INFORMATION FOR BUILDING CAPACITORS:			Comments
Material	Dielectric strength "K"	Puncture Voltage per Mil (0.001 inch)	
Miscellaneous			
Vacuum	1.0		
Paper, bond	3.0	200	
Paper, Royal Grey	3.0	200	
Paper, telephone, treated	2.5 - 4	200 - 250	*
Paper, Parafin Coated	2 -3.5		
Paper, Kraft	2.2		
Oil, Castor	4.67		
Oil, Mineral, Squibb	2.7	200	
Oil, Mineral	2.2		
Oil, Transformer	2.1 - 2.5	75	*
Rubber	3.0		
Rubber, Hard	3.0	160 - 500	*
Rubber, Vulcanized	3.2 - 3.9		1
Fibre	5.0 - 7.5	150 - 180	
Fibre, Red	5.0		
Mica	4.5 - 8.0	3800 - 5600	
Mica, Ruby	5.4	3800 - 5600	
Quartz	3.8 - 5.0	1000	
Quartz (Fused)	4.2	150 - 200	*
Shellac	2.5 - 4.0	200 - 400	
Spar Varnish	4.8 - 5.5		
Steatite, low loss	5.8	150 - 315	
Steatites (Magnesium silicate,etc)	5.5 - 7.5	200 - 300	
Cambric (Varnished)	4.0		2
Alsimag 196	5.7		
Gutta Percha	4.0		3
Amber	3.0 - 7.0		4
Resin	2.48 - 2.57		
Enamel	5.1	450	
Mycalex	7.4	250	
Silicone RTV	3.6	550	
Wood	2.0 - 5.2		
Wax (Parafin)	2.1 - 2.5	250 - 450	*
Beeswax	2.9 - 3.0		
Slate	7.0		5
Barium titanate(25 C)	1200		
Bariam titanate	6000		
Titanium dioxide	125		
Cellulose acetate	3.3 - 3.9	250 - 600	
Casein, Moulded	6.4		6
Polytetraflourethylene	2.0		A
Aluminum oxide	8.7		
Tantalum pentoxide	22		
Glass			
Glass	4.8 - 10	300	
Plate Glass	6.8 - 8.4		

Pyrex Glass	4.8 - 10	335	
Window Glass	7.6 - 7.8	200 - 250	
Ceramics			
Cordierite ceramics	5.0 - 5.5	100	
Magnesium titanate ceramic	12 - 18	150	
Porcelain	5.1 - 7.5	40 - 280	
Titanium dioxide ceramic	70 - 90	100	
Titanium-zirconium dioxide ceramic	40 - 60	150	
Plastics			
Bakelite	4.4 - 5.8	300	
Bakelite, Mica filled	4.7	325 - 375	
Epoxy Circuit Board	5.2	700	
Formica	4.6 - 4.9	450	7
Nylon (lowest values of 3 types)	3.2	407	
PVC (rigid type)	2.95	725	
Plexiglass	2.8	450 - 990	
Polyethylene	2.2 - 2.3	450 - 1200	
Polycarbonate (Lexan)	2.96	400	
Polyethylene Terphthalate (Mylar)	3.0 - 3.1	7500	
Polystyrene	2.5 - 2.6	500 - 700	
Teflon	2.1	1000 - 2000	
Gases			
Air (dry air at 1 atm)	1.0006	30 - 70	
Air (20 atm, 19 deg. C)	1.0108	500	*
Carbon dioxide (1 atm, 0 deg. C)	1.000985	36	*
Carbon dioxide (20 atm, 15 deg. C)	1.020		
Hydrogen (1 atm,0 deg.C)	1.000264	26.1	*
Liquids			
Amonia (liquid)	22		
Benzene	2.28		
Carbon tetrachloride	2.24		8
Chlorinated diphenyl	6.5		9
Ethyl Alcohol (O C)	28.4		
Ethyl alchohol (20 deg.C)	25.8		
Methyl alchohol	33.1		
Water (distilled)	80 - 81		

LEGEND:

* = Measured in Kilovolts per centimeter. All others are Volts per mil (.001 inch) unless otherwise stated.
1 = Vulcanized means it has been melted, or heated in some way.
2 = Cambric is a finely woven white linen or cotton fabric.
3 = Gutta Percha is a rubbery substance made from the latex of tropical trees and is used in insulation, waterproofing, and dentist use it in thin sheets sometimes when working on teeth.
4 = Amber is a hard, translucent, yellow, orange, or brownish yellow fossil resin, used in making ornamental objects like jewelry.
5 = Slate is a fine grained metamorphic rock that splits into thin smooth faced layers. Black Boards for writting are made of this. Also used as roofing material in some areas.
6 = Casein is a white, tasteless, oderless milk and cheese protein used in the manufacture of plastics, glues, paints, and food. The word 'moulded' means it has been shaped by a mold.
7 = Formica is a trademark for any of various high-pressure laminated plastic sheets of melamine and phenolic materials used for chemical and heat-resistant surfaces.
8 = Carbon tetrachloride is a very toxic substance. It has also been shown to cause cancer in lab animals. It is banned in most labs. It is a liquid that was used as a strong solvent.

9 = Chlorinated diphenyl is a liquid dielectric that is used to impregnate Kraft paper in small A.C. capacitors. This is a PCB and may cause cancer, handle carefully.
A = Polytetraflourethylene films retain good properties even at 200 degrees Celsius (200 C).

atm = atmospheres (pressure of air at sea level is 1 atm).
deg.C = degrees Celsius.

Warning - Some liquids and gases listed may be explosive under the right conditions. Many solids can catch fire and burn. Use CAUTION and GOOD COMMON SENSE.

Note: Some books gave very different values for each substance so I have given you the highest and lowest values reported. The values will depend on the purity of the substance your using. If you know your substance is very pure then use the higher value reported. If you know your substance is contaminated or of poor quality then use the lower values reported. If you have unknown purity then use the average of the values given.

==========

EXPLAINATION OF EQUATIONS:

Here are some real handy equations. They are very simple and easy to use.

x = Multiply by
/ = divide by (may also use line seperating terms above and below line as in standard mathematics).
( ) = Terms in parentheses should be calculated first as in standard algebraic equations.
pi = 3.141592654. The circumferance of a circle divided by it's diameter will always give you this constant.

Z^2 = means the term "Z" multiplied by itself one time,"Z x Z".

Note: In some cases I do not use the symbol "x" but instead simply put the terms close together, example: "LC" instead of "L x C". This is standard for algebraic equations and means "multiply by".

==========

MATH FOR TESLA COILS

1. Determine your neon sign transformer (or other transformer's) Impedence:

$$Z = \frac{E}{I}$$

Z = Impedence
E = volts
I = current in Amps
Note: divide milliamps by 1000 to get Amps. 30 milliamps = .030 Amps.

The Impedence of the primary capacitor should match the Impedence of the transformer at 60 Hz (60 Hz is the AC cycle rate of common household wall sockets, at least in America).

2. To match Impedence and determine capacitor value:

$$C = \frac{1}{2 \times \pi \times Z \times .00006}$$

C = capacitance in microfarads needed for primary capacitor.
Z = Impedence from equation one (Transformer Impedence)
pi = 3.141592654
Note: The .00006 is the 60 Hz AC, if you live outside the US then substitute your cycle rate.

Next you need to find the Reactance of the primary capacitor at the frequency you have choosen. Many times the frequency is decided by the length of wire used on the secondary coil. See below for equations that determine frequency by length of wire used on secondary.
When we find the Reactance , we can then find your needed Inductance for the Primary coil.

3. To determine Reactance of capacitor:

$$X(C) = \frac{1}{2 \times pi \times C \times F}$$

X(C) = capacitor Reactance
C = Capacitor value in microfarads, from equation 2)
F = Frequency in Mhz (megahertz)
pi = 3.141592654
Note: To convert kilohertz to megahertz simply divide by 1000.
190 Khz = .190 Mhz

4. To determine the Inductance needed for Primary coil:

Set X(L) = X(C)

$$L = \frac{X(L)}{2 \times pi \times F}$$

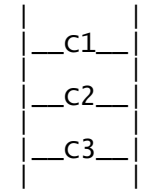
L = Inductance in microhenries needed for Primary Coil.
To get millihenries divide the answer by 1000.
X(L) = Reactance from equation 3, same as X(C).
F = frequency in Megahertz. Divide Khz by 1000 to get Mhz.
pi = 3.141592654

Now you know the values for your capacitor and primary coil. These values will give you the best ringing for your circuit (ie. more bang for your buck)! Use the equations below to finnish the project.

Note: Many people don't go to the trouble to work these equations out. They simply slap the parts together and then try to tune. If you work the equations out first you will save lots of time in tuning, you will at least be in the right ball park! Also, just because you worked it out on paper that doesn't mean it will work the first time you plug it in. Trial and error is a large part of the Tesla Coil hobby!

==========

CAPACITORS IN PARALLEL:



Capacitance = C1 + C2 + C3, etc...

Maximum voltage rating will be equal to the voltage rating of the lowest voltage capacitor of the group.

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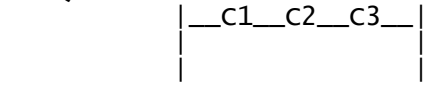
CAPACITORS IN SERIES:

TESLA coil EQUATIONs and data



$$\text{Capacitance} = 1 \Big/ \frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}, \text{ etc...}$$

The total capacitance of several capacitors in series will always be LESS than that of the smallest capacitor.

Total voltage rating increases with number of capacitors in series. Simply add the voltage ratings together.
When capacitors are placed in series to increase voltage rating they should have the same capacitance and voltage rating else voltages will divide unevenly, most likely causing failure.

==========

EQUATION 1: PLATE TYPE CAPACITORS

Capacitance (in picofarads) = (0.224 KA / d) (N-1)

$$C = \frac{0.224 \times \text{Dielectric Strength} \times \text{Area of plate}}{\text{distance between plates in inches}} \times (\text{Number of plates} - 1)$$

Note: to convert picofarads to microfarads divide by 1000000.

==========

EQUATION 2: LEYDEN JAR or SALT WATER TYPE CAPACITORS (jar/bottle type)

$$C = \frac{.0884\ k\ (\pi\ r^2 + 2\ \pi\ r\ l)}{1{,}000{,}000\ t}$$

C = Capacitance in microfarads
k = dielectric strength
r = jar radius in centimeters
l = height of the jar portion used (in centimeters)
t = thickness of the jar wall in centimeters
pi = 3.141592654

$r^2 = r \times r$ (radius squared)

==========

EQUATION 3: FREQUENCY OF A CIRCUIT

$$f = \frac{1}{2\ \pi\ \sqrt{L\ C}}$$

f = frequency in cycles per second
L = circuit inductance in henries
C = circuit capacitance in farads
pi = 3.141592654

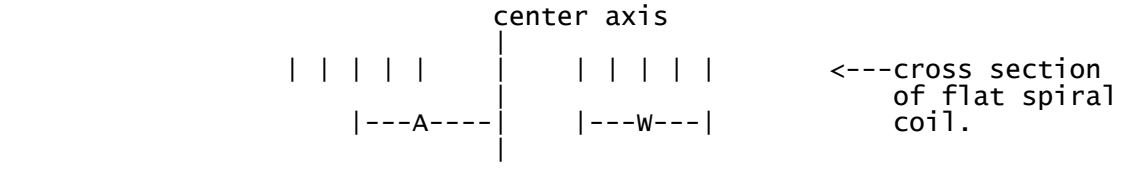
The symbol " $\sqrt{\ }$ " means the square root
For a result "f" in Khz: enter "C" in microfarads, "L" in microhenries and multiply result by 1000.

==========

EQUATION 4: INDUCTANCE OF A FLAT PANCAKE COIL

Picture a 1 inch flat ribbon that is about 30 feet long. Now, roll that ribbon into a spiral that has all its sides about 1/2 inch apart.

Most common material is Aluminum Roof Flashing. Use plastic bolts to hold sections of strips together if you have short pieces of ribbon. This makes a good mechanical connection (you can't solder aluminum).



$$L = \frac{a^2 \times n^2}{8a + 11w}$$

L = inductance in microhenries.
a = average radius in inches as measured from the central axis to the middle of the winding.
n = number of turns in the winding.
w = width of the coil in inches.
Note: Make sure you measure "a" from center axis - the very middle of your secondary sitting inside of your primary.

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EQUATION 5: NUMBER OF TURNS FOR A HELICAL PRIMARY

$$N = \sqrt{\frac{L\ [(9 \times R) + (10 \times H)]}{R^2}}$$

N = Number of turns needed.
L = inductance in microhenries desired.
R = radius (inches).
H = height (inches).

The symbol " $\sqrt{\ }$ " means the square root, in this case of whole equation.

==========

EQUATION 6: LENGTH OF WIRE NEEDED FOR DESIRED FREQUENCY OF COIL

$$L = \frac{300{,}000}{f} / 4 \times (3 / .9144)$$

f = frequency, in Khz, that is desired for coil.
L = length of wire needed, in feet, for desired frequency.
/ = divided by.

Note - 300,000 is the speed of light in Kilometers per second. the term "3/.9144" is a conversion factor to turn meters to feet. You don't have to understand this. Just thought I would tell those who were wondering.

==========

EQUATION 7: FRQUENCY OF COIL

$$f = \frac{300{,}000}{T \times W \times \pi \times (.9144 / 36) \times 4}$$

TESLA coil EQUATIONs and data

f = frequency of coil in Khz
T = number of turns on coil
W = width of the coil in inches
pi = 3.141592654

==========

EQUATION 8: CAPACITANCE OF A SPHERE IN SPACE

$$C = \frac{R}{9 \times 10^{9}}$$

C = capacitance in Farads
R = radius in meters

$9 \times 10^{9} = 9{,}000{,}000{,}000$

Note: To convert Farads to microfarads simply multiply by 10^{6} or in other words by 1,000,000.

==========

EQUATION 9: CAPACITANCE OF A SPHERE SUSPENDED IN A DIELECTRIC

$$C = \frac{K \times R}{9 \times 10^{9}}$$

C = capacitance in Farads
R = radius in meters
K = dielectric constant

Note: To convert Farads to microfarads simply multiply by 10^{6} or in other words by 1,000,000.

==========

EQUATION 10: CAPACITANCE OF A TOROID

$$C = (1 + (0.2781 - d2/d1)) \times 2.8 \times \sqrt{\frac{2\pi (d1-d2)(d2/2)^2}{4\pi}}$$

C = capacitance in picofarads (+- 5%)
d1 = outside diameter of toroid in inches
d2 = diameter of cross section (cord) of toroid in inches

Equation courtesy of Bert Pool

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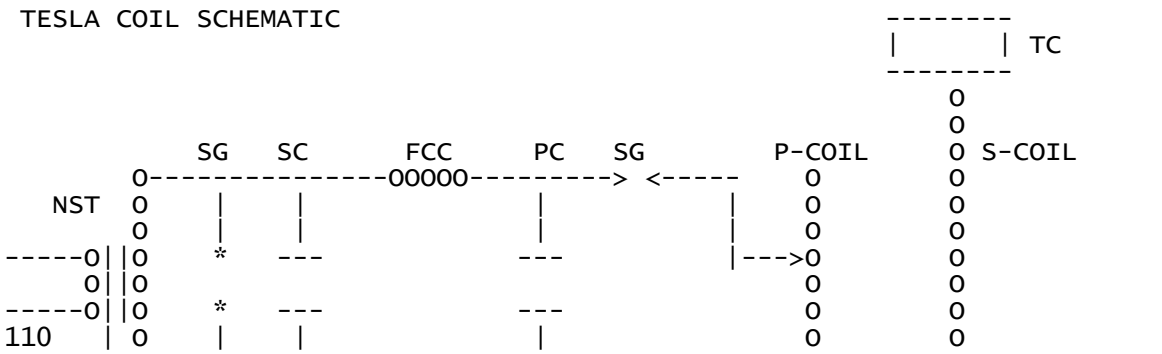
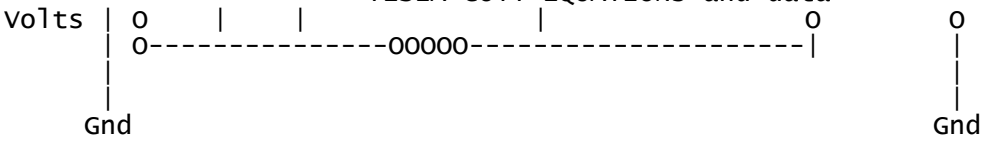
TESLA COIL SCHEMATIC



TESLA coil EQUATIONs and data



NST = Neon Sign Transformer, 110 volts primary, 15,000 volt secondary at 30-60 miliamps.
SG = Safty Gap. A spark gap to insure your transformer doesn't get fried.
SC = Safty Capacitor. 300-500 picofarad rated at 50 KV.
FCC = Ferrite Core Choke. This prevents real high voltages from coming back towards your transformer. It also seperates the capacitors.
PC = Primary Capacitor. Normally .01-.02 microfarads rated 50 KV.
SG = Spark Gap.
P-COIL = Primary Coil.
S-Coil = Secondary Coil.
TC = Terminal Capacitor. The big ball or coffee can on top.
Gnd = Ground.

Note: This is one of several possible schematics. It's just the one I happen to use.

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WARNING:

Only people who are experienced with High Voltage devices should attempt to build Tesla Coils. They can be very deadly if you don't know what your doing. Remember, if they find you on the floor turning blue and frothing at the mouth - THERE IS NO SECOND CHANCE!

A FEW Safety Tips:

1. Don't ever touch the machine when it is plugged in.
2. Use a safe methode to short out the primary capacitor after the machine has been run.

3. Don't ever get close to a running Tesla coil, the Primary can shoot hot white arcs at you that will kill you instantly!
4. Always have a small fire extinguisher close by.
5. Always use kickback preventer circuits so you don't send 15,000 volts back through the wall!
6. Pets, children, and irresponsible adults should be kept away from your machine intirely!!!
7. Read many books on Tesla Coils and other High Voltage devices and learn as much as you can about High Voltage Safety!

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Special thanks to Mr. Pool who caught some glaring errors in the second draft and who contributed with an equation of his own.

I wrote this file because I felt there was a need for some real information for those of us who actually build Tesla Coils, as opposed to those who just talk of building them (Grin). I will be adding to this file from time to time, so watch for updates. I hope it helps you out!

P.S. Let us not forget the words of Tesla, "Let the future tell the truth and evaluate each one according to his work and accomplishments. The present is theirs, the future, for which I really worked, is mine".

========== END OF FILE ==========