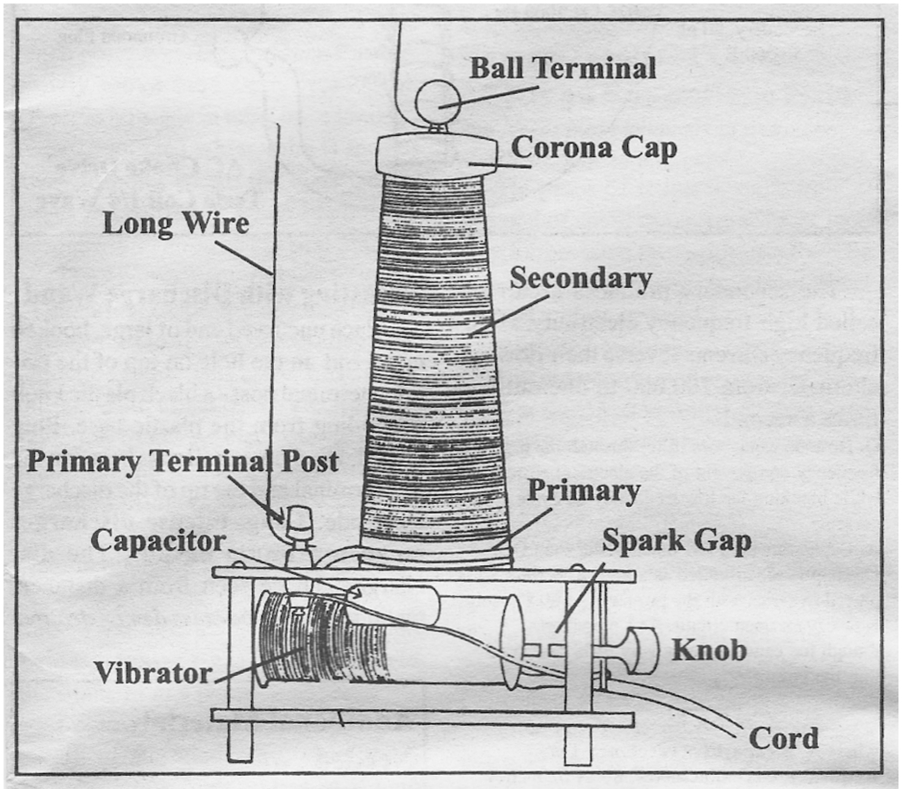
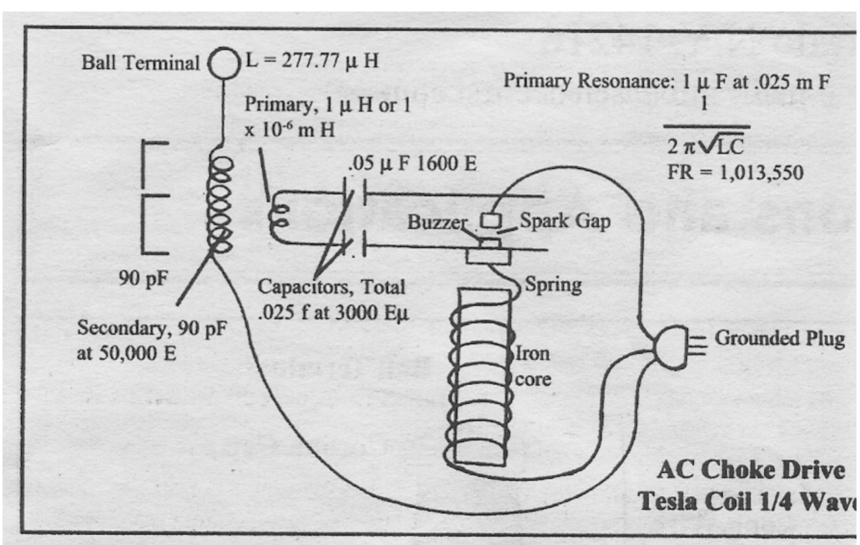
Tesla Coil (Science First)





Experiments

Experiment 1:
Discharging

You Need: *Metal piece (coin, key, bare uninsulated wire etc.)*

Plug in Coil and approach ball terminal with metal piece held in hand. The high frequency high voltage electrical discharge forms an arc between ball terminal and a metal object. How far can you draw this arc?

Experiment 2
How a Conductor Affects the Flow of High Frequency High Voltage Currents

You Need: *Short length of bare wire*

With the ball terminal in place, plug in Coil. Examine ball terminal to see if there are any signs of an electrical discharge. The ball terminal, being metal, is a conductor. There will normally be no such discharges, since the smooth rounded surface of the ball causes a uniform stress on the surrounding air.

Operate the Coil in a darkened room. Examine the ball terminal. (If the Coil is adjusted properly it may break down the surrounding air despite the smooth, round ball terminal. This discharge is most noticeable in the dark.)

Unplug the Coil and unscrew the ball terminal from its top. Take a short length of thin, bare wire, preferably pointed at one end. Fasten wire to the screw end from which the ball terminal has been removed, with pointed end of wire bent upward. Plug in Coil and note profuse discharge that issues from the sharp bare point. This type of discharge is known as *Corona Discharge.*

Experiment 3:
How Insulators Behave at High Frequency

You Need: *100 -200 volt clear glass light bulb; special lamp socket (included); metal piece; insulator (wood, plastic etc.)*

With Coil unplugged, remove ball terminal from top of Coil. Screw special lamp socket on exposed threaded stud. Screw bulb onto lamp socket.

Plug in Coil, place your finger tip on top of the glass light bulb and move it quickly over surface of bulb. Observe the discharges which take place in the bulb and lightning-like feelers that reach out from the light bulb's electrodes to a point on the inner surface of the bulb directly beneath your finger.

Take piece of metal and touch bulb with it. Observe difference in appearance of discharges.

Although the high frequency currents from the Tesla Coil pass through the glass of the light bulb and into your finger tip, you receive no physical sensation. This is because high frequency currents flow over the surface of the skin and the total current is distributed over the entire area of your finger tip in direct contact with the glass.

Keep your finger moving quickly to prevent burns.

This experiment shows that glass, considered an excellent insulator for medium and low frequency currents, is broken down by high frequency high voltage electricity.

Test the insulating properties of other materials. Remove the bulb and socket and replace ball terminal. Hold wood, plastic or paper in direct contact with the ball terminal with one hand while attempting to draw a discharge through the insulating material to a piece of metal held in your other hand.

Experiment 4: Ionizing Gases by Electrical Stress

You Need: *Fluorescent lamp tube, 40 watt recommended; neon lamp, short bare wire.*

With Tesla Coil unplugged, attach neon lamp to ball terminal. This is a small light bulb (NE2) with 2 thin copper wires protruding. Use thin wires to attach lamp to ball terminal. Wind wire around screw stud onto which ball terminal is mounted.

Plug in Coil and watch how brightly neon lamp lights up despite the fact that it is connected by only one wire.

With the short length of bare wire (NOT your hand) touch the glass bulb of the neon tube. Watch how the red-orange discharge becomes brighter and more concentrated. Not only do the electrodes in the neon lamp glow - the entire bulb exhibits a red-orange glow.

Unplug Tesla Coil. Remove neon lamp from ball terminal. Plug in Coil and approach ball terminal holding fluorescent light bulb in your hand. Note difference in color of the fluorescent light bulb compared to the neon lamp.

The glow appearing in both lamps is caused by **ionization**. Ionization occurs when 2 atoms collide, splitting off one or more electrons and giving off energy in the form of light. Every gas will produce its own characteristic color when it becomes ionized.

When the gases in the neon and fluorescent tubes are subjected to high electrical stress at low pressure, their atoms are excited and give off characteristic glows. In the neon tube, neon gas is excited; in the fluorescent tube, mercury vapor and argon gas.

Experiment 5: How Pressure Affects Ionization of Gases

You Need: *one 100-200 watt clear glass light bulb*

Operate Coil with ball terminal in place. Hold light bulb by glass bulb (not touching metallic base.) Bring base slowly toward ball terminal. Stop when gas in the bulb begins to ionize.

Observe the distance between ball terminal and point at which the bulb begins to glow. The gas contained in the bulb ionizes at the same distance from the Tesla Coil even though the electrical stress at this point is much less than it is at the ball terminal's surface.

Note that although the gas inside is ionized, the gases in the surrounding air are not. In fact, the gases in the atmosphere do not ionize even when they are in contact with the ball terminal, where the electrostatic stress is greatest.

The gas usually used in high wattage incandescent light bulbs is nitrogen, a small amount of which is introduced into what is otherwise a vacuum inside the bulb for the purpose of preventing the filament from growing brittle. The nitrogen is therefore at very low pressure inside the bulb.

This experiment shows that a gas at low or reduced pressure, such as the nitrogen in the evacuated light bulb, will ionize more easily than the same gas at atmospheric pressure.

Experiment 6: How Gases Differ in the Ease With Which They Ionize

***You Need:** fluorescent tube, any size; 100-200 watt clear glass light bulb; Neon lamp (included)*

Certain rare gases, such as neon, argon, xenon, krypton and helium, will ionize more readily than others due to their atomic structure.

This is demonstrated using a standard high wattage light bulb (containing nitrogen gas), a fluorescent tube (containing a combination of mercury vapor and argon), and a neon lamp (containing neon.)

Hold each bulb by the glass itself, not touching the metal base. Bring each bulb in turn toward the ball terminal while the Coil is operating. Stop when the gas in each bulb ionizes.

Compare the distances from the ball terminal at which the 3 gases ionize.

The standard high-wattage light bulb must be brought much closer to the ball terminal before its gas ionizes. Therefore nitrogen must be brought into an area of greater electrical stress than either neon or a combination of argon and mercury vapor before it breaks down.

Experiment 7: Demonstrating Sparking Potential

***You Need:** About 7 inches of stiff bare wire (included -cut to size)*

While the Coil is unplugged, connect one end of length of copper wire to primary terminal post, a plastic knob protruding from plastic base.

Connect the wire to the terminal post by unscrewing the top knob of post enough to expose a hole horizontal to the base. Bend your length of wire to form a small "L" at one end.

Insert small length of the "L" through the hole and then screw the top knob of the terminal post back into place, so wire is held in position, with free end projecting upward.

Operate Coil and move free end of wire toward ball terminal by hand. Stop at point where spark jumps between free end of wire and ball terminal.

The distance between the free end of wire and the ball terminal represents the distance over which the electrical stress generated by the Coil breaks down, or ionizes, the air. The amount of electrical stress needed to create a spark is called SPARKING POTENTIAL. For normal dry air, the sparking potential is *30,000 volts per centimeter.*

By measuring the distance between the free end of wire and the surface of the ball terminal, and by assuming that the sparking potential between the two is 30,000 volts per centimeter, you can estimate the sparking potential that exists between the wire and ball terminal.

Experiment 8:
How High Voltage Power is Transmitted

***You Nee:**. 2 lengths of bare copper wire, about 12" and 7" in length (- cut to length)*

Fasten 12 inch length of bare copper wire to ball terminal of Coil by winding it around screw stud onto which the ball terminal is secured.

Fasten 7 inch length of bare copper wire to primary post as before.

Position 2 wires in vertical direction, parallel to each other and about 1.5 inches apart. This simulates a high voltage power transmission line, in which 2 wires are spaced far apart.

Operate Coil and observe the ionization that occurs. (Best if performed in a dark room.) Note how ionization is confined to a zone surrounding the 2 lengths of wire, and how it takes the form of a visible corona discharge.

Gradually decrease distance between 2 wires until the point is reached where the air breaks down or sparks. Observe effect that decreasing the spacing of the wires has on the corona discharge.

High voltage transmission lines work in a similar fashion with two lines spaced far apart running parallel. When the air surrounding the wires ionized, the ionization is confined to a zone around both wires and produces a discharge in the air called a **corona**. The distance between the two wires is crucial: it must be far enough so that sparking between wires does not occur.

Experiment 9:
High Frequency High Voltage Electricity

***You Need:** One 100-200 watt clear glass light bulb; 12 inch length of plastic stranded wire (included); special lamp socket (includcd)*

Replace ball terminal with special lamp socket. Insert 100-200 watt clear glass light bulb into lamp socket.

Operate Tesla Coil. Adjust for maximum output by turning buzzer knob **counterclockwise** (as you face Coil with buzzer on right) until buzzer just stops working. Then slowly turn knob clockwise and observe changes in light bulb.

(The reason for this procedure is because the Tesla Coil is finely adjusted in the factory. You will be able to determine the point at which it just begins operation by first turning knob counterclockwise.)

The discharges taking place inside the light bulb have differing characteristics. At one setting they resemble slow-rising, smoke-like streamers. At another setting they take the form of miniature bluish-colored lightning bolts. At a third setting you observe quick, erratically moving little points of bluish flame travelling up and down wires inside the lamp. Brush discharges produced by high frequency electricity are more pronounced in a gas at reduced pressure (i.e. low-pressure nitrogen inside the evacuated bulb) than in air. Remove lamp socket from top of Coil. Strip insulation off both ends of 12 inch plastic stranded wire to a length of about one inch. Fasten one end of wire to screw stud from which lamp socket has been removed, with other end protruding upward. Fan out individual strands of free stranded wire so they are arranged like a comb.

Operate Coil at different settings of buzzer contacts. Observe types of brush discharges that result.

Experiment 10:

Transmitting High Frequency Electricity Over A Single Conductor

You Need: *lamp socket; 100-200 watt clear glass light bulb; 3' plastic 20 gauge stranded wire (-cut to size); 8/32 screw; glass or plastic tumbler*

Cut 3-foot length off 4-foot plastic stranded wire. Strip insulation off both ends to one-half inch. With ball terminal in place, fasten one end of wire to screw stud onto which ball terminal is mounted. Connect other end to base of lamp socket by winding wire around threaded spacer at base of socket and fastening with screw.

Stretch wire out to full length between light bulb and Coil so it has no contact with other objects. Install high-wattage bulb in lamp socket. Insert bulb inside glass. The bulb must be insulated from the surface on which Coil is placed.

Operate Tesla Coil. Observe how high frequency electricity is carried by single wire (with no second wire to serve as return path) to light bulb. Once reaching bulb, the high frequency high voltage electrical currents stream out from its filaments to ionize gas inside bulb. From there they pass into the air surrounding the bulb and eventually back to the Coil

This experiment shows how **air** is the return path between bulb and Coil where no second wire exists as return path.

Experiment 11:

Demonstrating The Two Components of High-Frequency Electrical Fields

You Need: *12" length of solid plastic stranded wire; 2 to 3 volt miniature screw-base flashlight bulb; fluorescent tube, any size; radiating antenna plate, small or large*

Unplug Coil, remove ball terminal. Fasten radiating antenna plate to screw stud by placing small hole in bent L of plate over stud. The bulk of plate will project upward in vertical direction. Secure plate by screwing ball terminal back onto screw stud.

Plug in Coil. Hold metal base of fluorescent tube in your hold, approach radiating antenna plate. When you reach point where gas in tube ionizes, slowly move tube away from Coil. Observe how gas in tube, once ionized, remains ionized when tube is moved away to point where the electrostatic stress is lower than value required to produce ionization in the first place.

The 2 components of high frequency electrical fields are: an electrostatic radiation field and an electromagnetic induction field. This experiment demonstrates the effect of the electrostatic radiation field. Its electrostatic stress is insufficient to initiate ionization (as shown by bringing the tube close to the Coil to cause it to glow) but is sufficient to maintain ionization in a gas at reduced pressure (shown when you moved the tube away.) The radiation field can ionize a gas but cannot light the filament in a lamp.

Remove antenna plate. Take 12" length of stranded wire, strip about 1/2" insulation from both ends of wire and form a single-turn loop about 3 to 3 1/2 inches in diameter.

When Coil is unplugged, arrange loop around base (corona cap) near top, beneath ball terminal. Fasten ends of plastic wire (scraped free of insulation) to each screw terminal of flashlight lamp socket by winding each wire end around each screw terminal.

Insert 2 to 3 volt screw-base flashlight lamp into lamp socket fastened to top of Coil. Operate Coil.

The flashlight lamp is short-circuited by this wire loop. No electrical energy can come from the electrostatic radiating field. An additional factor is the weakness of the field itself, which can maintain but not initiate ionization. And yet the flashlight lamp glows brightly. The energy for this must come from the electromagnetic induction field generated by the Tesla Coil.

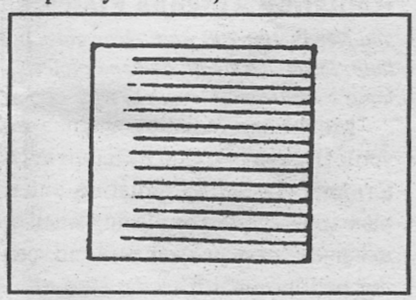
Experiment 12:
How Faraday Shields Affect Electrostatic Radiation

***You Need:** 12" square piece of metal foil; neon lamp (included)*

Construct a simple Faraday Shield by cutting slots in piece of aluminum foil like a comb. *See Diagram below.*

A Faraday Shield is a network of parallel wires or conductors connected to a common conductor at one end only, like a comb. The common conductor is usually grounded. Faraday Shields are used where electrostatic shielding is needed.

With ball terminal on, operate Tesla Coil. Hold neon lamp by glass bulb and bring toward ball terminal until neon gas ionizes. Stop at point where neon ionizes. Holding Faraday Shield in your other hand, lower it slowly between ball terminal and neon lamp. (Holding Faraday Shield in your hand provides the ground needed for high frequency currents.)



Observe how neon lamp deionizes or stops glowing when Faraday Shield is between lamp and Tesla Coil.

Bring neon lamp closer to ball terminal and repeat procedure.

This shows how a simple Faraday Shield can cut of the electrostatic radiation field from the Tesla Coil.

Experiment 13:
How an Insulated Conductor Affects an Electrostatic Field

***You Need:** Neon lamp; small radiating plate; string or rubber band*

Tie piece of string through hole at one end of small radiating plate or loop long rubber band through hole. (Purpose is to insulate radiating plate from direct contact with your hand.)

With ball terminal in place, operate Coil. Hold neon lamp by glass bulb and bring toward ball terminal. Stop at point at which neon gas in lamp ionizes.

Withdraw lamp to position just beyond that in which neon gas deionizes or ceases to glow. While holding lamp, pick up string or rubber band attached to small radiating plate with other hand. Bring plate toward neon lamp until it touches one of lamp terminals (thin wires protruding from base of lamp.)

Observe how neon lamp ionizes when insulated conductor - the plate - touches one terminal.

Break contact with insulated conductor by removing radiating plate from between lamp and ball terminal. Observe that lamp stops glowing.

This experiment demonstrates effect of an insulated electrical conductor on an electrostatic field. Introducing an insulated conductor alters the electrostatic stress distribution by concentrating stress around the conductor. The conductor will then ionize lamp when lamp is located at greater distance from ball terminal than distance required to ionize lamp in the first place.

Experiment 14:
Stress Distribution on Insulated Conductor in Electrostatic Field

***You Need:** Neon lamp ; small plate; string or rubber band*

Suspend radiating plate from string or rubber band as in experiment above.

Holding lamp by glass bulb, bring it toward ball terminal, stop at point at which neon gas ionizes, and withdraw neon lamp to position just beyond that in which neon gas stops glowing.

Hold plate in your other hand by means of attached string or rubber band. Approach lamp from opposite side with lamp between the plate and ball terminal. Touch one terminal of lamp with radiating plate. Observe that lamp starts to glow when insulated conductor -the plate - touches one terminal, despite fact that lamp is too far away from ball terminal to ionize on its own.

Radio and TV antennas on rooftops serve as insulated conductors to intercept high frequency broadcasts from radio & TV transmitters.

Experiment 15
Transmitting Electrical Power Through Space without Wires

***You Need:** 2-3 volt flashlight bulb; miniature screw-base socket; string or rubber band; small plate; large plate; 2 lengths of plastic insulated wire, 18" each*

Cut 3 foot length of wire (used in **Experiment 10)** in **halt,** yielding two **18"** sections. Strip insulation 1/2" from both ends of both pieces. Remove ball terminal and mount either small or large plate vertically on threaded stud. Fasten by screwing ball terminal onto stud.

Connect one end of one wire length to 'primary terminal post" by inserting bare end of wire through small hole located between two black plastic portions of primary terminal post. Fasten other end of wire to one side of miniature lamp socket. Unscrew nut on one of socket terminals, wind bare end around screw stud, and replace nut on stud.

Connect second stripped wire between remaining terminal of lamp socket and second antenna plate. (Connect antenna plate by looping one bare end of wire through hole at one end of plate.) Mount miniature flashlight bulb into lamp socket. Attach rubber band or piece of string through hole at end of second antenna plate (through which one wire end is already looped) to support plate vertically. This is plate connected to lamp socket.

Operate Tesla Coil. Holding antenna plate connected to lamp socket (*receiving* antenna plate) by rubber band or string handle, slowly bring toward other plate mounted to top of Coil.

Observe that at a certain point the 10-watt lamp will light despite fact there is only one wire connecting it to Coil.

This experiment illustrates the dream of inventor Nikola Tesla: to send electrical power through the air, without wires, to run factories and homes. Tesla lit a bank of 200 lamps a distance of 20 miles from his Coil by plugging one wire into the ground and connecting the other to an electrical receiving aerial.

To transmit electrical power without wires in an actual situation, the metallic connection between the suspended receiving plate and Tesla Coil in this experiment would be replaced by the ground return through earth.

Experiment 16:
How Concentrating Output Produces High Temperatures

You Need: *Piece of metal (coin, key); sheet of paper*

> **Warning: Perform in Area Where Fire Can be Promptly Extinguished**

Operate Coil with ball terminal in place. Holding piece of metal in your hand, approach ball terminal until discharge occurs. This initial discharge takes the form of a thin blue spark.

Move piece of metal closer to ball terminal. Observe that discharge grows into arch with yellow flame as distance between piece of metal and ball terminal is decreased. Take sheet of paper with your other hand and hold it close to ball terminal, without touching directly. Hold piece of metal behind paper. This will draw discharge through paper.

Move metal closer so discharge becomes an arc. Observe how quickly paper ignites.

This experiment demonstrates how a high temperature is produced when the entire output of the Coil is concentrated in an arch discharge.

Experiment 17:
How Air and Metal Compare as Conductors of High Frequency Currents

You Need: *Piece of Metal; Length of stiff bare wire copper wire (about 7")*

Operate Tesla Coil with ball terminal in place. Hold piece of metal in your hand and draw out discharge as far as possible. This is the maximum separation in which you can get a discharge.

Unplug Tesla Coil. Fasten 7' length of bare copper wire through small hole in primary terminal post by unscrewing knob of terminal post, inserting tip of bare wire (bent into small "L") through exposed hole, and screwing knob back into place. Bend free end of wire upward so it projects vertically and is about 1" or less from ball terminal. This is the **discharge electrode.**

Operate Tesla Coil. Move free end of discharge electrode away from ball terminal to draw out discharge as far as possible. Move wire at its base, close to where it attaches to primary terminal post. Observe length of this second maximum separation. Compare distances of maximum length of discharge created by these two methods.

Observe how the length of discharge is greater using discharge electrode than the piece of metal. This discharge electrode provides a metallic return path for the electrical current, whereas the metal requires that the current pass through the air-tilled space between your body and the Coil .

It is impossible to obtain the full output of the Coil in this experiment, due to high resistances offered by your body and the air to the flow of high frequency electrical currents.

Experiment 18: Demonstrating Principles of Modulation

You Need: *Piece of Metal*

This experiment illustrates basic concepts of **modulation,** a condition in which *a lower frequency can supersede a higher one*. Here the several million cycle per second high frequency voltage produced by the Tesla Coil is modulated by the 60 cycle per second power line frequency.

Operate the Coil, holding the piece of metal in your hand. Move metal up and down rapidly in a small arch near the ball terminal. Observe that discharges are not continuous but instead occur in the form of individual sparks.

The individual sparks occur at a rate of 120 sparks per second - one discharge at each peak of the 60-cycle power frequency. The Tesla Coil generates a few million cycles per second. Therefore the individual sparks serve to modulate, or bring down to a lower level, the high frequency generated by the Coil to a 60-cycle per second modulating frequency.

Experiment with different speeds as you move the piece of metal up and down. You add the dimension time to your observations because at each instant the metal occupies a different position with respect to the ball terminal.

You may actually be able to make individual sparks appear to stand still, a condition known as **synchronizing.** When your speed of movement is in step with the 60-cycle per second power line frequency, each discharge appears to occur at the same point in space between the moving metal and ball terminal.

Experiment 19:

Transmitting Power with Radiating Antenna Plates

You Need: 100-200 watt clear glass light bulb; large and small antenna plates; lamp socket; small length of wire

Mount one radiating antenna plate vertically to top of Coil by removing ball terminal, fastening radiating antenna plate to screw stud by placing small hole in bent 'L' of plate over stud and screwing ball terminal back on stud to hold plate in place. This is the **transmitting antenna plate.**

Attach special lampsocket to second radiating plate (receiving plate) by threading small length of wire through both the hole in the bent "L" of antenna plate and hole in base of lamp socket, then looping wire over securely.

Place light bulb in special lamp socket. Operate Tesla Coil.

Position both antenna plates so they are parallel to each other. Holding receiving antenna plate by the glass of the light bulb, approach the transmitting plate, keeping both plates parallel.

Observe the point at which the air in the light bulb ionizes. You must approach transmitting plate closely when the plates are parallel to each other. Turn receiving plate at right angles to transmitting plate and repeat procedure. Compare distance at which ionization occurs.

How to Teach with Tesla Coil

Concepts: High frequency electricity, generation. Resonance in electromagnetic field. Reversed polarity induction.

Curriculum Fit: Physical science; Electricity & Magnetism. *Unit: Moving Charge and Magnets.* **Grades 11-12.**

Subconcepts: Primary Secondary Coil. Mutual inductance. Voltage/current relationship during induction. Open& closed circuits, short circuiting. Energy conservation in electromagnetic fields. Transformation of electricity to magnetism. Vice versa. Capacitor. Discharge through sparks.

Curriculum Fit: Physical Science/ Electricity& Magnetism. *Unit: Electric Circuits. Unit: Energy Transformation.* Physical Science; Electricity & Magnetism. *Unit: Static Charge.* **Grades 6-10.**

Safety Tips and Features

This product is designed to be safe when used properly. As with any electrical appliance, please follow these safety rules:

1. Plug into grounded (3-prong) 110 volt 60 cycle outlet **only** (household current.) For 10-206, plug into 220 volt outlet.
2. Do not operate in wet or damp location or outdoors.
3. Check for loose, worn or frayed wires. Replace defective parts.
4. While high frequency high voltage electricity will not produce a shock, it can cause a burn if taken into your body at one small point of contact. Do not come too close to a discharge; you may be burned. Use a piece of metal to take away discharge so it will not build to unsafe levels of intense heat.
5. Do not remove plastic cover (ring around bottom of Coil.) This is a safety guard to ensure your fingers will not come into contact with the vibrator or spark gap.

Removal of safety guard is a shock hazard.

6. Operate Tesla Coil on bench or table with nonmetallic top.
7. Operate Tesla Coil under adult supervision.