Formulas and Multipliers for Bending Conduit or Electrical Pipe

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Helpful Formulas for Bending Electrical Conduit

Very few beginning electricians are taught anything beyond the most basic instructions for bending electrical conduit pipe (EMT, electrical metallic tubing). As a result, they can have enormous difficulty when trying to bend larger conduit (greater than 1”). Even more experienced journey-level electricians seldom have any idea of the wide range of possibilities available. Nevertheless, learning how to bend conduit to very nearly any angle you want is not difficult.

The math and formulas that make up a simple conduit-bending guide are actually quite simple and easily learned. The only tools you need for more complex bends are an angle finder and a cheap scientific-type hand calculator.

Any electrician bending large conduit should already have an angle finder as without a hand bender to tell the angle being bent an angle finder is necessary. If you don't, there are some examples at the end of this article. And now that we have smartphones, the calculator isn't just cheap; it's free. Recommended for Android phones is the RealCalc scientific calculator app, available from the Google Play store at no charge. Simply search the store for RealCalc and download it.

Math Used for Bending Conduit

The math of conduit-bending that we will discuss here comes from two sources. Some of the math is already built into a common hand bender device, and the rest of it involves the geometry of a triangle.

Note that making concentric bends requires using some additional math not discussed in this article.

Math From Hand Benders

Deducts, bend radiuses, and multipliers

Lots of math is built into the hand bender device. Only a few numbers and math operations need to be memorized to make offsets, saddles and 90 degree bends. Even the “multiplier” and “deduct” figures are usually stamped onto the bender device.

For more information on using a hand bender, see my comprehensive guide to bending conduit.

Radius and Deduct Figures for Conduit

Size of Conduit	Radius of Bend	Deduct for 90 degrees
1/2"	4"	5"
3/4"	4 1/2"	6"
1"	5 3/4"	8"

Multipliers for Conduit Offsets

Degree of Bend	Multiplier
10 degrees	6.0
22 degrees	2.6
30 degrees	2.0
45 degrees	1.4
60 degrees	1.2

Math From Triangles

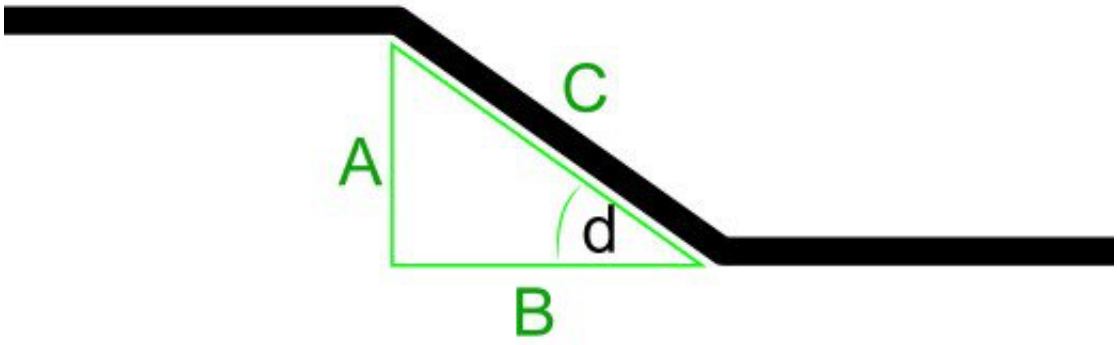
The geometry of a triangle provides formulas useful for many conduit bends

Most conduit bends, in addition to a simple 90-degree bend, can be understood and calculated using the geometry of a right triangle.

Using a Triangle to Understand an Offset

Offset | Source

The pipe above is bent into an offset. In the diagram below, the heavy black line represents the bent piece of conduit; the green triangle shows some useful lengths and angles.



Offset

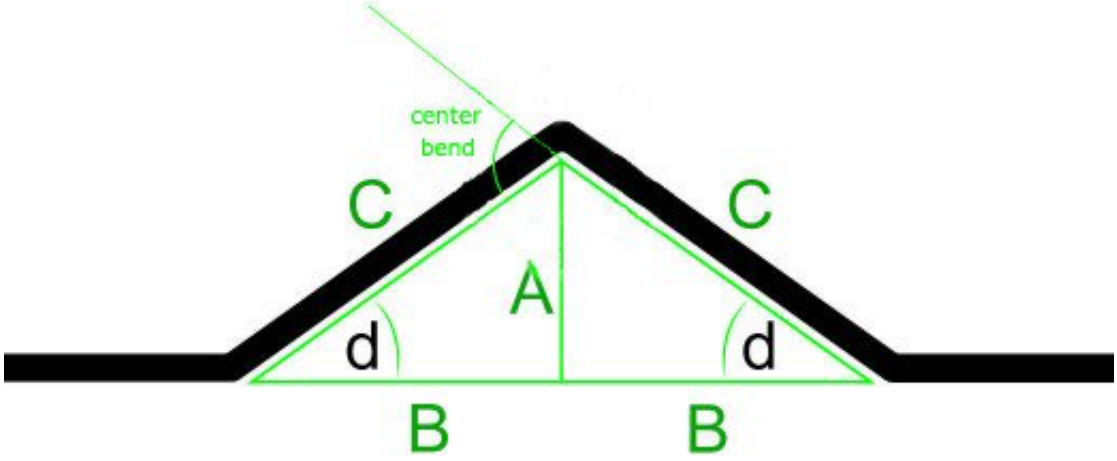
The angle "d" is the angle at which the conduit is bent. One of the remaining angles of the triangle is always 90 degrees, while the third angle always depends on the first, being 90 degrees minus angle d. The sides of the triangle are labeled A, B and C; these letters represent the length of each side. From the angle, using formulas below, you can get the relationships between these lengths.

In real life, of course, conduit is not a one-dimensional line, but rather a three-dimensional object with curved, not sharp, corners. But these considerations only affect the measurements you use in a very minor way; in everyday work you can ignore them.

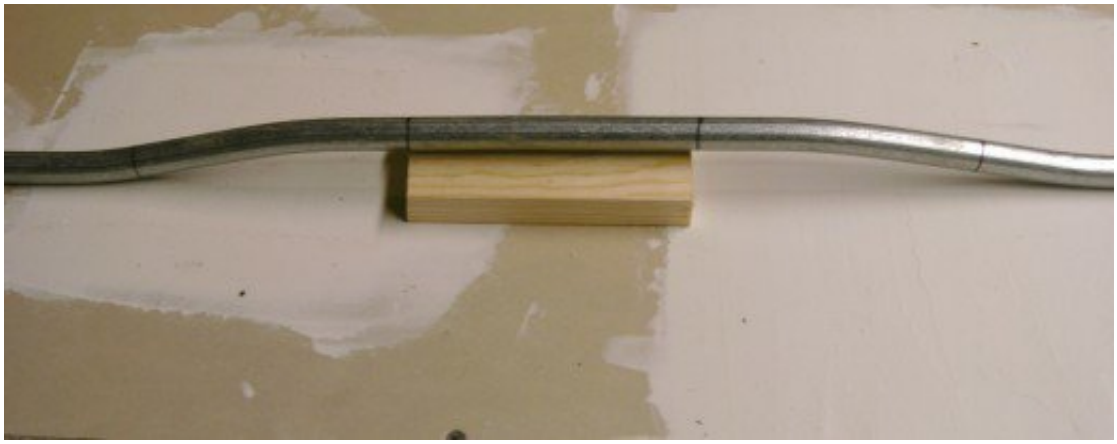
Using Triangles to Understand Saddles

Saddles are used to route conduit around an obstruction. Look at the photos below to see how you would use the triangle concept for a three-point saddle (by placing a second triangle back-to-back with the first one) and a four-point saddle (by placing a second triangle divided from the first one by a length of straight conduit).

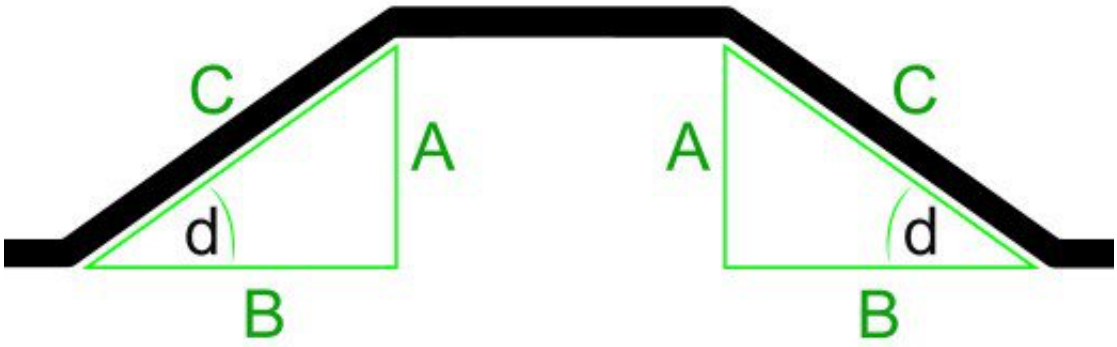
Three-point saddle | Source



Three-point saddle



Four-point saddle | Source



Four-point saddle

Math Formulas From Triangles

The math formulas we will be using are sine, cosine, and tangent. These are just the relationships between the sides of a right triangle; they depend on the angle (“d”) of the triangle. The formulas are listed below, with algebraic equivalents in each case. Each set of formulas—sine, cosine, and tangent—are just the same formula expressed three different ways.

Calculations Using the Sine

Sine(d) = A/C

That is, the sine of angle d is the length of side A divided by the length of side C.

A = sine(d) * C

The length of side A is sine (d) times the length of side C.

C = A/sine(d)

The length of side C is the length of side A divided by sine (d).

Calculations Using the Cosine

Cos(d) = B/C

The cosine of angle (d) is the length of side B divided by the length of side C.

B = cos(d) * C

The length of side B is the cosine of angle (d) multiplied by the length of side C.

C = B/cos(d)

The length of side C is the length of side B divided by the cosine of angle (d).

Calculations Using the Tangent

Tan(d) = A/B

The tangent of angle (d) is side A divided by the length of side B.

A = tan(d) * B

The length of side A is the tangent of angle (d) times the length of side B.

B = A/tan(d)

The length of side B is the length of side A divided by the tangent of angle (d).

Your calculator will give you the sine, cosine, and tangent of any angle. Because different calculators want you to press the keys in different sequences to get your results, you will have to read and understand the instructions for your particular calculator to use the trigonometric functions in it. In particular, you will have to know how to get *inverse* functions on your calculator; these functions convert a sine, cosine or tangent figure into an angle, into the degrees of bend you need.

And make sure that your calculator is set to describe angles in degrees, not in radians; radians are useless for the electrician.

Examples

Examples Using Math to Bend Conduit

- Assume that we need a 2" offset in 3 1/2" conduit. Normally, this would be impossible using a 10º bend, as two bends cannot be made that close together (12”) in that large a size of conduit. Using the sine formulas above, let's try a 2º bend. We know side A is 2". The calculator shows that the sine of a 2-degree angle is .0349. Two inches divided by .0349 = 57". That's a little far apart for our bends, so let's try again using a 5º bend. The sine of 5 degrees is .087, and 2 / .087 = 22.98, or about 23". That's a more reasonable length for an offset in 3 1/2" pipe, so it can be used where a 10º offset cannot.
- As an exercise, consider an offset of 12" using two 22º bends. Again, C = A / sine(22º). Note that this can also be written as C = A * (1 / sine(22º)). The sine of 22º = .3846, and 1 / .3846 = 2.6, which is the familiar multiplier for a 22º offset. This kind of math is where those multipliers come from!
- Assume we need a 4" offset, and that it *must* take place in exactly 15". What is the angle to be used? We know that A = 4 and B = 15. We also know that tan(d) = 4 / 15, or .2666. The calculator tells us that the *inverse tangent* of .2666 = 15º. At the same time we can find the multiplier of a 15º bend by dividing one by the sine of 15º; the answer comes back that the multiplier for 15º is 3.86.
- Assume we need a 4" 3-point saddle, and that we will use 45º as the center bend with 22.5º angle bends on each end. What is the conduit shrinkage—that is, the amount by which the center of the bend will be closer to the end of the conduit than the measured length of pipe? We know that A = 4" and angle d = 22.5º. What are B and C? Side C = 4” / sine(22.4º), or 10.45". Side B = 4" / tan(22.5º) or 9.65". The difference between B and C is our shrinkage; the center of our three-point saddle will move just under 1". Most electricians forget about or ignore this shrinkage on three-point saddles and as a result the center of their bend is not centered over the obstruction they are crossing.

Bend Any Angle You Want

Using these formulas will enable the electrician to bend very nearly any angle he or she wants to. As an electrician myself, I have often found myself attempting to bend large conduit into odd angles and dimensions to match the demands of a building or get the appearance people want. Bending 3" or 4" conduit into odd angles by trial and error gets *very* expensive *very* quickly.

Memorizing these simple formulas can make the bending of large conduit much easier. My own memory aid is this:

Sine(d) = opposite / hypotenuse

Cosine(d) = adjacent / hypotenuse

Tangent(d) = opposite / adjacent

where the “hypotenuse” is the longest side, the “opposite” is the side opposite the angle, and the “adjacent” is the side that touches the angle but is not the hypotenuse.

“SOH-CAH-TOA” is the acronym you may hear for this memory aid.

Or simply tape the formulas to the back of your calculator; believe it or not I grew up before there *were* calculators and I had to memorize.

A final note: this article is but one of several written by an electrician, for electricians. If you don't find what you

are looking for among my other articles, leave a comment and I'll consider addressing your question in future articles; the whole series is a work in progress.

Electricians and Trigonometry

Have you ever used trigonometry functions to bend pipe?

Yes, I often use this math

Seldom, but I have used it before

No, I never have

Vote See results

Angle Finders On Amazon

Two examples of angle finders from Amazon are shown below. One is considerably cheaper, but the other more accurate and easier to use. Either will work, just make sure that any one you choose has a magnet on at least one side to hold it to the pipe.

Johnson Level & Tool and Tool 700 Magnetic Angle Locator

Buy Now

Wixey WR300 Digital Angle Gauge

Buy Now

QUESTIONS & ANSWERS

Ask the author a question

Ask

Question:
How do I figure out how to match 90 degree bends with different size pipe?

Answer:
The only way to do it is with "concentric bends" where the bends are equal, not concentric. The problem is that the radius of the bend varies with the size of pipe so instead of using the bender to determine the radius it must be matched to that of the largest conduit.

Helpful 12

Question:
Is there a formula for concentric conduit bending?

Answer:
Not in the sense of the formulas given here. But an article on concentric bending does show the math used in the calculations: Emt Electrical Conduit Pipe Bending Instructions for Making Concentric Bends.

Helpful 4

Question:
I have a 10' piece of 3/4" aluminum electrical conduit. I need to have 80" in the middle, with a 90° on each end. What is the length loss of a 90° bend?

Answer:
Assuming your brand of bender uses the minimum radius of bends (most do) the NEC indicates that that figure is 4.5" for 3/4 pipe.

The "length" of the bend is then 4.5", but the length of pipe used to make that bend is 3.14*4.5/2, or 7". The "loss" is then 7-4.5, or 2.5". This is all assuming that the pipe is a pencil line, not a 3-dimensional object, which we know is not true. You would have to check in practice, but I suspect that the NEC figure is to the inside of the bend, meaning that the loss will be 3/4" less than what is calculated: the length of the completed bend will be 3/4" more than the minimum radius.

Why not just use the star on the bender rather than the arrow?

Helpful 2

Question:
I'm trying to bend a 10’ stick of 4” EMT in the centerline of the conduit so I can get equal lengths on both ends. Is there a formula for that?

Answer:
There is no real formula, but it can be calculated with a fair degree of precision.

Multiply the radius of the bend you want to make by 6.28, then by degrees, bend and divide by 360. Divide once more by two, measure from the center of the pipe that far then set that mark at the front edge of the bending shoe. The center of the bend should be very close to the center of the pipe. If you use the NEC codebook to find the minimum radius of your bend, be aware that the figure given there is to the center of the pipe, not the edge, and correct accordingly.

Helpful 2

Question:
What is the Formula for 2 45 = 90? How do I measure and layout bend marks for this?

Answer:
Instructions can be found here: https://dengarden.com/home-improvement/EMT-Electri...

Helpful 1

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