



REPEATABLE CONDUIT BENDING

Cliffhanger Tools

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<http://www.cliffhangertools.com>

Purpose for this Training

- Repeatable Bending
- Review theory
- Learn how to gather the facts
- Understanding the Cliffhanger Tools
Conduit Bending Program
- Practice bending conduit
- Talk about the art of conduit bending

The Theory of conduit bending

- There are a number of good conduit bending books available
 - JATC curriculum
 - Cox conduit bending
 - Many others you can find on the web
- We'll discuss Pythagorean theorem
- We'll discuss Trig Functions - Sally and Oscar
- Formulas for circumference of a circle

The Theory of conduit bending

If we let c be the length of the hypotenuse and a and b be the lengths of the other two sides, the theorem can be expressed as the equation:

$$a^2 + b^2 = c^2$$

or, solved for c :

$$c = \sqrt{a^2 + b^2}$$

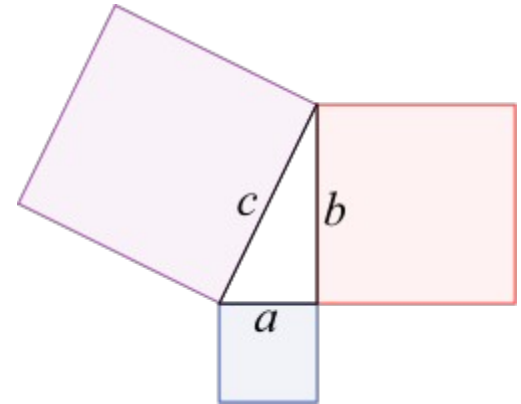
If c is already given, and the length of one of the legs must be found, the following equations can be used (The following equations are simply the converse of the original equation):

$$c^2 - a^2 = b^2$$

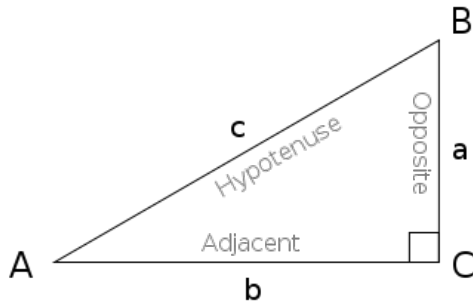
Or

$$c^2 - b^2 = a^2$$

This equation provides a simple relation among the three sides of a right triangle so that if the lengths of any two sides are known, the length of the third side can be found. A generalization of this theorem is the law of cosines, which allows the computation of the length of the third side of any triangle, given the lengths of two sides and the size of the angle between them. If the angle between the sides is a right angle it reduces to the Pythagorean theorem.



The Theory of conduit bending



$$\sin A = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{a}{c}$$

$$\cos A = \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{b}{c}$$

$$\tan A = \frac{\text{opposite}}{\text{adjacent}} = \frac{a}{b} = \frac{\sin A}{\cos A}$$

$$\cot A = \frac{\text{adjacent}}{\text{opposite}} = \frac{b}{a}$$

$$\sec A = \frac{\text{hypotenuse}}{\text{adjacent}} = \frac{c}{b}$$

$$\csc A = \frac{\text{hypotenuse}}{\text{opposite}} = \frac{c}{a}$$

The *Sine*, or Sin of the angle \emptyset is the length of the side Opposite the angle \emptyset divided by the length of the Hypotenuse.

The *Cosine*, or Cos of the angle \emptyset is the length of the side Adjacent to the angle \emptyset divided by the length of the Hypotenuse.

The *Tangent*, or Tan of the angle \emptyset is the length of the side Opposite the angle \emptyset divided by the length of the side Adjacent to the angle \emptyset .

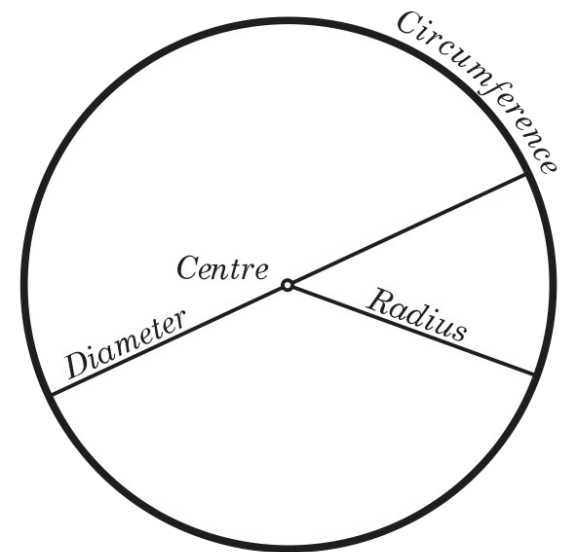
The *Cotangent*, or Cot of the angle \emptyset is the length of the side of the triangle Adjacent to the angle \emptyset divided by the length of the side Opposite the angle \emptyset .

The *Secant*, or Sec of the angle \emptyset is the length of the Hypotenuse of the triangle divided by the length of the side Adjacent to the angle \emptyset .

The *Cosecant*, or Csc of the angle \emptyset is the length of the Hypotenuse of the triangle divided by the length of the side Opposite the angle \emptyset .

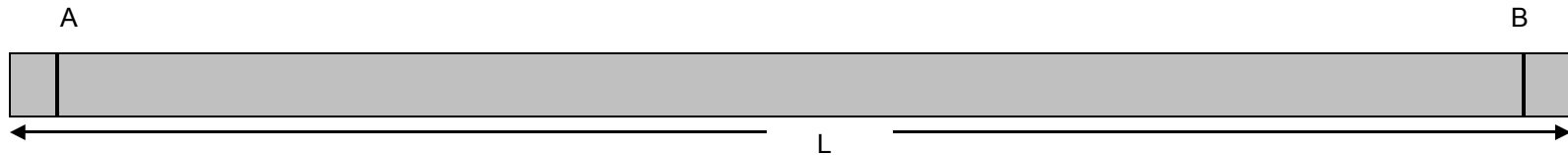
The Theory of conduit bending

- **Length of circumference**
- The ratio of a circle's circumference to its diameter is π (pi), a constant that takes the same value (approximately 3.1416) for all circles. Thus the length of the circumference (c) is related to the radius (r) by
 - $c = 2 \pi r$
- or equivalently to the diameter (d) by
 - $c = \pi d$
- Or to find diameter when circumference is know
 - $d = c / \pi$



Repeatable Conduit Bending

- Bending conduit is best done with a partner. One runs the front of shoe and the bender, the other supports the conduit and runs the Cliffhanger
- Create a measured length of conduit “L” (enter measurement on fact sheet)
- Mark conduit 2” from both ends of conduit “A” & “B”
- Put conduit in bender with front of shoe on mark “A”



- Find Zero = make this a personal quest
 - Your ability to consistently find the zero mark is the first step to being able to repeat bends
 - The conduit should be squeezed tight enough to require a pipe wrench to level the Cliffhanger, but do not start to bend the conduit
- Finding the Travel Mark “T”
 - When the conduit is in the zero position, a stationary point “Z” (behind the bending shoe) is established to determine the correct travel for the desired bend (enter measurement ZB into fact sheet)
- Bend a true 90°
- Find the Spring back Mark “T” and mark conduit
 - This mark “T” is determined at the maximum bend before release (93°)

Gathering the facts

- Place true 90° bend on bending table to check for accuracy
- Deduct = FA
- Minimum stub = FA
- Gain = (FC + ED) – L
- Travel = (ZB – TB) = ZT
- Back to Back = Deduct – Gain

Deduct _____

FC + ED _____

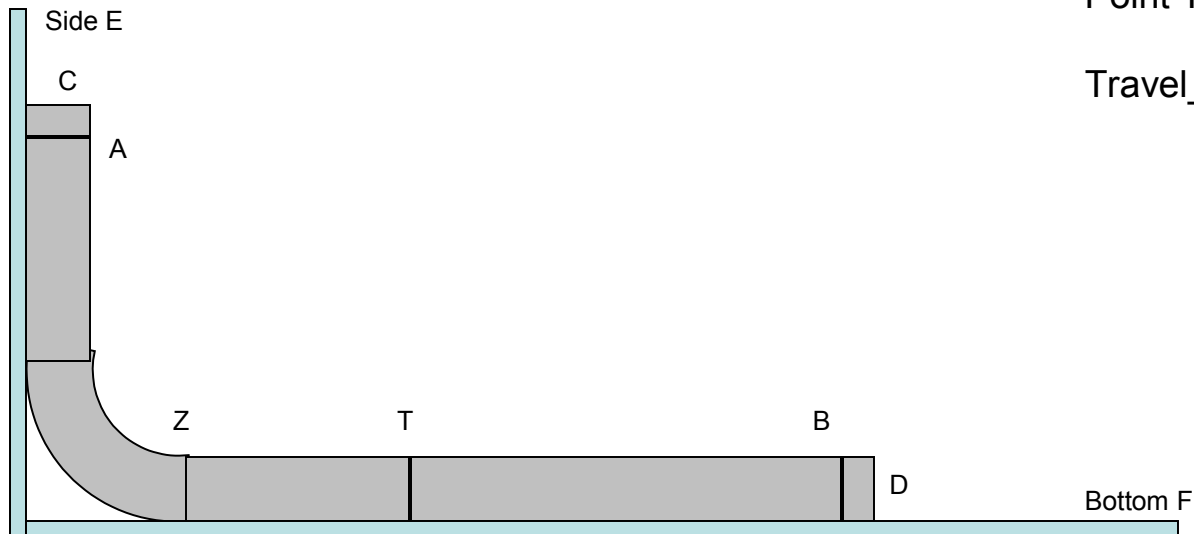
Length _____

Gain _____

Point ZB _____

Point TB _____

Travel _____



Cliffhanger Tools Repeatable Conduit Bending Program

CONDUIT	Bend Mark	Stub A	Length B	Cut Length	Travel	Deduct	Gain	B to B
3/4" IMC	6.375	15.500	35.500	47.500	9.000	9.125	3.500	5.625

Seg Travel	Degrees	Travel
3/4" IMC	35	3.500

Offset	12		3/4" COB	1" COB	Seg Travel	Seg Travel	Seg Travel	Seg Travel	
Mark	Degrees	Shrink	4.646	5.906	3/4" IMC	1" IMC	1 1/2" IMC	2" IMC	Cosecant
687.584	1	0.105	2.586	2.600	0.100	0.126	0.151	0.164	57.2987
343.844	2	0.209	2.638	2.666	0.200	0.253	0.303	0.328	28.6537
229.288	3	0.314	2.689	2.731	0.300	0.379	0.454	0.492	19.1073
172.027	4	0.419	2.741	2.797	0.400	0.506	0.606	0.656	14.3356
137.684	5	0.524	2.793	2.863	0.500	0.632	0.757	0.819	11.4737
114.801	6	0.629	2.844	2.928	0.600	0.758	0.908	0.983	9.5668
98.466	7	0.734	2.896	2.994	0.700	0.885	1.060	1.147	8.2055
86.224	8	0.839	2.948	3.060	0.800	1.011	1.211	1.311	7.1853

Cliffhanger Tools Repeatable Conduit Bending Program

20.416	36	3.899	4.393	4.897	3.600	4.550	5.450	5.900	1.7013
19.940	37	4.015	4.444	4.962	3.700	4.676	5.601	6.064	1.6616
19.491	38	4.132	4.496	5.028	3.800	4.803	5.753	6.228	1.6243
19.068	39	4.249	4.548	5.094	3.900	4.929	5.904	6.392	1.5890
18.669	40	4.368	4.599	5.159	4.000	5.056	6.056	6.556	1.5557
16.971	45	4.971	4.857	5.487	4.500	5.688	6.813	7.375	1.4142

Radius

75.000

dev length

117.750

30 Bends

20 Bends

18 Bends

15 Bends

10 Bends

3.925

5.888

6.542

7.850

11.775

3 deg

4.5 deg

5 Deg

6 deg

9 deg

Fractions

1/16 0.0625

1/8 0.1250

3/16 0.1875

1/4 0.2500

5/16 0.3125

3/8 0.3750

7/16 0.4375

1/2 0.5000

Cliffhanger Tools Repeatable Conduit Bending Program

CONDUIT	Bend Mark	Stub A	Length B	Cut Length	Travel	Deduct	Gain	B to B
1/2" IMC	4.625	12.125	24.000	33.250	7.000	7.500	2.875	4.625
1/2" Chicago	25.000	25.000	35.000	60.000				0.000
3/4" IMC	6.375	15.500	35.500	47.500	9.000	9.125	3.500	5.625
3/4" PVC	5.625	16.750	77.000	89.375	11.313	11.125	4.375	6.750
3/4" Chicago	0.250	9.000	36.000	41.875	7.500	8.750	3.125	5.625
1" IMC	24.313	35.313	13.000	44.438	11.375	11.000	3.875	7.125
1" Chicago	0.000			0.000				0.000
1"PVC	21.750	36.000	52.000	82.625	14.375	14.250	5.375	8.875
1 1/2" IMC	20.500	35.375	47.000	76.500	13.625	14.875	5.875	9.000
1 1/2 Rigid	9.875	25.000	40.000	59.000	13.500	15.125	6.000	9.125
1 1/2 PVC	0.875	17.250	26.000	37.563	14.750	16.375	5.688	10.688
2"	5.625	22.000	21.000	36.375	14.750	16.375	6.625	9.750
2 1/2"	14.250	38.000	33.000	63.188	11.125	23.750	7.813	15.938
3"	0.000			0.000				0.000
3 1/2"	0.000			0.000				0.000
4"	0.000			0.000				0.000

Input the facts

CONDUIT	Bend Mark	Stub A	Length B	Cut Length	Travel	Deduct	Gain	B to B
3/4" IMC	6.375	15.500	35.500	47.500	9.000	9.125	3.500	5.625

- Select the conduit size and type (Tan cell drop down box) in the bending program.
- Insert the data from fact sheet into the appropriate green column in the bending program.
- No need to input data into the Back to Back column, the program calculates this measurement.
- You can only change or input data into a highlighted cell. All others are locked to prevent changing needed formulas and other data.
- Repeat the Gathering of facts for each size conduit and type as needed.
- You are now on your way to Repeatable Bending.

Cliffhanger Tools Repeatable Conduit Bending Program

- To Bend a stub 90°
 - Select Conduit size and type
 - Click on the blue box @ “Stub A”
 - Enter the measurement for stub “A”
 - Measurement can be a decimal number (25.5) or a fractional number (25 ½)
 - The computer calculates the bend mark
 - (stub) A – D (deduct) – BM (bend mark)
 - Place conduit in bender with the bend mark at the front of shoe and find “zero” or “Z” mark
 - Place travel mark “T” (green box) on conduit
 - Bend conduit until the “T” mark is reached

Cliffhanger Tools Repeatable Conduit Bending Program

- To Bend a stub 90° with a length “B”
 - Select Conduit size and type
 - Click on the blue box @ “Stub A”
 - Enter the measurement for stub “A”
 - Click on the blue box @ “length B”
 - Enter the measurement for length “B”
 - The computer calculates the
 - bend mark ($A - D = BM$) and the
 - cut length ($A + B - G$ (gain) = cut length CL
 - Mark conduit for “BM” and “CL” and cut and thread conduit at “CL”
 - Place conduit in bender and proceed to bend stub “A”
 - Remove from bender and check for accuracy

Cliffhanger Tools Repeatable Conduit Bending Program

- Bending an Offset
 - Enter desired offset measurement in the Blue box @ “Offset”
 - Measurement can be a decimal number (25.5) or a fractional number (25 ½)
 - Chose the best combination of degree and hypotenuse length for desired offset
 - Place offset marks on conduit.
 - Place conduit in bender with front mark at front of shoe and find “zero”
 - Install Cliffhanger level in end of conduit and level
 - Determine “Segment Travel” (Segment travel includes spring back) $ST = \text{Travel} \div 90 \times \text{degrees}$
 - Enter degrees in blue box @ Degrees
 - Mark conduit for “T” and bend conduit to “T” mark
 - Release bender and turn conduit over 180° and find zero
 - Rotate conduit until Cliffhanger is level
 - Mark conduit for “T” and bend conduit to “T” mark, remove conduit to bending table and check for accuracy

Cliffhanger Tools Repeatable Conduit Bending Program

- Bend a 90° with a kick
 - Install Cliffhanger level in end of conduit and level
 - Bend the desired stub 90°
 - Remove to bending table and check
 - Enter the desired kick measurement into the blue box @ degrees
 - Chose the best combination of degree and hypotenuse length for desired kick
 - Mark conduit at the kick mark (this mark is the center of the bend)
 - Deduct measurement from center of bend “COB” column
 - Place conduit in bender with “cob” mark at front of shoe and find zero
 - Rotate conduit until Cliffhanger is plumb
 - Determine segment travel for desired degree of kick “T”
 - Bend conduit to “T” mark. Remove to bending table and check for accuracy

Cliffhanger Tools Repeatable Conduit Bending Program

- Shrink for kicks and offsets
 - Go to the shrink column on the program sheet
 - This figure is based on the Pythagorean theorem
 - $c^2 - a^2 = b^2$
 - $c - b = \text{shrink}$
 - And the gain of the segment bend needs to be considered – formula to follow
 - This deduct amount is a good estimate for kicks and offset

Cliffhanger Tools Repeatable Conduit Bending Program

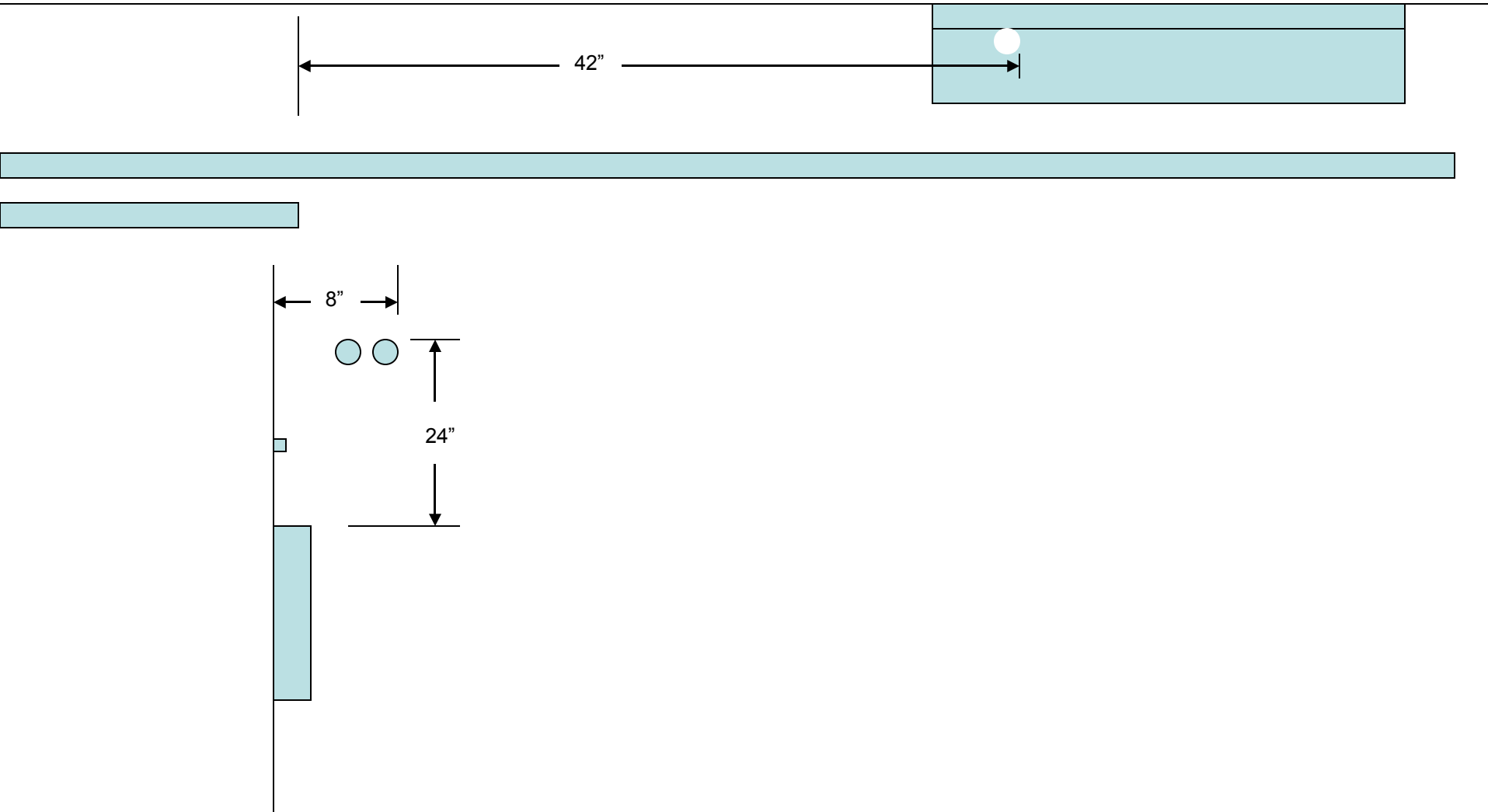
- Center of bends for saddles, offsets, and kicks
 - Go to the COB column in the bending program
 - For the math to work on these bends the measurement is made to the center of the bend or the length of the hypotenuse
 - This deduct amount gives you the front of the shoe for bending purposes
 - Other sizes and a formula to follow

Art of conduit bending

- **Measurements and the Art of Conduit Bending**
 - This conduit bending method will give you the ability to create any bend to specific measurements
 - If you have a bad measurement.... The conduit will not fit
 - Good measurements are critical
 - Plumb, level and square reference points allow good measurements
 - Good measurements = fitting conduits
 - When you understand this bending method it allows time to apply the art of bending conduit
 - Fewer couplings and conduit unions
 - Fewer return trips to the bending table
 - Fewer re-cuts and rethreading of miss-measured conduit
 - Evenly spaced conduit racks with matching bends that any electrician would be proud to install
 - No bone pile to hide
 - Increased productivity = more jobs for quality craftspeople

Art of conduit bending

- Cliffhanger offset



Trigonometric Table

Rad	Deg	Sin	Cos	Tan	Csc	Sec	Cot		
0	0	0	1	0	Infinity	1	Infinity	90	1.570796
0.017453	1	0.017452	0.999848	0.017455	57.29869	1.000152	57.28996	89	1.553343
0.034907	2	0.034899	0.999391	0.034921	28.65371	1.00061	28.63625	88	1.53589
0.05236	3	0.052336	0.99863	0.052408	19.10732	1.001372	19.08114	87	1.518436
0.069813	4	0.069756	0.997564	0.069927	14.33559	1.002442	14.30067	86	1.500983
0.087266	5	0.087156	0.996195	0.087489	11.47371	1.00382	11.43005	85	1.48353
0.10472	6	0.104528	0.994522	0.105104	9.566772	1.005508	9.514364	84	1.466077
0.122173	7	0.121869	0.992546	0.122785	8.205509	1.00751	8.144346	83	1.448623
0.139626	8	0.139173	0.990268	0.140541	7.185297	1.009828	7.11537	82	1.43117
0.15708	9	0.156434	0.987688	0.158384	6.392453	1.012465	6.313752	81	1.413717
0.174533	10	0.173648	0.984808	0.176327	5.75877	1.015427	5.671282	80	1.396263
0.191986	11	0.190809	0.981627	0.19438	5.240843	1.018717	5.144554	79	1.37881
0.20944	12	0.207912	0.978148	0.212557	4.809734	1.022341	4.70463	78	1.361357
0.226893	13	0.224951	0.97437	0.230868	4.445411	1.026304	4.331476	77	1.343904
0.244346	14	0.241922	0.970296	0.249328	4.133565	1.030614	4.010781	76	1.32645
0.261799	15	0.258819	0.965926	0.267949	3.863703	1.035276	3.732051	75	1.308997
0.279253	16	0.275637	0.961262	0.286745	3.627955	1.040299	3.487414	74	1.291544
0.296706	17	0.292372	0.956305	0.305731	3.420304	1.045692	3.270853	73	1.27409
0.314159	18	0.309017	0.951057	0.32492	3.236068	1.051462	3.077684	72	1.256637
0.331613	19	0.325568	0.945519	0.344328	3.071553	1.057621	2.904211	71	1.239184
0.349066	20	0.34202	0.939693	0.36397	2.923804	1.064178	2.747477	70	1.22173
0.366519	21	0.358368	0.93358	0.383864	2.790428	1.071145	2.605089	69	1.204277
0.383972	22	0.374607	0.927184	0.404026	2.669467	1.078535	2.475087	68	1.186824
0.392699	22.5	0.382683	0.92388	0.414214	2.613126	1.082392	2.414214	67.5	1.178097

Trigonometric Table

Rad	Deg	Sin	Cos	Tan	Csc	Sec	Cot		
0.401426	23	0.390731	0.920505	0.424475	2.559305	1.08636	2.355852	67	1.169371
0.418879	24	0.406737	0.913545	0.445229	2.458593	1.094636	2.246037	66	1.151917
0.436332	25	0.422618	0.906308	0.466308	2.366202	1.103378	2.144507	65	1.134464
0.453786	26	0.438371	0.898794	0.487733	2.281172	1.112602	2.050304	64	1.117011
0.471239	27	0.45399	0.891007	0.509525	2.202689	1.122326	1.962611	63	1.099557
0.488692	28	0.469472	0.882948	0.531709	2.130054	1.13257	1.880726	62	1.082104
0.506145	29	0.48481	0.87462	0.554309	2.062665	1.143354	1.804048	61	1.064651
0.523599	30	0.5	0.866025	0.57735	2	1.154701	1.732051	60	1.047198
0.541052	31	0.515038	0.857167	0.600861	1.941604	1.166633	1.664279	59	1.029744
0.558505	32	0.529919	0.848048	0.624869	1.88708	1.179178	1.600335	58	1.012291
0.575959	33	0.544639	0.838671	0.649408	1.836078	1.192363	1.539865	57	0.994838
0.593412	34	0.559193	0.829038	0.674509	1.788292	1.206218	1.482561	56	0.977384
0.610865	35	0.573576	0.819152	0.700208	1.743447	1.220775	1.428148	55	0.959931
0.628319	36	0.587785	0.809017	0.726543	1.701302	1.236068	1.376382	54	0.942478
0.645772	37	0.601815	0.798636	0.753554	1.66164	1.252136	1.327045	53	0.925025
0.663225	38	0.615661	0.788011	0.781286	1.624269	1.269018	1.279942	52	0.907571
0.680678	39	0.62932	0.777146	0.809784	1.589016	1.28676	1.234897	51	0.890118
0.698132	40	0.642788	0.766044	0.8391	1.555724	1.305407	1.191754	50	0.872665
0.715585	41	0.656059	0.75471	0.869287	1.524253	1.325013	1.150368	49	0.855211
0.733038	42	0.669131	0.743145	0.900404	1.494477	1.345633	1.110613	48	0.837758
0.750492	43	0.681998	0.731354	0.932515	1.466279	1.367327	1.072369	47	0.820305
0.767945	44	0.694658	0.71934	0.965689	1.439557	1.390164	1.03553	46	0.802851
0.785398	45	0.707107	0.707107	1	1.414214	1.414214	1	45	0.785398
		Cos	Sin	Cot	Sec	Csc	Tan	Deg	Rad

Conduit Data

CONDUIT	Travel	Deduct	Gain	B to B
1/2" IMC				
1/2" Chicago				
3/4" IMC				
3/4" PVC				
3/4" Chicago				
1" IMC				
1" Chicago				
1"PVC				
1 1/2" IMC				
1 1/2 Rigid				
1 1/2 PVC				
2"				
2 1/2"				
3"				
3 1/2"				
4"				