Instructions & Applications for Tesla Coil
Introduction:
The Tesla Coil is an air-core transformer with primary and secondary coils tuned to resonate. The primary and secondary circuits function as step-up transformer which converts relatively low-voltage high current to high-voltage low current at high frequencies.

The Tesla Coil demonstrates the fundamental principles of high frequency electrical phenomena. It shows the principles of ionization of gases and behavior of insulators and conductors when in contact with high frequency electrical fields.

Its inventor, Nikola Tesla, conceived it to be a means to transmit electrical power without wires. An antenna would pull the transmitted electrical energy into the electrical system. You can also consider it a simple radio transmitter operating within a broad range of high frequencies, which transmits power rather than information.

Components:
The Tesla Coil consists of a vibrator or transformer, two high voltage capacitors, a primary, and a Secondary connected to a ball terminal or antenna.

The vibrator is composed of an air slot core around which coils of copper are wound; and a buzzer which consists of two tungsten points or contacts which open and close by means of a spring as alternating current and electricity passes through the core and discharges in the spark gap. The capacitors are two large cylinders on either side of the spark gap. They are high voltage capacitors of a predetermined size and value.

The primary coil is a pair of thick insulated copper wires located next to, but not touching, the secondary and connected in series with the capacitors and spark gap.

The secondary is a cone-shaped coil (cone-shaped to keep the coil compact and for manufacturing reasons as less wire is needed) consisting of 400 turns of thin enameled copper wire. It functions as a transformer by stepping up voltage to high levels. The high voltage is given off by the terminal.

How a Tesla Coil Works:
When powered from a suitable outlet, electricity flows through the vibrator, an iron core with hollow center wound with coils of copper wire. This core becomes an electromagnet. The buzzer, 2 tungsten contacts opposite each other, not quite touching, pulls apart when the electromagnet is activated and closes when the magnetic field decays. This occurs 100 or 120 times per second - each time the AC current changes polarity of the electromagnet.

The capacitors charge up when the buzzer contacts are open, since the current passes into them to complete the electrical circuit. When the contacts are closed, the capacitors are shorted together and current does not pass into them. The open contacts allow the air in the spark gap—the small space between open contacts to ionize, which permits a discharge that short circuits the transformer and capacitors. But the capacitors retain their electric charge, since the function of a capacitor is to store an electrical charge and thus provide energy to create an electromagnetic field.

This spark taking place in this spark gap does not consist simply of a single spark passing in one direction, as would appear to the eye, but a number of separate sparks passing back and forth in opposite directions. They take place so rapidly you cannot see the direction
change. The time during which the spark appears to pass may only be a fraction of a second, but during that time the current may have oscillated back and forth several thousand times.

The electromagnetic field is formed by the primary which converts the charge stored in the capacitors to magnetic energy. The electrical charge is transferred to the primary by the capacitors when the magnetic field in the iron core decays. When the magnetic field in the iron core is reactivated, the field generated in the primary is the one to decay, and the electrical charge is transferred back to the capacitors with every half cycle. A charge of increasingly higher voltage as each activation of the magnetic field adds to the charges previously generated.

The vibrator also acts as an air core transformer, boosting the voltage to medium high levels with every half cycle pulse of AC current. The high frequencies produced are rich in harmonics since each pulse of electricity across the spark gap is composed of many surges of electrical energy.

The capacitors in this Coil have a particular size and value. They serve the dual function of storing electric charge and filtering through the high frequency component of electrical current while blocking low frequency 50 or 60 cycles current. This is a safety feature, since by isolating the primary from the 60 cycle component of the current, the electrical circuit will not be complete in regard to the 50 or 60 cycle component and thus the output terminal has some isolation from the mains output. Another safety feature is the fact that an air-core transformer by its nature does not pass 50 or 60 cycles current well. The result is that high frequency electrical energy is built up by the generation and decay of the magnetic field in the primary every half cycle, often reaching many million cycles per second.

When the high frequency is great enough and reaches the voltage predetermined by the size and value of the capacitor, the primary induces a magnetic field in the secondary. Inducing means a moving magnetic field causes a magnetic field to form in another wire coil located close to, or inside, the first coil.

The primary consists of two thick insulated copper wires which are resonated by the capacitors to equal the natural resonant frequency of the secondary. When the resonance equals that of the secondary, a magnetic field is formed in the secondary. Resonance may be compared to a cymbal: when a cymbal of a certain size and weight is struck, it rings at a specific frequency. In the Tesla Coil the capacitors and secondary coil “ring” at the chosen high frequency.

Resonance may also be compared to a swing. When inductive impedance and capacitive impedance of a circuit are equal, the electricity oscillates back and forth between inductive component (primary) and capacitive component (capacitors, also called condensers). When pushing a swing, a person can cause large forward and backward motions with small pushes administered at the correct frequency. Applying energy correct frequencies builds up high potentials in a resonant circuit.

A person in a swing weighing 200 pounds may be pushed by a small child about 50 pounds who may push with only one pound of force. If he times his pushes to coincide with the direction of the swing and keeps adding a pound of force each time, he will eventually have to stop to avoid hurling the person in the swing out into space.
An analogy used by inventor Nikola Tesla himself is to picture a wine glass broken by a violinist’s note. The glass is shattered because the vibrations happen to be the same frequency as the vibrations of the glass.

The secondary, like the vibrator, functions independently as a step-up transformer of about 3,000 volts. It has many more coil turns of copper wire in its secondary than the primary.

As the electrical energy from the vibrator is fed to the capacitors of the primary air core transformer and coil at its base, it now creates another independent circuit of the vibrator type transformer. The vibrator secondary output of 3,000 V is applied to this primary circuit, known as the air core Tesla resonant transformer (oscillator).

**How To Operate:-**
Use Tesla Coil on bench or table with nonmetallic surface to rule out danger of electric shock. **Plug into a grounded mains outlet.** Voltage of household current may vary slightly. Turn front knob on vibrator until a buzzing sound is heard.

**Adjust with Discharge Wand:-**
The discharge electrode is a large hooked metal rod. Its un-curved end is placed in the hole in the top of the primary terminal post - a black knob protruding from the plastic base. When you plug in your Coil, discharges will pass between the ball terminal and the tip of the discharge electrode. Long, intense discharges mean maximum output.

The discharges can be seen from a distance, making this a good class demonstration.

**Adjusting for Peak Performance:-**
*For best results, adjust your Coil for proper operation.*

1. **While machine is unplugged,** fasten some of the provided wire to ball terminal. Take a small piece of thin bare wire provided and place in the ball terminal and point free end upward.

2. **Plug in** Coil. Plug into an ordinary household outlet. Light streamers will issue from the tip of the wire, since the wire’s sharp end will break down the surrounding air more easily than will the ball terminal.

3. Adjust buzzer knob until longest possible streamers emanate from wire end. Long streamers indicate circuit of primary and secondary coils are resonated. In this condition your machine operates at maximum efficiency.

**Experiment 1: Discharging**
*You Need:*
*• Piece of metal (coin, key, bare uninsulated wire etc.)*
Hold a small piece of metal in one hand. Plug in Tesla Coil and approach ball terminal with metal. The high frequency high voltage electrical discharge forms an arc between ball terminal and a metal object. See how far out you can draw an 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 your Coil. Examine ball terminal to see if there are any signs of an electrical discharge issuing from it. The ball terminal, being metal, is a conductor. However, 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 shape of the ball terminal. Any such discharge will be 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 issue from the sharp bare point. This type of discharge is known as Corona Discharge.

This experiment illustrates the fact that high frequency high voltage electricity issues more readily from a conductor with sharp points than a conductor with smooth round surfaces. (This is the reason that sharp bends, pointed projections and sharp corners are avoided in wiring high frequency equipment.) A practical example of this principle is the way high voltage metal enclosures of televisions are wired.

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**Experiment 3: How Insulators Behave at High Frequency**

*You Need:*
- 100-200 watt clear glass light bulb
- Special lamp socket, included
- Piece of metal
- Other insulators (wood, plastic)

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

Mount the light bulb onto lamp socket by screwing it on. Plug in the 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 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. The reasons are: one, high frequency currents flow over the surface of the skin; two, the total current is distributed over the entire area of your finger tip which is in direct contact with the glass.
Remember to keep your finger moving quickly. You may get a burn if you concentrate the discharge at a single point on your finger.

This experiment shows that glass, an excellent insulator for medium and low frequency currents, is readily broken down by high frequency high voltage electricity. Test the insulating properties of other materials.

Remove the light bulb and special lamp socket and return ball terminal to the top of the Coil.

Hold wood, plastic or paper in direct contact with the ball terminal with one hand while trying to draw a discharge through the insulating material to a piece of metal in your other hand.

**Experiment 4: Ionizing Gases by Electrical Stress**

*You Need:*
- Fluorescent lamp tube, 40 watt
- Neon lamp. Included
- Short length of bare wire

While the Tesla Coil is not in operation, attach the neon lamp to the ball terminal. The neon lamp is a very small light bulb (N E2) with two thin copper wires protruding.

Use one of the thin wires to attach lamp to ball terminal. Wind the wire around screw stud onto which the ball terminal is mounted. Plug in the Coil and watch how brightly the neon lamp lights up despite the fact that it is connected to the Tesla Coil 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 even brighter and more concentrated. Not only do the electrodes in the neon lamp glow - the entire bulb exhibits a red-orange glow.

Unplug the Tesla Coil. Remove neon lamp from ball terminal. Plug in the Tesla Coil and approach ball terminal holding fluorescent light bulb in your hand.

Note the 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:*
- 100-200 watt clear glass light bulb

Operate your Coil with the ball terminal in place. Hold bulb by its glass, not touching metallic base. Bring the base of the bulb slowly toward the ball terminal. Stop at the point where the gas in the bulb begins to ionize.
Observe the distance between the ball terminal and the point at which the bulb begins to glow. The gas contained in the bulb ionizes at the same distance from the Coil even though the electrical stress at this point is much less than it is at the ball terminal’s surface.

Observe 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 to prevent 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.*
- One fluorescent tube, any size
- One 100-200 watt clear glass light bulb
- Neon lamp

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 at which the three 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.

**Safety Tips and Safety 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) 220 volt 60 cycle outlet only (household current.)
2. Do not operate in wet or damp locations or outdoors.
3. Check for loose, worn or frayed wires. Have defective parts replaced.
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 open black enclosure. This is a safety guard to ensure your fingers will not come into contact with the vibrator or spark gap.

6. Operate the Tesla Coil on a bench or table with a nonmetallic top.

Opening black enclosure is a shock hazard.

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

**How to Teach with Tesla Coil:**

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

**Curriculum Fit:** Physical Science, Electricity and Magnetism. *Unit: Moving Charge and Magnets. Grades 11-12*


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