Formulas for Tesla Coils

v. 3.3

Ohm's Laws

$$V = I \times R = P / I = SQRT(P \times R)$$
$$I = V / R = SQRT(P / R) = P / V$$
$$R = V / I = P / (I^2) = V^2 / P$$
$$P = I \times V = I^2 \times R = V^2 / R$$

Where:
V = Voltage in Volts
I = Current in Amps
R = Resistance in Ohms
P = Power in Watts

Resonate Frequency

$$Fo = 1 / (2 \times pi \times SQRT(L \times C))$$

Where:
Fo = Resonant frequency in Hertz
pi = 3.14159...
SQRT = Square root function
L = Inductance in Henries
C = Capacitance in Farads

Reactance

$$Xl = 2 \times pi \times F \times L$$

$$Xc = 1 / (2 \times pi \times F \times C)$$

Where:
Xl = Inductive reactance in Ohms
Xc = Capacitive reactance in Ohms
pi = 3.14159...

F = Frequency in Hertz
L = Inductance in Henries
C = Capacitance in Farads

RMS

$$V_{peak} = V_{rms} \times SQRT(2)$$ For sine waves only

Where:
Vpeak = Peak voltage in volts
Vrms = RMS voltage in Volts RMS
SQRT = Square root function

Energy

$$E = 1/2 \times C \times V^2 = 1/2 \times L \times I^2$$

Where:
E = Energy in Joules
L = Inductance in Henries
C = Capacitance in Farads
V = Voltage in Volts
I = Current in Amps

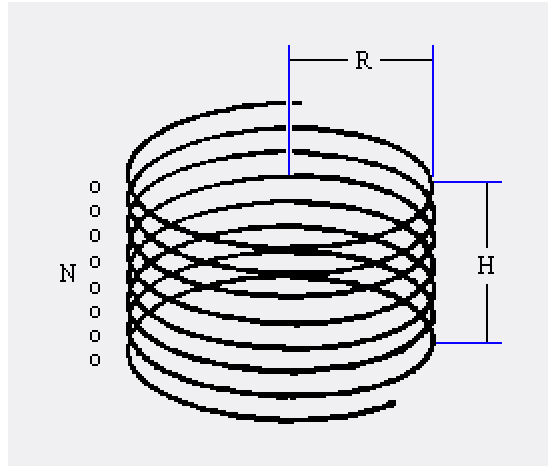
Power

$$P = E / t = E \times BPS$$

Where:
P = Power in Watts
E = Energy in Joules
t = Time in Seconds
BPS = The break rate (120 or 100 BPS)

Helical Coil

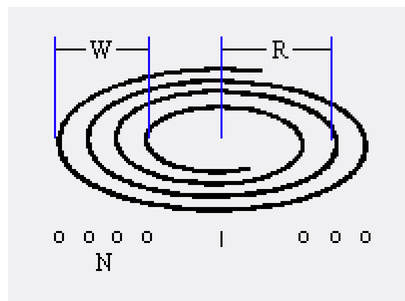
Lh = (N x R)^2 / (9 x R + 10 x H)



Where:
Lh = Inductance in micro-Heneries
N = number of turns
R = Radius in inches
H = Height in inches

Flat spiral

Lf = (N x R)^2 / (8 x R + 11 x W)

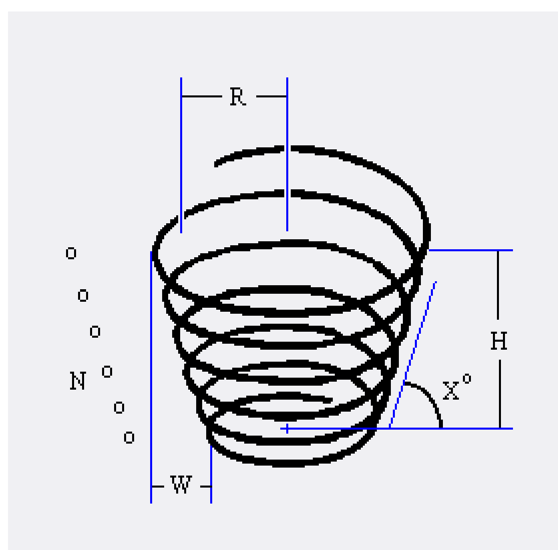


Where:
Lf = Inductance in micro-Heneries
N = number of turns
R = Average radius in inches
W = Width in inches

Conical Primary

L1 = (N x R)^2 / (9 x R + 10 x H)
L2 = (N x R)^2 / (8 x R + 11 x W)

Lc = SQRT(((L1 x sin(x))^2 + (L2 x cos(x))^2) / (sin(x)+cos(x)))



Where:
Lc = Inductance in Microhenries
L1 = helix factor
L2 = spiral factor

SQRT = Square root function
N = number of turns
R = average radius of coil in inches
H = effective height of the coil in inches
W = effective width of the coil in inches
X = rise angle of the coil in degrees

Resonant Primary Capacitance

Cres = I / (2 x pi x Fl x V)

Where:
Cres = Resonant capacitor value in Farads
I = NST rate current in Amps
pi = 3.14159...
Fl = AC line frequency in Hertz
V = NST rated voltage in Volts

Static Gap Primary LTR Capacitance

Cltr = I / (4 x Fl x V)

Where:
Cltr = The LTR cap size in Farads
I = NST rate current in Amps
Fl = AC line frequency in Hertz
V = NST rated voltage in Volts

Sync Gap Primary LTR Capacitance

Cltr = 0.83 x I / (BPS x V)

Where:
Cltr = The LTR cap size in Farads
I = The NST rated current in Amps
V = The NST rated voltage in Volts
BPS = The break rate (120 or 100 BPS)

Top Voltage

Vt = Vf x SQRT(Ls / (2 x Lp))

Where:
Vt = Peak top voltage in Volts

Vf = gap firing voltage in Volts
SQRT = Square root function
Ls = Secondary inductance in Heneries
Lp = Primary inductance in Heneries

PFC Capacitors

$$Cpfc = Vo \times Io / (2 \times pi \times Fl \times Vi^2)$$

Where:
Cpfc = Power factor correction capacitance in Farads
Vo = NST output voltage in Volts
Io = NST output current in Amps
pi = 3.14159...
Fl = AC line freqeuncy in Hertz
Vi = NST input voltage in Volts

Power-BPS

$$P = BPS \times 1/2 \times Cp \times Vf^2$$

Where:
P = Coil power in Watts
BPS = Breaks per second
Cp = Primary capacitance in Farads
Vf = Gap firing Voltage

Transformers

$$Vi \times Ii = Vo \times Io$$

Where:
Vi = Input voltage in Volts
Ii = Input current in Amps
Vo = Output voltage in Volts
Io = Output current in Amps

Primary Peak Current

IPpeak = Vf x SQRT(Cp / Lp)

Where:
IPpeak = Peak primary loop current Amps
Vf = Firing Voltage in Volts
SQRT = Square root function
Lp = Primary inductance in Heneries
Cp = Primary capacitance in Farads

Surge Impedance

Zs = SQRT(Lp / Cp)

Where:
Zs = Surge impedance in Ohms
SQRT = Square root function
Lp = Primary inductance in Heneries
Cp = Primary capacitance in Farads

Secondary "Q" Factor

Q = 2 x pi x Fo x Ls / Rac = SQRT(Ls / Cs) / Rac

Where:
Q = "Q" factor
Fo = Fundamental frequency in Hertz
Ls = Secondary inductance in Heneries
Cs = Secondary capacitance in Farads
Rac = Secondary "AC" resitance in Ohms
SQRT = Square root function

Freau Spark Length Formula

$$L = 1.7 \times \text{SQRT}(P)$$

L = Maximum spark length in Inches
SQRT = Square root function
P = Wallplug Watts

Appendix

Wire Chart

Guage No. B. & S.	Diam in Mils[1]	Circular Mil Area	Turns Per Linear Inch[2]	Feet per Lb.		Ohms per 1000ft. 250 C.	Current Carrying Capacity @ 1500 C.M. per Amp[3]	Diameter in mm
			Enamel	Bare	Enamel			
1	289.3	82690	-	3.95	-	0.13	55.7	7.35
2	257.6	66370	-	4.98	-	0.16	44.1	6.54
3	229.4	52640	-	6.27	-	0.2	35.0	5.83
4	204.3	41740	-	7.91	-	0.25	27.7	5.19
5	181.9	33100	-	9.980	-	0.32	22.0	4.62
6	162.0	26250	-	12.58	-	0.4	17.5	4.12
7	144.3	20820	-	15.87	-	0.5080	13.8	3.665
8	128.5	16510	7.6	20.01	19.6	0.64	11.0	3.264
9	114.4	13090	8.6	25.23	25	0.81	8.7	2.906
10	101.90	10380	9.6	31.82	31.5	1.02	6.9	2.588
11	90.74	8234	10.7	40.12	39	1.28	5.5	2.305
12	80.81	6530	12.0	50.59	49.9	1.62	4.4	2.053
13	71.96	5178	13.5	63.8	62.9	2.04	3.5	1.828
14	64.08	4107	15.0	80.44	79.94	2.58	2.7	1.628
15	57.07	3257	16.8	101.4	100.4	3.25	2.2	1.450
16	50.82	2583	18.9	127.9	126.8	4.09	1.7	1.291
17	45.26	2048	21.2	161.3	159.4	5.16	1.3	1.150
18	40.30	1624	23.6	203.4	201.1	6.51	1.1	1.024
19	35.89	1288	26.4	256.5	253.2	8.21	0.86	0.91
20	31.96	1022	29.4	323.4	318.4	10.35	0.68	0.81
21	28.46	810.1	33.1	407.8	400.6	13.05	0.54	0.72
22	25.35	642.4	37.0	514.2	507.1	16.46	0.43	0.64
23	22.57	509.5	41.3	648.4	633.7	20.76	0.34	0.57
24	20.10	404.0	46.3	817.7	804.5	26.17	0.27	0.51
25	17.90	320.4	51.7	1031	1010	33.0	0.21	0.45
26	15.94	254.1	58.0	1300	1279	41.62	0.17	0.4
27	14.20	201.5	64.9	1639	1600	52.48	0.13	0.36
28	12.64	159.8	72.7	2067	2028	66.17	0.11	0.32
29	11.26	126.7	81.6	2607	2513	83.44	0.08	0.29
30	10.03	100.5	90.5	3287	3208	105.2	0.07	0.25
31	8.928	79.70	101	4170	4052	132.7	0.05	0.23
32	7.950	63.21	113	5160	4995	167.3	0.04	0.2
33	7.080	50.13	127	6550	6337	211.0	0.03	0.18
34	6.305	29.75	143	8320	8055	266.0	0.03	0.16
35	5.615	31.52	158	10500	10250	335.0	0.02	0.14
36	5.000	25.00	175	13200	12800	423.0	0.02	0.13
37	4.453	19.83	198	16300	15750	533.4	0.01	0.11
38	3.965	15.72	224	20600	20020	672.6	0.01	0.1
39	3.531	12.47	284	27000	26240	848.1	0.01	0.09
40	3.145	9.88	282	34400	33330	1069	0.01	0.08

Capacitor Chart

MMC Capacitor Chart

Capacitor Value (uF)

NST Type		60Hz				50Hz		
		Resonant	Static Gap LTR	Sync Gap LTR		Resonant	Static Gap LTR	Sync Gap LTR
7.5/30		0.0106	0.0159	0.0277		0.0127	0.0191	0.0332
7.5/60		0.0212	0.0318	0.0533		0.0256	0.0382	0.0664
7.5/90		0.0318	0.0477	0.0830		0.0382	0.0573	0.0996
7.5/120		0.0424	0.0637	0.1107		0.0509	0.0764	0.1328
9/30		0.0088	0.0133	0.0231		0.0106	0.0159	0.0277
9/60		0.0177	0.0265	0.0461		0.0212	0.0318	0.0553
9/90		0.0265	0.0398	0.0692		0.0318	0.0477	0.0830
9/120		0.0354	0.0531	0.0922		0.0424	0.0637	0.1107
10/23		0.0061	0.0092	0.0159		0.0073	0.0110	0.0191
12/30		0.0066	0.0099	0.0173		0.0080	0.0119	0.0208
12/60		0.0133	0.0199	0.0346		0.0159	0.0239	0.0415
12/90		0.0199	0.0298	0.0519		0.0239	0.0358	0.0623
12/120		0.0265	0.0398	0.0692		0.0318	0.0477	0.0830
15/30		0.0053	0.0080	0.0138		0.0064	0.0096	0.0166
15/60		0.0106	0.0159	0.0277		0.0127	0.0191	0.0332
15/90		0.0159	0.0239	0.0415		0.0191	0.0286	0.0496
15/120		0.0212	0.0318	0.0553		0.0255	0.0382	0.0664

Warning!! Never use "Resonant" cap values anymore!!! Use "LTR" instead to keep from damaging NSTs!!!

Metric Prefixes

Prefix	Symbol	Decimal	Exponential
pico	p	0.000000000001	1e-12
nano	n	0.000000001	1e-9
micro	u	0.000001	1e-6
milli	m	0.001	1e-3
kilo	k	1000.0	1e+3
Mega	M	1,000,000	1e+6
Giga	G	1,000,000,000	1e+9

Cornell Dubilier 942 Series polypropylene Metal Foil Caps (Recommended)

Part Number	Cap. µF	D inches (mm)	L inches (mm)	d inches (mm)	Typical ESR milli0hm$	Typical ESL nH	dV/dt V/µs	I Peak A	IRMS A
942C20S1K	0.01	0.472 (12.0)	1.339 (34.0)	0.040 (1.0)	50	20	5137	51	2.2
942C20S15K	0.015	0.571 (14.5)	1.339 (34.0)	0.040 (1.0)	40	21	5137	77	2.8
942C20S22K	0.022	0.650 (16.5)	1.339 (34.0)	0.040 (1.0)	20	22	5137	113	4.2
942C20S33K	0.033	0.768 (19.5)	1.339 (34.0)	0.040 (1.0)	12	23	5137	170	6.0
942C20S47K	0.047	0.709 (18.0)	1.811 (46.0)	0.040 (1.0)	10	28	2879	135	7.1
942C20S68K	0.068	0.807 (20.5)	1.811 (46.0)	0.040 (1.0)	6	29	2879	196	9.9
942C20P1K	0.1	0.965 (24.5)	1.811 (46.0)	0.047 (1.2)	5	30	2879	288	12.1
942C20P15K	0.15	1.161 (29.5)	1.811 (46.0)	0.047 (1.2)	5	32	2879	432	13.5

Metal Foil caps are normally the best type to use for MMCs.

Cornell Dubilier 940 Series polypropylene Metal Film Caps

Part Number	Cap. µF	Vdc	Vac	D inches (mm)	L inches (mm)	d inches (mm)	Typical ESR milli0hms	Typical ESL nH	dV/dt V/µs	I Peak A	IRMS A
940C20S22K	0.022	2000	630	0.453 (11.5)	1.339 (34.0)	0.040 (1.0)	35	6	1712	38	2.6
940C20S33K	0.033	2000	630	0.531 (13.5)	1.339 (34.0)	0.040 (1.0)	20	21	1712	57	3.8
940C20S47K	0.047	2000	630	0.591 (15.0)	1.339 (34.0)	0.040 (1.0)	12	22	1712	80	5.2
940C20S68K	0.068	2000	630	0.689 (17.5)	1.339 (34.0)	0.040 (1.0)	8	23	1712	116	6.9
940C20P1K	0.1	2000	630	0.827 (21.0)	1.339 (34.0)	0.040 (1.0)	7	24	1712	171	8.3
940C20P15K	0.15	2000	630	0.768 (19.5)	1.811 (46.0)	0.040 (1.0)	7	29	960	144	8.9
940C20P22K	0.22	2000	630	0.866 (22.0)	1.811 (46.0)	0.040 (1.0)	8	30	960	211	9.0
940C20P33K	0.33	2000	630	1.063 (27.0)	1.811 (46.0)	0.047 (1.2)	8	32	960	317	10.1
940C20P47K	0.47	2000	630	1.260 (32.0)	1.811 (46.0)	0.047 (1.2)	6	34	960	451	13.0
940C20P56K	0.56	2000	630	1.220 (31.0)	2.126 (54.0)	0.047 (1.2)	7	37	754	422	12.6
940C20P68K	0.68	2000	630	1.339 (34.0)	2.126 (54.0)	0.047 (1.2)	6	39	754	513	14.3
940C20W1K	1	2000	630	1.614 (41.0)	2.126 (54.0)	0.047 (1.2)	5	42	754	754	17.7

Metal Film caps are normally not recommended for MMCs unless the primary peak current is well within the capacitor's ability.

McMaster Carr's Polycarbonate tubing cut to length:

ID	OD	Part#	Per Foot
1"	1-1/4"	8585K15	$4.58
1-1/4"	1-1/2"	8585K16	5.32
1-3/8"	1-1/2"	8585K43	3.24
1-1/2"	1-3/4"	8585K17	6.51
1-3/4"	2"	8585K18	7.00
2"	2-1/4"	8585K46	8.19
2-1/4"	2-1/2"	8585K19	8.73
2-1/2"	2-3/4"	8585K34	10.01
2-3/4"	3"	8585K21	10.70
3-1/4"	3-1/2"	8585K33	13.25
3-3/4"	4"	8585K22	17.06
4-3/4"	5"	8585K45	24.38
5-3/4"	6"	8585K23	29.92
7-3/4"	8"	8585K48	33.36

Magnet Wire

Great for use in motors, transformers, relays, and other high-speed winding applications. Wire is made of solid copper and has a clear enamel coating that gives it good resistance to moisture and heat, so it can be used in hermetic motors. Maximum temperature is 392° F. Meets NEMA 1000 MW-73 and MW-35. UL recognized.

Wire OD: 36 AWG is 0.006", 34 AWG is 0.008", 32 AWG is 0.010", 30 AWG is 0.012", 28 AWG is 0.014", 26 AWG is 0.018", 24 AWG is 0.022", 22 AWG is 0.028", 20 AWG is 0.035", and 18 AWG is 0.043".

AWG	Spool Lg., ft.		Per Spool
36	12,300	7588K85	$20.61
36	24,600	7588K84	41.20
34	7,800	7588K87	19.36
34	15,600	7588K86	41.98
32	4,350	7588K89	18.51
32	8,700	7588K88	35.15
30	3,000	7588K71	14.88
30	6,000	7588K51	28.27
28	2,000	7588K73	13.05
28	4,000	7588K53	24.78

AWG	Spool Lg., ft.		Per Spool
26	1,500	7588K75	$11.54
26	3,000	7588K55	22.09
24	792	7588K77	11.19
24	2,000	7588K57	22.11
22	750	7588K79	12.75
22	1,500	7588K59	25.49
20	500	7588K81	16.73
20	900	7588K61	25.08
18	300	7588K83	12.30
18	600	7588K63	24.59