A *Tesla Coil* is a circuit which has the following components:

- **Primary Coil**
- **Secondary Coil**
- **Capacitors**
- **Transformer**
- **RF Chokes**
- **Spark Gap**
- **Discharge Terminal**

The **Transformer** must be a high-voltage, low-frequency, current-limiting type. For proper performance, the potential must be at least 9,000 volts. The transformers can be connected in series to increase the current yield, but note that this will not affect the voltage. Several transformers may be connected in series to increase the current of the electricity entering into the spark gaps. The best place to find an appropriate transformer is from someone who deals in neon signs and their parts.

The **RF Chokes** are not necessary for the coil to work, but are used to extend the life of the transformer. The High voltages generated by the *Tesla Oscillator* will eventually destroy the transformer during kickback if protective measures are not taken -- this is the function of the RF Chokes.

The **Secondary Coil** acts as a transformer, raising the voltage from several thousand to perhaps over 1,000,000 volts. This is also known as the *Tesla Oscillator* and is the heart of the machine. Polyvinyl Chloride (PVC) is the best choice for secondary coil form. I usually use #28 AWG gauge wire for the secondary.

The **Capacitors** are used to charge and discharge the Primary Coil into the Secondary Coil, thus creating a magnetic field in the Secondary. Before the magnetic field induced in the secondary decays, the capacitors release more energy into the secondary -- this allows the voltage to rise to extremely high levels. It is important to realize that Tesla Coils operate as a result of capacitance and inductance, not inductance alone, like other transformers do. Several capacitors may be connected in series to increase performance. *Never* use electrolytic capacitors in a Tesla Coil -- they are for direct current circuits only. Using an electrolytic capacitor in a Tesla circuit will probably result in an explosion. Capacitors can be made from *Leyden Jars*, or from alternating strips of polyethylene and aluminum flashing.

The **Primary Coil** takes the energy produced by the transformer and feeds it into the capacitors. It also creates a magnetic field which induces another magnetic field in the secondary. I generally use #14 AWG gauge wire for this purpose.

The **Spark Gap** acts as a switch which allows the transformer to discharge its energy into the capacitors, and for the capacitors to empty its excess energy back into the primary when the polarity changes. Remember that Tesla Coils operate only on *alternating current*. A spark gap is easily constructed from two pieces of angle iron. Rotary spark gaps are more effective, but much harder to build. Solid state coils use semiconductor components or vacuum tubes in place of the spark gap.

The **Discharge Terminal** or **Terminal Capacitor** allows all of the energy generated by the circuitry to be discharged from the coil into the atmosphere. It is usually topped by a *toroid*, to allow a more even distribution of electrical energy. A metallic screw or nail would make an excellent discharge terminal.
Operating Theory

An important electrical concept in Tesla Coil theory is the idea of reactance. Reactance in an alternating current circuit reduces, or in some cases, stops the flow of current through a circuit. In this it is much like the resistance property of direct current circuits, but it differs in that reactance varies with the frequency whereas resistance does not. The main components of a Tesla Coil are the inductors, or coils of conducting wire, which, due to their reactive properties, tend to resist the current flow as the frequency of the electricity increases. Capacitors act similarly, but in an opposite fashion. They reduce current flow as the frequency of the electricity is decreased through increased resistance. When an inductor and a capacitor are connected in series, there is a frequency where the inductive reactance and the capacitative reactance cancel each other out and current flow is maximized. This is referred to as the resonant frequency. When this resonant frequency is reached, the maximum amount of energy is transferred from the primary coil to the secondary coil and the best results are obtained. Due to the large number of factors that can alter Tesla Coil performance, this resonant frequency is best arrived at through trial and error. This experimental improvement of the energy transfer is referred to as tuning the coil, and is achieved by varying the lengths of the primary coil. The total reactance in the L-C circuit does not affect the resonance, but it can have marked effects on the Q (Quality) Factor of the circuit. The transformer acts as an electron pump that tries to fill the capacitors up with energy. The capacitor, in turn, charges the spark gap electrodes until the air within the gap is ionized by a sufficiently high potential. At this point, ionization occurs, the electricity has broken down the insulating properties of the air, and current begins to flow across the gap. The gap thus acts as a switch, which the high voltage turns on. As current flows across the gap and into the primary coil, a magnetic field is created and allows the energy in the primary coil to be transferred to the secondary coil. For this to happen, there need be no direct electrical connection between the primary and secondary -- the magnetic field alone accomplishes the job. Almost immediately, the magnetic field begins to collapse, and the current then reverses, and flows across the spark gap in the opposite direction, which recharges the capacitor. Once the field has totally collapsed, the capacitor will have been recharged and will then discharge into the primary coil after bridging the spark gap. This process continues until the capacitor no longer has sufficient charge to ionize the air in the spark gap. When the circuit reaches this point, it is said to be ringing. The frequency of this ringing is determined by the L-C constant. This is what accounts for the 60 Hz input frequency being converted to HF electricity. As the magnetic field in the primary expands and contracts at the resonant frequency, the secondary begins to resonate and to charge the discharge terminal. At this point, the electricity had reached its maximum voltage and frequency and streams out into the atmosphere. The uncanny rise in voltage is due to the ratio of turns of the secondary coil to the number of turns on the primary. The streamers that radiate from the discharge terminal will not produce a shock because of the nature of high frequency electrical discharges. The sparks are very hot, however, and should be treated with caution.

Note: Although the end results may look similar, the above theory is not how Wiemhurst or other types of electrostatic generators operate.

Inventor

[picture of Nikola Tesla]

The Inventor of the Tesla Coil was a Croatian man named Nikola Tesla, and he was one of the most prolific inventors of all time. He was a prime mover at the Westinghouse Electrical company and worked for Thomas Alva Edison for several years, although the two men did not get along well together. The patent for the coil was registered in 1891, which makes Tesla the true inventor of radio and not Marconi. The Tesla Coil is a very simple and crude form of radio, and a much smaller version of it is used in virtually every radio or television set in existence to generate the energy at high enough frequencies to be able to carry information. The original purpose for the Tesla Coil was to transmit wireless power, rather than information. This was Tesla's dream, and although his initial experiments were successful, he never received the funding necessary to complete his research into this area. The Tesla Coil today is used almost exclusively as a novelty item or as a hobby pursuit. The Marconi patent for radio was overturned in 1943, and Tesla was officially recognized as the true inventor of the wireless era, but this ruling received very little publicity and consequently most history books still credit Marconi
as the inventor of radio.

Safety

- All terrestrial electrical discharges are accompanied by noise, and in the case of Tesla Coils, a great deal of noise. It is advisable to wear ear plugs while operating these machines, otherwise permanent hearing damage is likely to result.
- The high temperature of the streamers will ionize large amounts of air and this will generate large amounts of ozone (O₃). This will be dangerous unless proper ventilation is used.
- No parts of any Tesla coil should ever be touched while in operation. Hundreds of amperes may be flowing through the primary circuit of a coil in operation at very high voltages. A current of as little as 1/10 amperes could be fatal.
- The inner workings of a Tesla Coil should be shielded if at all possible. The danger of a capacitor being overloaded and exploding are small, but real. Having a shield around the area where the capacitors are kept will minimize the damage of any explosion. The light that is generated when the spark gap is bridged by the current can be harmful if looked at directly for a substantial length of time and a shield will cut down on the probability of ocular injury. Also, touching a capacitor even if the coil is not in operation will almost certainly result in instant death. Before touching a capacitor, you must make sure that it is manually discharged. Never depend on any type of "bleeder resistor" to discharge sufficiently on its own to be safe. This done by using a discharge rod (a rod composed of a dielectric material with a metal fork at one end. The metal fork must allow a conducting path to traverse from the capacitor to the ground).
- Under no circumstances should anyone who wears a pacemaker be allowed anywhere near a Tesla Coil. The high frequency radiations from a Tesla Coil often causes sensitive electrical instruments to malfunction. This static could easily destroy a pacemaker and kill the individual who is wearing it. This should also serve as a warning to contain all sensitive electrical devices, such as computers, within all-metal enclosures known as Faraday Cages. The high-frequency electricity is shielded one hundred percent by these simple containers, since HF radiations does not go through conductors, but around them. This sort of electricity will, however, go directly through most insulators just as though they weren't there. This will protect these items from the Tesla radiations.
- A fire extinguisher should be kept at hand at all times in the case of a fire. To minimize this risk, the area around the spark gap should be well ventilated, since a substantial amount of heat can build up in a relatively small space. Consider using a quenched gap.
- High Frequency radiations can cause tissue damage to living creatures if they are exposed to it for too long. The radiations in the microwave range are among the most dangerous, but fortunately, most Tesla Coils do not resonate at such a high frequency. But the coiler should make efforts to keep the resonant frequency as low as possible to avoid the risk of repeated exposure to HF radiation. Using the coil in only fairly short bursts should help to cut down on this and the above problem.
- The only type of wire that should be used in coil construction is copper. Various other metals are known to emit X-rays when bombarded with HF radiations.
- The sparks from a Tesla Coil should never come into contact with any wall outlet. It will cause a power failure which may not be limited to your home if this happens.
- Beware of any interference that the coil could cause to anyone operating a two-way radio that uses frequencies close to the broadcast frequency of the coil. This is illegal.

Kirlian Photography

Kirlian Photography, also known as Corona Discharge Photography is a method of capturing the visible-spectrum interference pattern of any object and a high-frequency, high-potential electromagnetic field. It was popularized by Semyon and Valentina Kirlian, a Russian husband and wife team of electrical engineers, although Tesla had reported noticing similar phenomena in his lab during various experiments. In the past it has been useful in diagnosing physical and mental diseases and disorders, often before any symptoms become apparent. What these disorders are cannot yet be determined by the Kirlian process, however. Whether the Kirlian photographs depict anything more than an "interference pattern" is open to debate. Many parapsychologists claim that these electrophotos are really photographs
of the "astral body" or aura, which all humans possess. The strongest evidence of their claim comes from the fact that "ghost photographs" of a leaf can be obtained when part of a leaf is cut away and then photographed. A very dim outline of the original shape of the leaf remains even though there is nothing physically present in that space. People with psychic abilities are said to have stronger auras than others, but due to the rarity of such people and the capriciousness of psychic phenomena no definitive proof of these claims has been forthcoming. Even allowing for the improbability of the parapsychologists' argument, physical scientists have yet to come up with an adequate explanation for these ghost photographs.

The term "photography" is somewhat misleading, since no conventional camera with lenses is used. A Tesla Coil is connected to a conducting plate which is covered with a photographic plate and an object is placed on the plate for a few seconds in the Kirlian Photographic process. An excessive voltage gives deceptively bright electrographs, so the Tesla Coil thus used must have an output rating of no higher than six kilovolts to yield any genuine information. This process must take place in a darkened room, just as in conventional film developing. It is safe to take electrographs of living creatures, since the high-frequency nature of the electrical field causes no electrical shock. Most of what we know about the Kirlian process today is the result of the research of Dr. Thelma Moss, who studied these phenomena at UCLA during the 1970's and 1980's. Documentation of her research can be found in her books The Body Electric and The Probability of the Impossible.

Kirlian Photograph of my fingertips

Kirlian Electrograph of my fingertips using one of my smaller Tesla Coils.

Kirlian Photograph of a woman's hand

Kirlian Electrograph of a woman's hand using a Homebrew Kirlian Machine.

For information on purchasing already built Tesla Coils or Kirlian Cameras, contact Information Unlimited or build your own using Brent Turner's Tesla Coil Book or Doug Hall's Sarchion Tesla Coil Cookbook as a guide.

Van de Graaf Generators

The Van de Graaf electrostatic generator is also capable of generating sparks, although the operating theory is much simpler. Any two insulators, when rubbed together, will create an electrostatic charge. The weaker insulator will lose electrons to the more powerful insulator, causing the former to become negatively charged, and the latter to become positively charged. Using this principle, we construct an belt assembly with a copper brush at either end. As the belt turns, the friction between itself and the pulleys will both to become electrically charged. As the belt continues to turn, it carries this charge up to the upper brush assembly, which attracts the charged particles. This will cause the toroid at the top to accumulate a net positive charge. Once this charge has been built up sufficiently, a spark will be emitted from the accumulator into the atmosphere to dispel the charge that has built up. This is the exact process by which lightning is created in the atmosphere.

The Tesla Coil Builder's Association

The Tesla Coil Builder's Association is a society of professional and amateur Tesla Coil builders and experimenters. We put out a quarterly newsletter approximately twenty pages in length and packed with current news of ongoing high-voltage research and tips on engineering Tesla Coils to work properly.
Some of the information is quite technical, but much of it is invaluable for the amateur scientist. The dues are only $25 per year. They may be contacted at the address below.

Mr. Harry Goldman  
c/o Tesla Coil Builders Association  
3 Amy Lane  
Queensbury, NY 12804-9432

Science Links

- **International NLP Platform** Increase your learning ability with Neuro-Linguistic Programming.
- **Arthur Cayley** For Linear Algebra and Non-Euclidean Geometry enthusiasts.
- **Platonic Realms** An introduction to Transfinite Set Theory.
- **Science and Math** External science links: mathophobics beware!
- **Tensors** Not for the squeamish.
- **PI** Everything you ever wanted to know about everyone's favourite transcendental number.
- **Sundials on the Internet** A hobby of mine.
- **Glaciers** Be prepared for the next ice age.
- **Rudy Rucker's Home Page** Explore hyperspace with one of the finest expositors of higher mathematics.
- **Edmund Scientific** Scientific and Engineering Supplies.
- **Fractory** If you want to learn about Fractals and Non-linear dynamics (Chaos Theory).
- **The Planetary Society** Brainchild of the late, great Carl Sagan.
- **Cryptography** Hill Ciphers and secret codes.
- **Dinosaurs!** For those of us who never grew up.
- **Electrostatics Society of America** Visit the Friendly Society!
- **Perspectives on Plague** Information on the scourge of the Middle Ages.

Weird Science Links

- **Static Generators** Learn to make homemade lightning.
- **Brent Turner's Tesla Page** One of the more impressive Tesla Coil sites.
- **Loch Ness Monster** If giant squids are real, why not Nessie?
- **Solaris** Seeking nature's secrets.

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**WARNING**

A Tesla Coil can quite literally generate millions of volts of electricity. They can be LETHAL if not constructed properly and operated with care. Do not attempt to build one of these fascinating...
devices unless you have a thorough understanding of the electrical principles and the potential dangers involved.