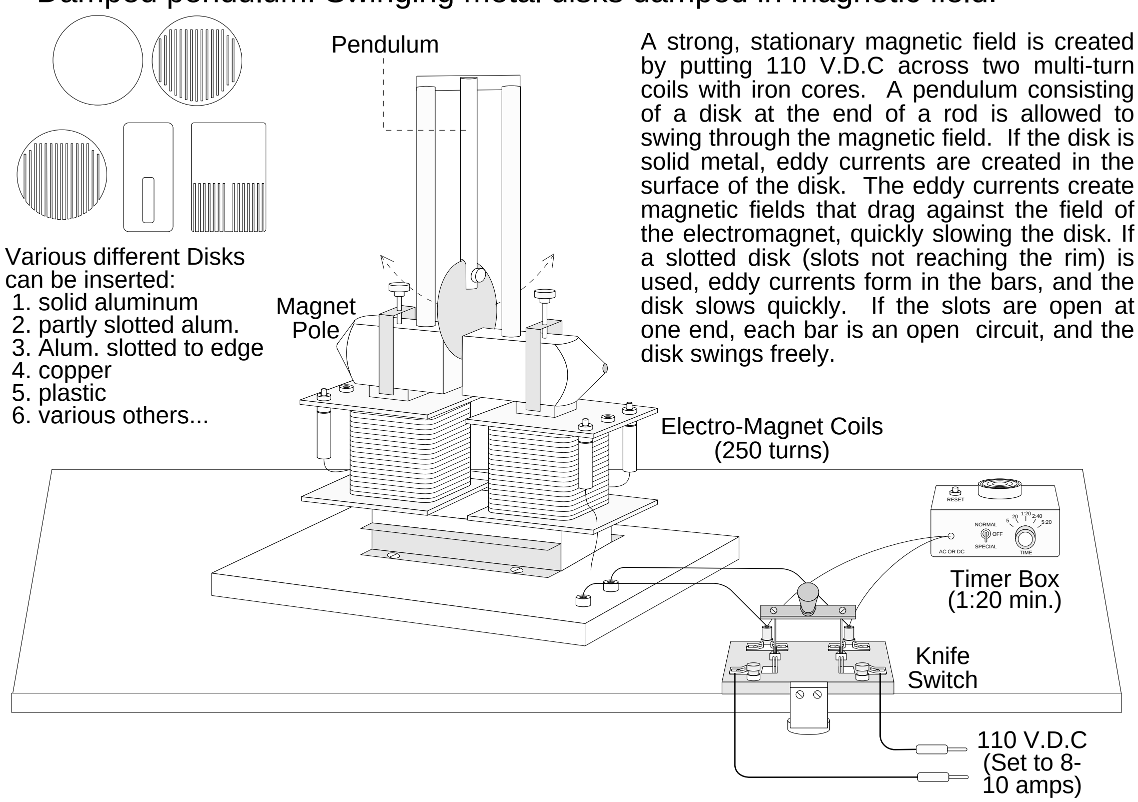
Turning the handle of the 'rotator' causes the strong Alnico magnet to spin rapidly beneath the copper disk. The changing magnetic flux from the magnet causes eddy currents in the copper. The eddy currents create magnetic fields that drag against the bar magnet. The net effect is that the copper disk starts to rotate in whatever direction the bar magnet is rotating



FARADAY'S LAW. **D+15+16**

Damped pendulum: Swinging metal disks damped in magnetic field.

A strong, stationary magnetic field is created by putting 110 V.D.C across two multi-turn coils with iron cores. A pendulum consisting of a disk at the end of a rod is allowed to swing through the magnetic field. If the disk is solid metal, eddy currents are created in the surface of the disk. The eddy currents create magnetic fields that drag against the field of the electromagnet, quickly slowing the disk. If a slotted disk (slots not reaching the rim) is used, eddy currents form in the bars, and the disk slows quickly. If the slots are open at one end, each bar is an open circuit, and the disk swings freely.

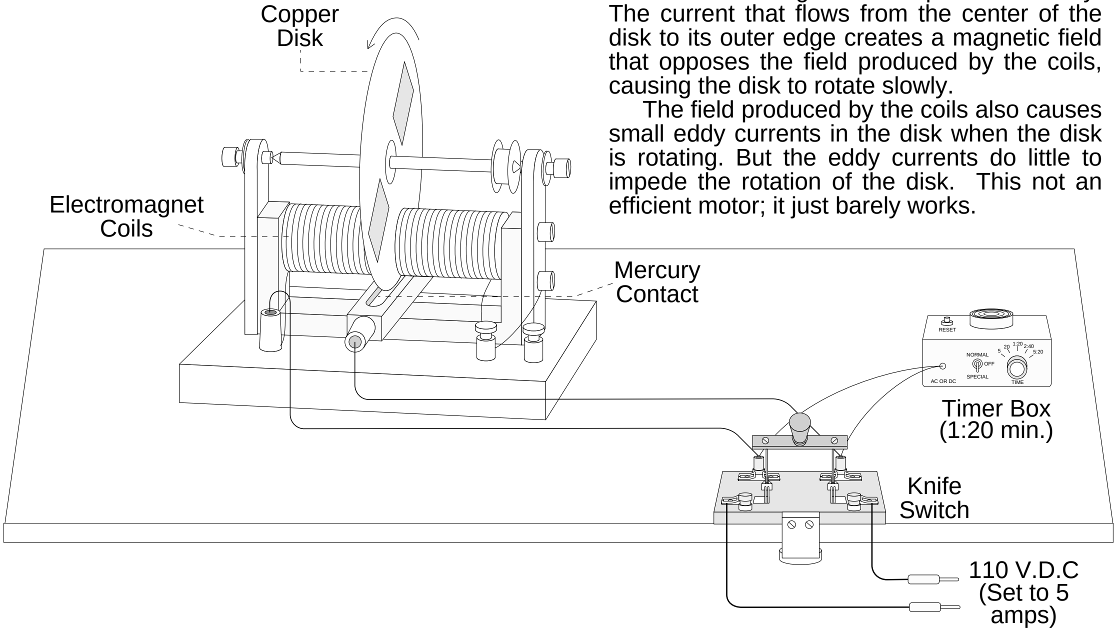


FARADAY'S LAW. D+15+18

Faraday's Disk: Copper disk in Hg rotates in magnetic field.

A strong, stationary magnetic field is created by putting 110 V.D.C across two multi-turn coils with iron cores. Mounted between the electromagnets is a copper disk, free to rotate. 110 VDC is also put across the disk, whose bottom edge sits in a pool of mercury. The current that flows from the center of the disk to its outer edge creates a magnetic field that opposes the field produced by the coils, causing the disk to rotate slowly.

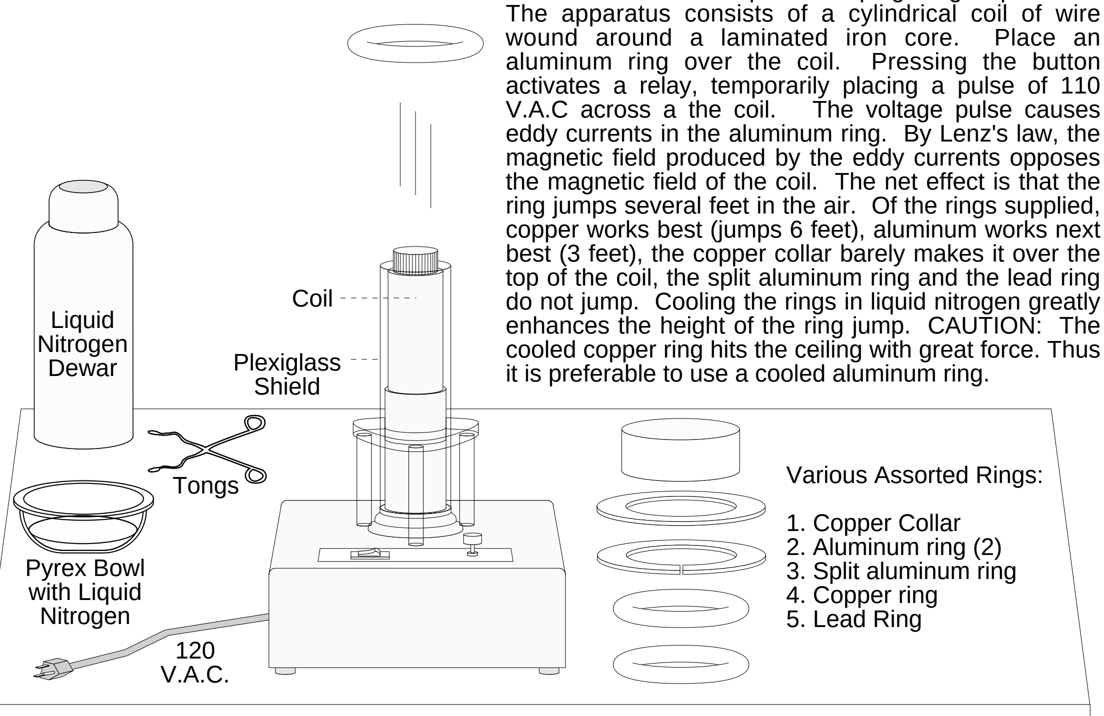
The field produced by the coils also causes small eddy currents in the disk when the disk is rotating. But the eddy currents do little to impede the rotation of the disk. This not an efficient motor; it just barely works.



FARADAY'S LAW. D+15+20

Jumping Rings: High current AC coil causes rings to jump.

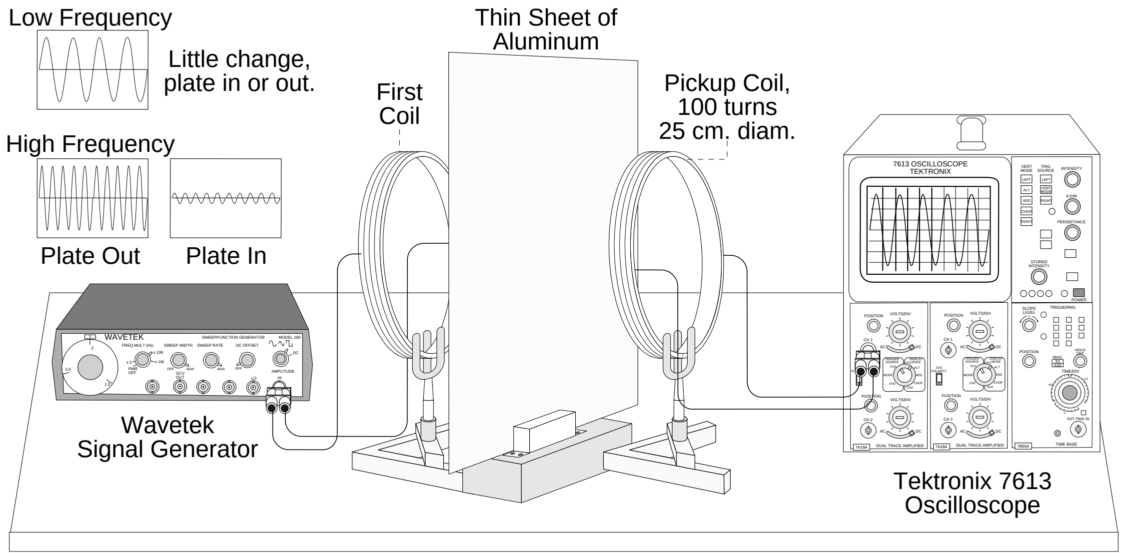
This is the Elihu Thompson 'Jumping Ring' experiment. The apparatus consists of a cylindrical coil of wire wound around a laminated iron core. Place an aluminum ring over the coil. Pressing the button activates a relay, temporarily placing a pulse of 110 V.A.C across a the coil. The voltage pulse causes eddy currents in the aluminum ring. By Lenz's law, the magnetic field produced by the eddy currents opposes the magnetic field of the coil. The net effect is that the ring jumps several feet in the air. Of the rings supplied, copper works best (jumps 6 feet), aluminum works next best (3 feet), the copper collar barely makes it over the top of the coil, the split aluminum ring and the lead ring do not jump. Cooling the rings in liquid nitrogen greatly enhances the height of the ring jump. CAUTION: The cooled copper ring hits the ceiling with great force. Thus it is preferable to use a cooled aluminum ring.



FARADAY'S LAW. D+15+22

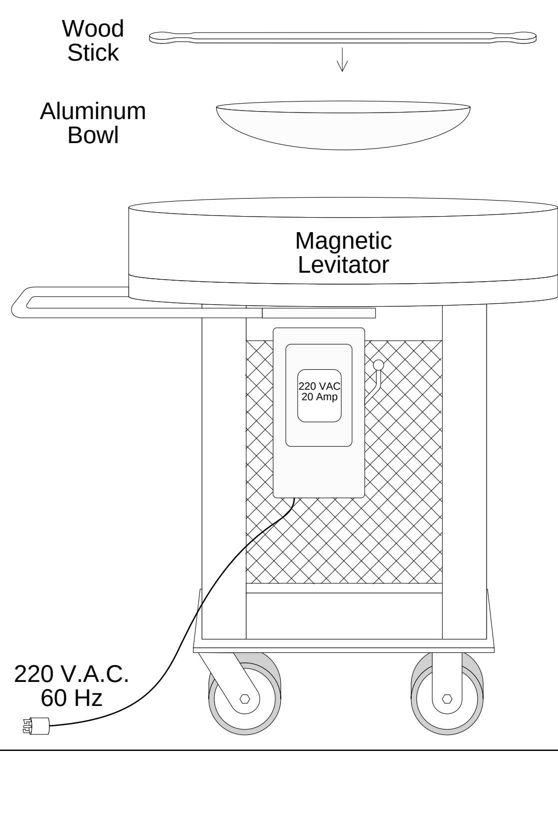
Skin effect: Metal sheet shielding varies with frequency.

This apparatus demonstrates the 'Skin effect'. The signal generator supplies a sinusoidal voltage to the first coil of wire, creating an sinusoidal magnetic field. The a.c. magnetic field penetrates the aluminum sheet. In the aluminum, if the flux $\phi = A\sin \omega t$, then the induced voltage = $d\phi/dt = A\omega\cos \omega t$. Thus, as ω gets larger, the induced voltage in the aluminum gets larger; the resultant eddy currents get larger; the repelling B-field from the eddy currents gets larger which helps to cancel out the B-field from the first coil. The net effect is that the B-field in the aluminum dies away exponentially as it leaves the front surface. This 'Skin effect' is minimal at low frequencies (10 Hz), and most of the B-field gets through the back surface to be picked up by the second coil. At high frequencies (10KHz and higher) little of the B-field gets through and the aluminum acts as a shield.



FARADAY'S LAW. D+15+24

Levitator: Aluminum dish floats four inches off platform.



This apparatus is a magnetic levitator, illustrating Lenz's law. The levitator can support an aluminum bowl about a foot in mid air in stable equilibrium.

The levitator is an electromagnet of special design. The top consists of concentric wire coils and an hexagonal array of iron cores. 220 V.A.C., at 60 Hertz, is applied to the coils, causing an intense alternating magnetic field. When the aluminum pan is placed in the field, eddy currents form in the aluminum, causing magnetic fields in the direction opposite to the levitator fields. The force on the bowl is upward, and sufficient to counteract the weight of the aluminum.

Should the bowl move to one side, the eddy currents give rise to a greater repulsive force on that side, causing the bowl to move back to center position. If the bowl tips, it experiences a force that restores it to horizontal equilibrium.

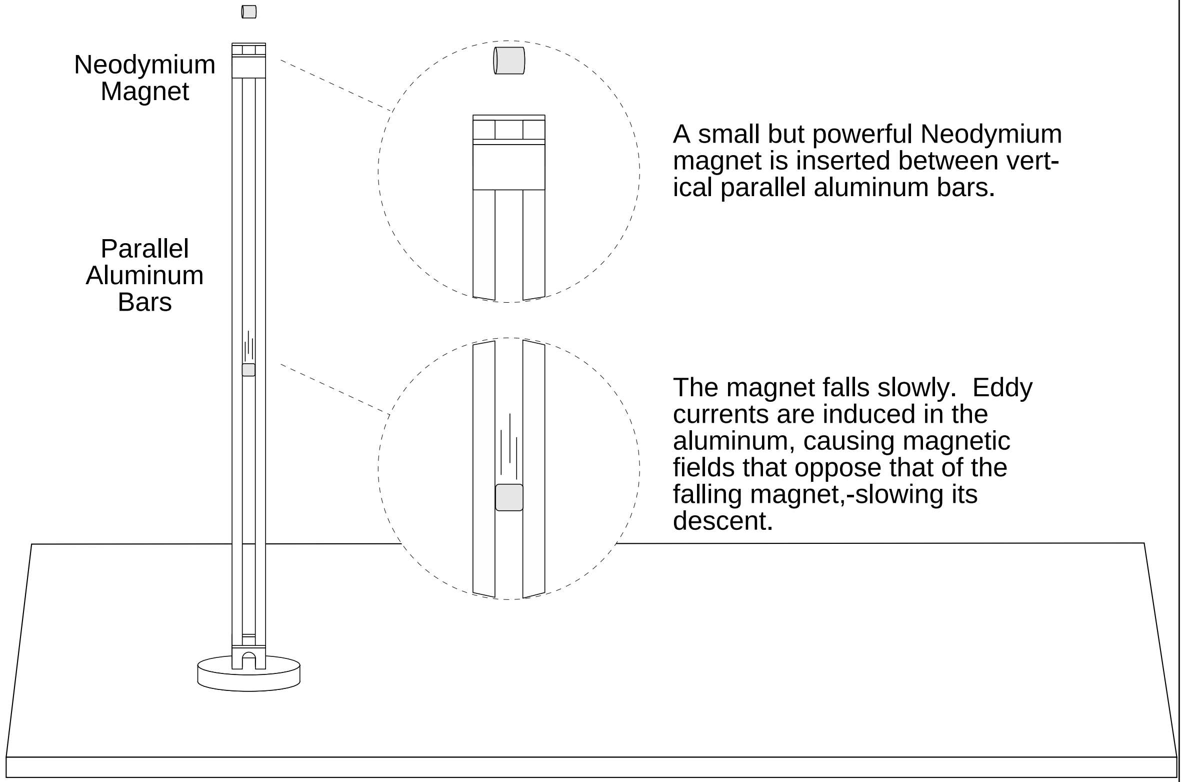
If a wood stick is used to press down on the bowl, the eddy currents increase significantly, causing the bowl to heat up dramatically. Some professors have cooked eggs in the bowl!

Because the coil windings of the levitator have a large inductive reactance, a large capacitance is inserted in the ac circuit (in the bottom part of levitator cabinet) to raise the power factor close to unity. I.E.: The current in the levitator coils is kept at a maximum, and the current supplied by the source is at a minimum.

FARADAY'S LAW.

D+15+26

Magnet drops slowly between aluminum bars due to eddy current effect.



A small but powerful Neodymium magnet is inserted between vertical parallel aluminum bars.

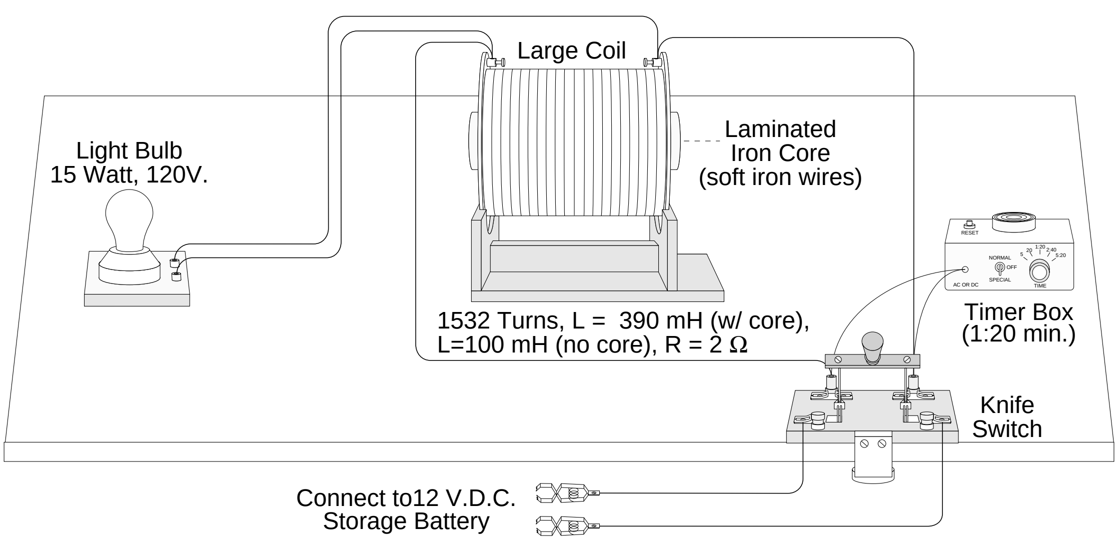
The magnet falls slowly. Eddy currents are induced in the aluminum, causing magnetic fields that oppose that of the falling magnet,-slowing its descent.

INDUCTANCE.

D+20+0

Energy stored in large coil with soft iron core flashes bulb.

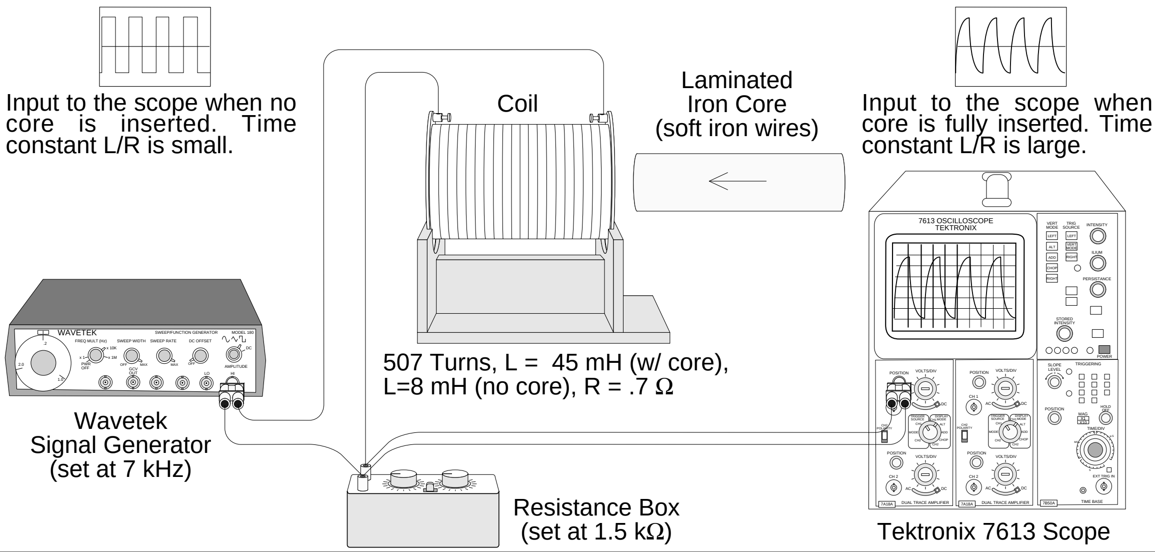
A laminated iron core is inserted into a large coil of 1532 turns. A 12 V.D.C. car battery is hooked up to the coil via a knife switch, and a 15 watt, 120 Volt bulb is attached in parallel. When the switch is closed, the bulb glows dimly. Most of the energy goes into the coil magnetic field. However, when the switch is quickly opened, the bulb flashes brightly. The energy from the collapsing magnetic field of the coil surges through the bulb, causing a brief flash.



INDUCTANCE. D+20+2

LR time constant: Square wave drives series LR on oscilloscope.

A signal generator places a 7 kHz square wave across a coil of 507 turns and a series resistor (1.5 kΩ). A laminated core is slowly inserted into the coil. When the voltage in the square wave goes suddenly positive, a current starts to flow in the inductor. This current is opposed by the induced emf in the inductor. However, as the current starts flowing, there is also a voltage drop across the resistor. Thus the voltage drop across the inductance is reduced, and there is less impedance to the current flow from the inductance. The current through the LR circuit rises exponentially until it reaches the value V/R, with a characteristic time constant L/R. When the square wave is suddenly zero, the current decays exponentially to 0, with the same time constant. When the square wave goes negative, similar arguments apply. When the core is fully inserted, L/R is large, and the scope signal is no longer a 'square' wave, but a series of scalloped rises and falls.



INDUCTANCE. D+20+4

AC dimmer: Soft iron core in coil dims lamps.

This is a series LR circuit (as was D+20+2). The lamps are the resistance R in this case. Either 120 V.D.C. or 120 V.A.C. can be applied by throwing the knife-switch, lighting the lamps. When D.C. voltage is selected, inserting the laminated iron core will cause no variation in the brightness of the lamps. However, if 60 Hz A.C. voltage is selected, inserting the core will cause the lamps to dim. Completely inserting the core will cause the lamps to completely turn off.

For the 120 V.D.C. case, the resistance of the lamps (in parallel) is about 30 Ω, and the current flowing is about 4 amps; plenty of current to light the lamps. There is no inductive impedance; no induced emf. But in the 120 V.A.C. case, there is an inductive impedance; and a rather large induced emf, especially when the core is inserted. When the core is inserted, the impedance of the inductor $X_L = 2 \Pi f L$ = 2x3.14x(60 Hz)x(.390 H) = 147 Ω, which means the current flowing in the circuit will be at least 80% reduced, and not enough to light the lamps.