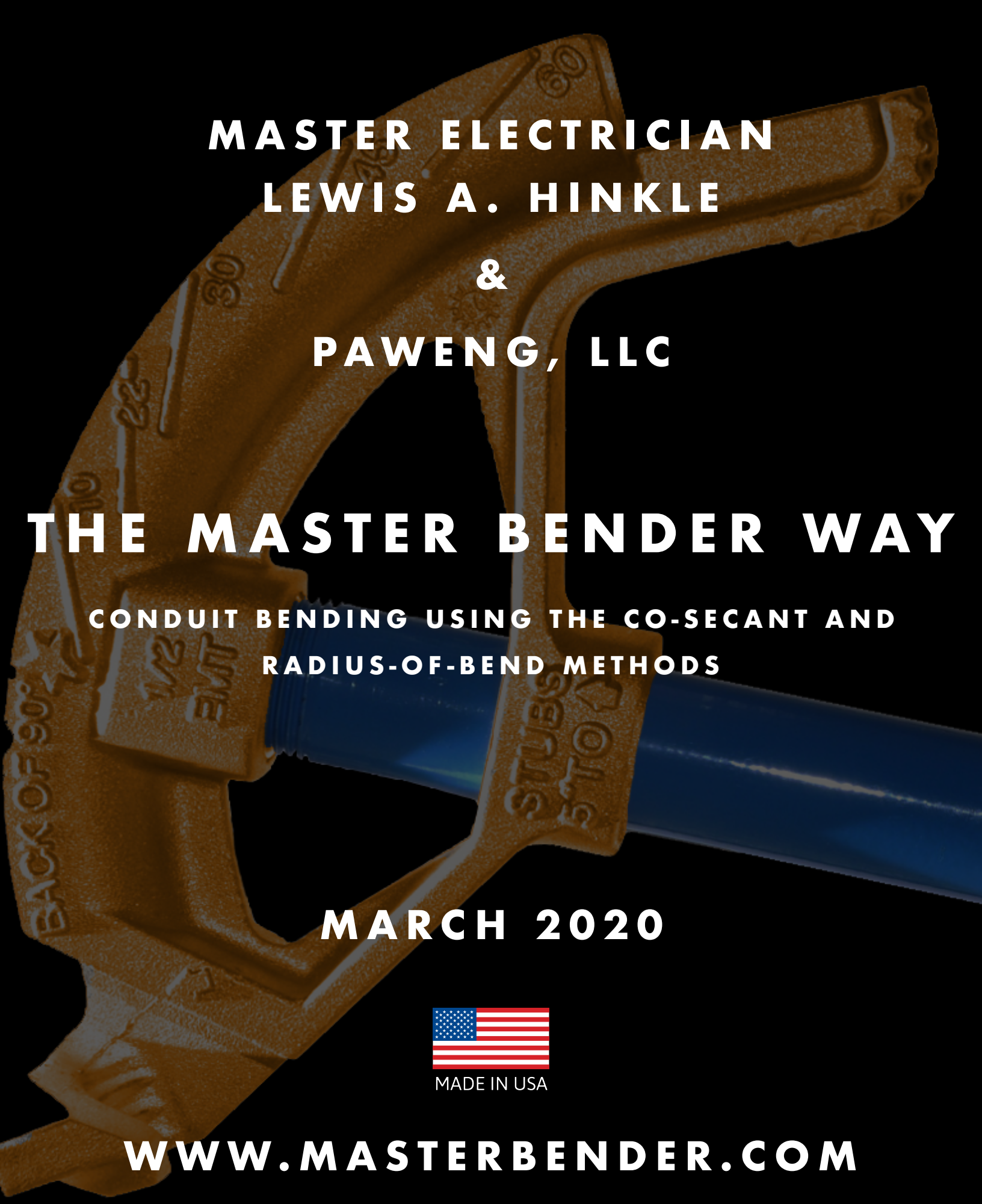
MASTER ELECTRICIAN
LEWIS A. HINKLE
&
PAWENG, LLC

# THE MASTER BENDER WAY

## CONDUIT BENDING USING THE CO-SECANT AND RADIUS-OF-BEND METHODS




MARCH 2020

MADE IN USA

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The Master Bender Way

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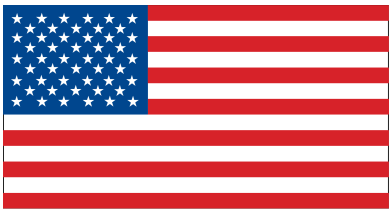
www.masterbender.com



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# INTRODUCTION

Conduit bending began in late 1930's by Jack Benfield. He was a salesperson for conduit. Current methods at the time often kinked the conduit, so he developed his own bender and associated mathematical bending formulas with the goal of selling more conduit. The blue colored handled Benfield conduit benders are still sold today, and his approximate co-secant method is also widely used today. Back then, they had no portable computers or calculators, and there were certainly no smartphones. The formulas used were only an approximation for bending. This is called the co-secant method because it uses the co-secant of the bending angles, e.g., 1.41 for 45° and 2 for 30°. The formulas work well in many instances but can in some cases be off by inches, in which case you better have those long neck couplers or connectors ready to make up for the shortfall in length.

While only an approximation, the co-secant method is still used today and can at times be useful. Using it for smaller sizes of conduit may be okay, but for precision work or when bending large conduit, we recommend using Master Bender Gold. Master Bender Gold is an iOS app that runs on most iPhones, iPod touches, and iPads. It uses a more precise algorithm called the Radius-of-Bend method, because it takes the bending radius of the bender into account. Use Master Bender Gold for speed, accuracy, and less waste.

Not all bending apps have the precision of Master Bender Gold. Some use the co-secant approximation, and therefore lack the precision of

Master Bender Gold. Master Bender Gold is the latest app in a series of mobile bending apps from PawEng, LLC dating back to 2007.

If you are interested in the mathematics of accurate conduit bending, we recommend you read "Mathematics of the Offset Bend" by Gerald Newton[1].

So when should you use Master Bender Gold, and when is it okay to use the co-secant approximation? Here are some rules of thumb:

Use Master Bender when:

- doing exposed precision work.
- bending conduit larger than 1 inch in diameter.
- bending at angles above 45°.
- doing more complicated bends like parallel, concentric, 3 and 4 point saddles, rolling offset bends, and bends around objects in corners.
- you just want to double-check the math you did for the co-secant approximation.

Of course, if it is Friday afternoon and you have one last stick left of 1¼ inch conduit to finish the job, you might also want to pull out Master Bender Gold!

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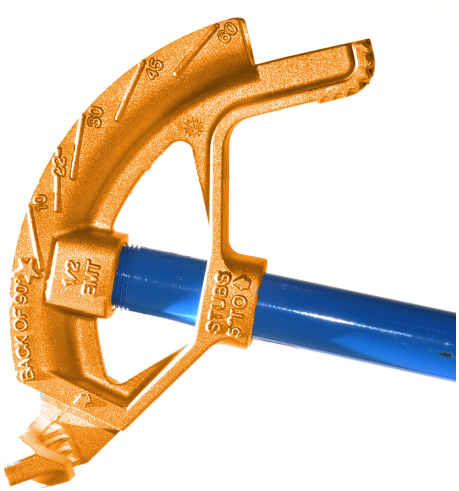
[1] See http://www.electrician2.com/electa1/offset.html




It is fast and easy to use Master Bender Gold. With a little practice, you can often enter the bend parameters and compute the bend in 20 seconds.

Use the co-secant approximation when:

- doing simpler bends like stubs, 90° bends, u-bends, kicks, back-to-back 90° bends, and simple offset bends.

The bends that can be done with the co-secant approximation represent the majority of bends made on most jobs.

The Master Bender way is to start the Master Bender Gold app on your smartphone, measure and enter data, mark your conduit, and do the bends. With practice, you will know what types of bends are required for speed and accuracy. If you measure and mark the conduit correctly and use proper techniques, you will have better accuracy than the estimated co-secant method, and you will have less wasted conduit. Master Bender Gold can pay for itself in less than an hour!

## When To Use Master Bender Gold

| Bend | Use Master Bender Gold | Typical Calculation & Number Entry Times |
|---|---|---|
| **Stub up** | No | |
| **Back to Back** | No | |
| **No Waste Kick 90°** | Yes | < 20 seconds |
| **Box Offset** | No | |
| **Rolling Offset** | Yes | < 20 seconds |
| **Three Point Saddle** | Yes | < 20 seconds |
| **Four Point Saddle** | Yes | < 20 seconds |
| **Parallel** | Yes | < 20 seconds |
| **Concentric** | Yes | < 20 seconds |
| **Segment** | Yes | < 20 seconds |

Some job sites and bosses ban smartphones. In such cases it makes sense to carry paper and pencil, a calculator, and bending tables like the ones found at the end of this book. You might even want to carry a copy of the tables in your wallet.

We always recommend you follow the rules for the job site, but if your boss bans smartphones, you may want to tell him about the advantages of using Master Bender Gold. After all, if you can do your job faster, with higher precision, and with less wasted materials, it would be a benefit to all. Master Bender Gold does away with all the tables. It also has a digital bubble level and angle finder.

## THE BENDER

The typical bending tool has a number of marks on it for helping you do your bends:

- An arrow mark located near the front of the bender.
- Angle marks for 10°, 22½°, 30°, 45°, and 60° bends. When your conduit lines up with one of these marks, it has been bent the indicated number of degrees as measured from the arrow point.
- Rim notches indicates the center of a bend. There are different notches for different angles. They are used for the center bend in a three point saddle bend. Some benders will have a tear drop mark.
- A star that is used for back to back bends.

The arrow is used for most bends. If you use the co-secant method, you should use the rim notch for the center of a three point saddle bend. Master Bender Gold computes the results of three point saddles using both the rim notch and the arrow point.

## COMMON BENDING TERMS

- "Back to Back bend" - A 90° bend located a short distance away a box, raceway fitting or another bend in the raceway.
- "Box offset bend" - An offset bend that lifts the raceway up to height of the opening of the box so that the raceway enters box in a straight direction instead of a slight angle to the box.

- "Chicago Bender" - A ratcheting type bender for larger raceway that usually is on wheels. Usually bends conduit up to two inches trade size.
- "Concentric bend" - Multiple 90° bends around a corner running parallel to each other, that all have the same center location.
- "Dog Leg" - A bending mistake when two bends in a raceway not line up with each other.
- "Electric Bender" - Works with conduit up to 3" and motor action bends with shoe.
- "Foot" - The part on the bender that the electrician puts pressure his foot to keep the raceway in the curved track of the bender. You should have constant pressure to prevent kinks.
- "Gain" - The distance a raceway will shorten when it bends in a curve a 90° corner instead of going all the way to the corner. Gain can be calculated by taking 43% of the radius of the bend.
- "Hand Bender" - A manually operated bender for conduits ½" to 1¼" in size. Usually one cannot bend larger sizes than 1¼" by hand because of human strength limitation and handle size. More than 80% of all bends done with this.
- "Hydraulic bender" - A type of bender often used for larger size conduit 3" to 5" in diameter.
- "Inclinometer" - Digital angle finder and analog bubble level that is included with Master Bender Gold.

- "Jamming" - A problem that occurs when pulling wires around bends that have been lost their round shape. This happens when three size wires are pulled into the raceway and the ratio of the diameter of one wire to the raceway's inside diameter is between 0.8 and 3.2. The wires will lay side by side inside the bend and then be stuck when the raceway returns to its round shape.

- "Kick" - Bend in the raceway, usually less than a 45° angle that changes the direction of the run.

- "Kink" - The location where a raceway folded rather than bent while bending the raceway, usually from poor foot pressure. NEC prohibits kinks in conduit.

- "Offset bend" - Two equal but opposite bends in a raceway that allow the run to change to another plane. Box offsets is a very common type small offset usually at 10°.

- "One Shot bender" - A bender that makes a complete bend in one step (not in segments).

- "Rise" - The distance that a raceway will offset or stub up in length.

- "Rolling Offset" - An offset that changes horizontally.

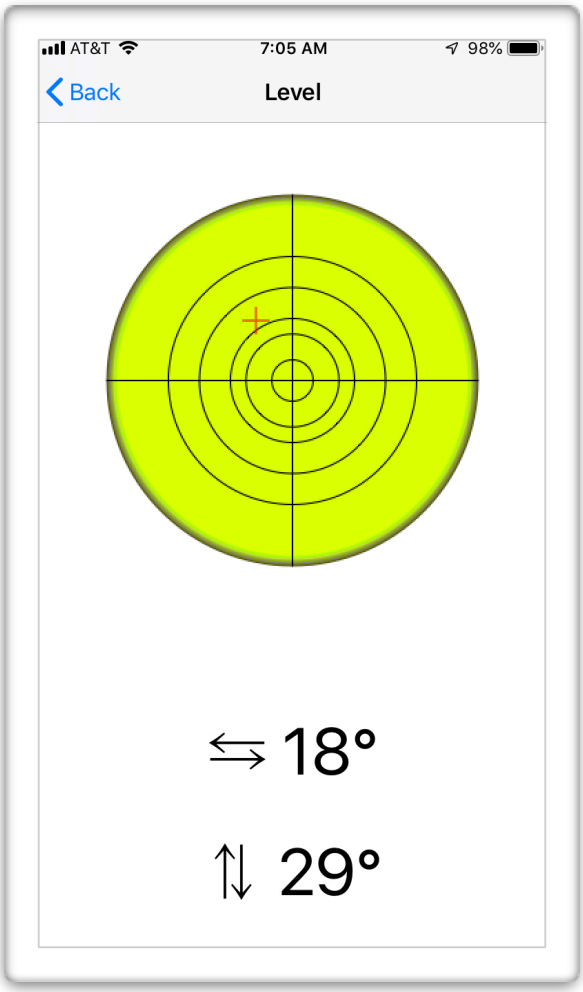
- "Run" - A term used for a complete path of raceway or cable two points, usually between boxes and/or panel boards.

- "Segment bend" - A large bend formed by a series of smaller bends.

- "Spring back" - The amount a raceway will straighten out after the of bending is released. This is more pronounced using electric and hydraulic benders and larger conduit.
- "Stub-up bend" - A 90° bend in raceway that is located very near end of the raceway that usually go into boxes or panels.

## MEASUREMENTS

The typical standard in the industry is to measure with a precision of 1/16 inch. When marking the conduit try using a pencil or a very thin felt pen. Put your arrow, star or rim exactly on the mark.




Levels are used for angle verifications. Torpedo levels for electricians usually have 0°, 30°, 45°, 60° and 90° bubbles, and are generally accurate to less than a degree. When bending the first angle for offset or four point saddle, it is most important that the angle is correct because the second bend is referenced to it. Master Bender Gold has a digital angle finder included. It has concentric markings for 10°, 22½°, 30°, 45°, and 60°.

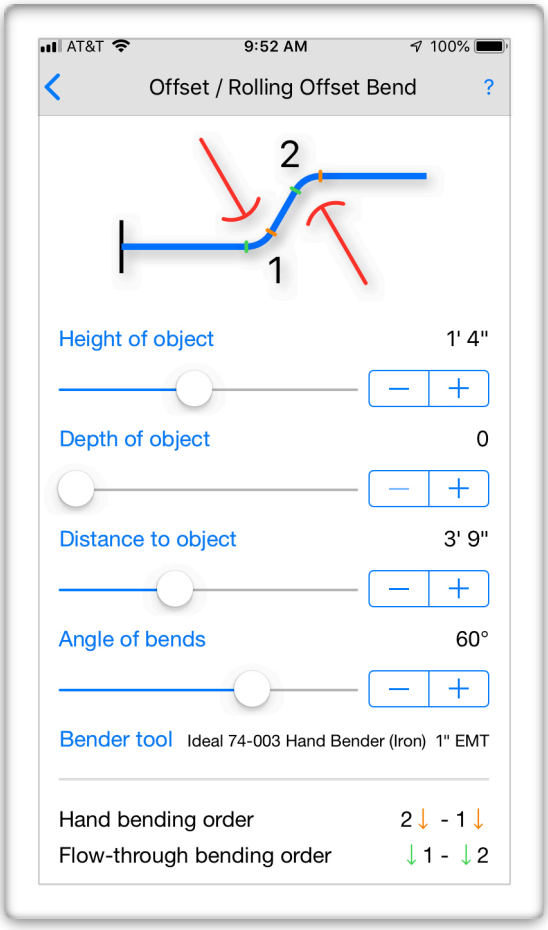
The bending marks on the bending tool are hard to see if bending on the floor. If bending from the air it is difficult to precisely bend the conduit to the right angle. Try to always check the first angle by placing the level on the conduit or on the handle. Two of the most popular benders have either 30° or 45° when handle is straight up. So when doing a 30° offset when handle is straight up (and handle not bent) the level should be zero. When doing a 90° bend on a handle with 30° it is best that you put the level on the conduit. Using a 45° handle will give you level at 90° bubble. The closer you are with both the angle and measurements, the better chance you will have for a precision bend.

## USING MASTER BENDER GOLD

There are three ways to enter a distance or angle in Master Bender Gold:

- Use the sliders to quickly get you in the right ballpark.
- Tap the name of the parameter to bring up a quick pick menu.
- Use the +/- buttons to make fine adjustments.

Master Bender Gold visualizes the bend for you. As you enter the parameters, the illustration of the raceway changes shape to reflect your bend.



The drawing of the raceway shows the conduit in blue. The black line at the left end of the conduit is an arbitrary point from which all measurements are taken. This could, for example, be the last coupler.

The bends are labeled with numbers. In this case, there are two bends: 1 and 2.

Next to each bend is a drawing of a bender. You will also see two lines marking arrow positions for each bend: one green and one orange. The green one marks the position of the arrow mark when bending toward the last coupler. The orange one marks the position of the arrow mark when bending away from the last coupler.

For three point saddle bends, you will also see a yellow mark. This is for the rim notch.

Below the bender tool, you will see two lines indicate the order in which you should perform the bends. The first line shows the order if you are using a hand bender. The second one shows the order if you are using a flow-through or push-through bender.

Tap on the blue “Bender tool” label. This brings up the bender tool selector. Here you can pick the bender tool you are using. Start by selecting the manufacturer, and then pick the model.

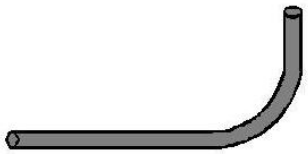
## SAFETY AND THE CODE LAW

When bending conduit, always use the proper personal protection equipment (PPE): Gloves, safety glasses, steel tip shoes, and hard hat.

Before you begin, consult the National Electrical Code™ for proper raceway builds. Some things like kinking and more than 360° bends in a run are not permitted. Some things like proper reaming of conduit are required.

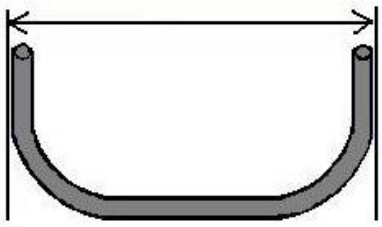
# OVERVIEW OF THE COMMON TYPES OF BENDS

## STUB-UP 90° BEND



The first type of bend is the stub up bend. A stub up bend is used to bring a raceway from under the floor up to a receptacle box or into a panel or wire way. It is usually between 12" to 24" high. Most of the time on other types of bends, we can mark the exact distance we want for a bend directly on the raceway and place the bender on one of the marks and bend it. But if the stub up bend is so close to the end of the raceway, the bender must be placed on the back side of the mark that is made on the raceway.

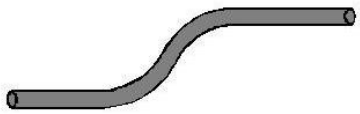
## BACK-TO-BACK 90° BEND



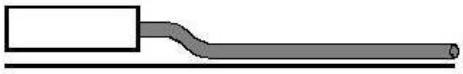
The next type of bend is the back-to-back bend. A back-to-back bend is any bend that needs a 90° bend located a predetermined distance away. This is probably the most common type of bend.

A mark is made on the raceway at exact distance that is needed for the 90 bend. Be careful not to dog leg this bend.

## OFFSET BEND

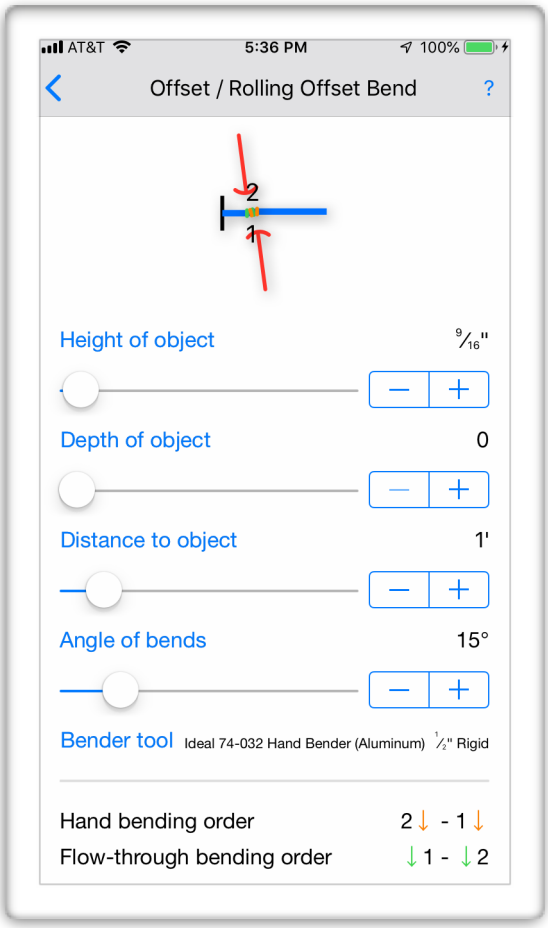


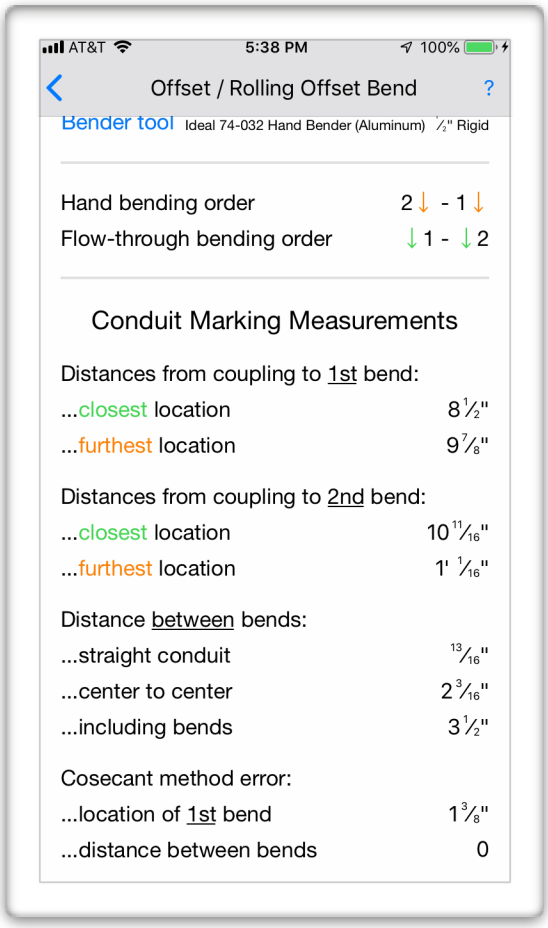
The third type of bend is the offset bend. This bend consists of two equal degree bends that are bent in opposite directions. This bend can be used when the run of raceway is changing elevations. Both marks are on the raceway before any bending takes place. It is common to use 30° and 45° angles.



A box offset is a small offset bend (usually two 10° or 15° bends). It is used to lift a raceway from the surface up to the knockout of the box it is entering. This allows the connector to enter the box on a straight angle.

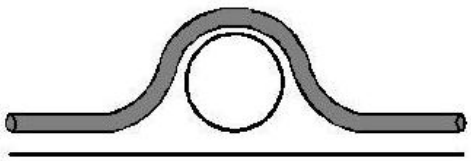
Example: Use Master Bender Gold to compute a box offset, where the conduit needs to be raised 9/16" above the ground. Select the Offset Bend tool in Master Bender Gold. Set the height of the object to 9/16", the depth (horizontal offset) to 0, select a distance to the object of 1' (could be anything since it is not specified in the problem description), and an angle of 15°. Select your bending tool; for example, the ½" Ideal Hand Bender.




Scroll down to see the results of the bend. Master Bender Gold will tell you that you have to make two bends 2 - 3/16" apart. You find this number under “Distance between bends” and “center to center”.

## THREE POINT SADDLE BEND



The fourth type of bend you will bend is the three point saddle. This bend is used to jump over small obstructions 6" or less in height. A common obstruction is an installed raceway that is running perpendicular to the raceway you are installing. This bend is made by bending the middle bend twice the number of degrees of the two side bends. Three marks are

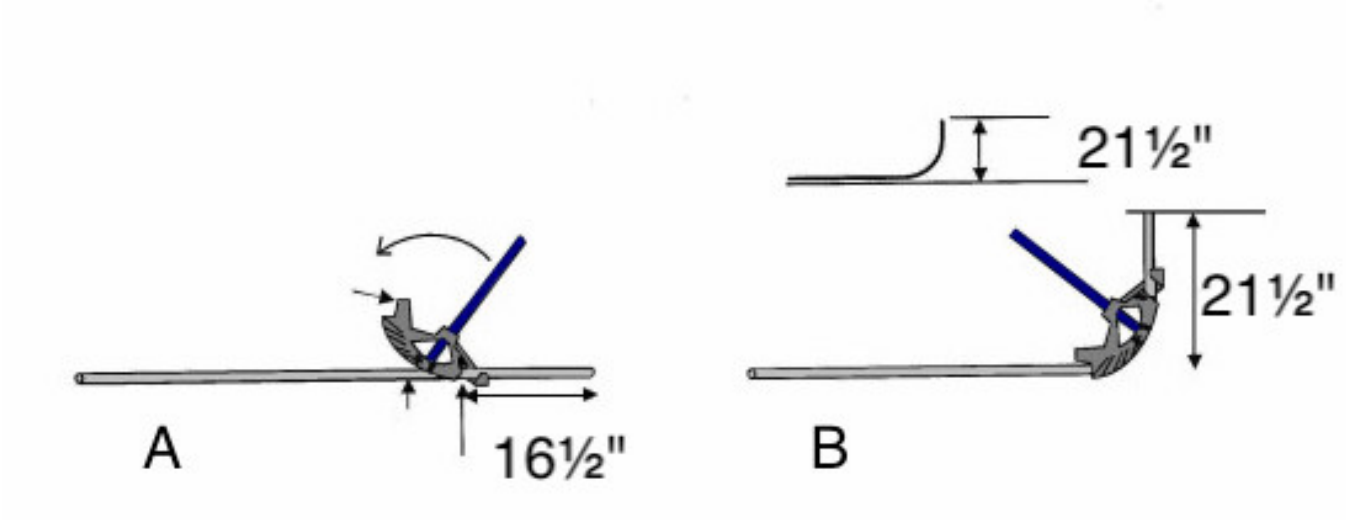
placed on the raceway before any bend. The center angles is usually either 30° or 45° with outside side bends at either 15° or 22½°.

### FOUR POINT SADDLE BEND

The last type of bend described in this manual is the four point saddle. This bend is made up of two equal size offset bends bent in opposite directions. This bend is used to jump over larger blockages than a three point saddle can handle. All four marks are placed on the raceway before any bending takes place.

## HOW TO PERFORM THE BENDS

### STUB-UP 90° BEND



Determine the height of the offset. In the example, the height is 21½". From the height, deduct the “take-up” for your bender:

**Take-Up for 90° Bends Using an EMT Bender**

| Size and Type of Conduit | Take-Up |
|---|---|
| ½” EMT | 5" |
| ¾” EMT or ½” rigid steel | 6" |
| 1” EMT or ¾” rigid steel | 8” |
| 1¼” EMT or 1” rigid steel | 11" |

Assuming we are using ½" EMT, we deduct 5" from the height of 21½", and we get 16½". Mark the conduit at this distance and bend the tubing on the arrow as shown in figure A. Bend the tubing to a 90° angle by applying pressure on the foot of the bender.

Stub-up bends are usually short 90° bends. If the bend is near the end of the raceway, it is not practical to bend the raceway on the same side of the mark as the end of the raceway. If we placed the mark at exactly 21½" from the end, the result would be a stub-up bend 26½" high. Therefore, we reduce the height of the ½" EMT tubing by 5”.

Instead of doing the math (26½” - 5" = 21½”), it is often faster to measure the full 26½" and then measure black 5". This saves you from doing the subtraction in your head, on paper, or on a calculator.

The direction of the “run” is important for a stub. If you are going toward a wall and need to go up 90° then measure from last connector/coupling to the wall and mark the conduit with that distance. Turn the bender shoe toward you, place the bender’s star

mark where you marked the conduit, and bend. If you are coming down the wall from a box or panel board to the floor then measure from box to floor for distance and mark the conduit then add the take-up amount in the direction of the box and bend using the arrow with shoe pointing toward the box or panel board. If the box or panel board requires a box offset this should be done first. Master Bender Gold can solve the location of the arrow mark by putting in the height and distance and then putting in the conduit size that will be used, but this is not usually done because of speed.

You can refer to the table above for Gain / Take-up values. Some benders also have the value written on them. Got some unusual bender? Just take a scrap piece of conduit and bend at the arrow at end of conduit then measure from end to the floor for take-up amount.

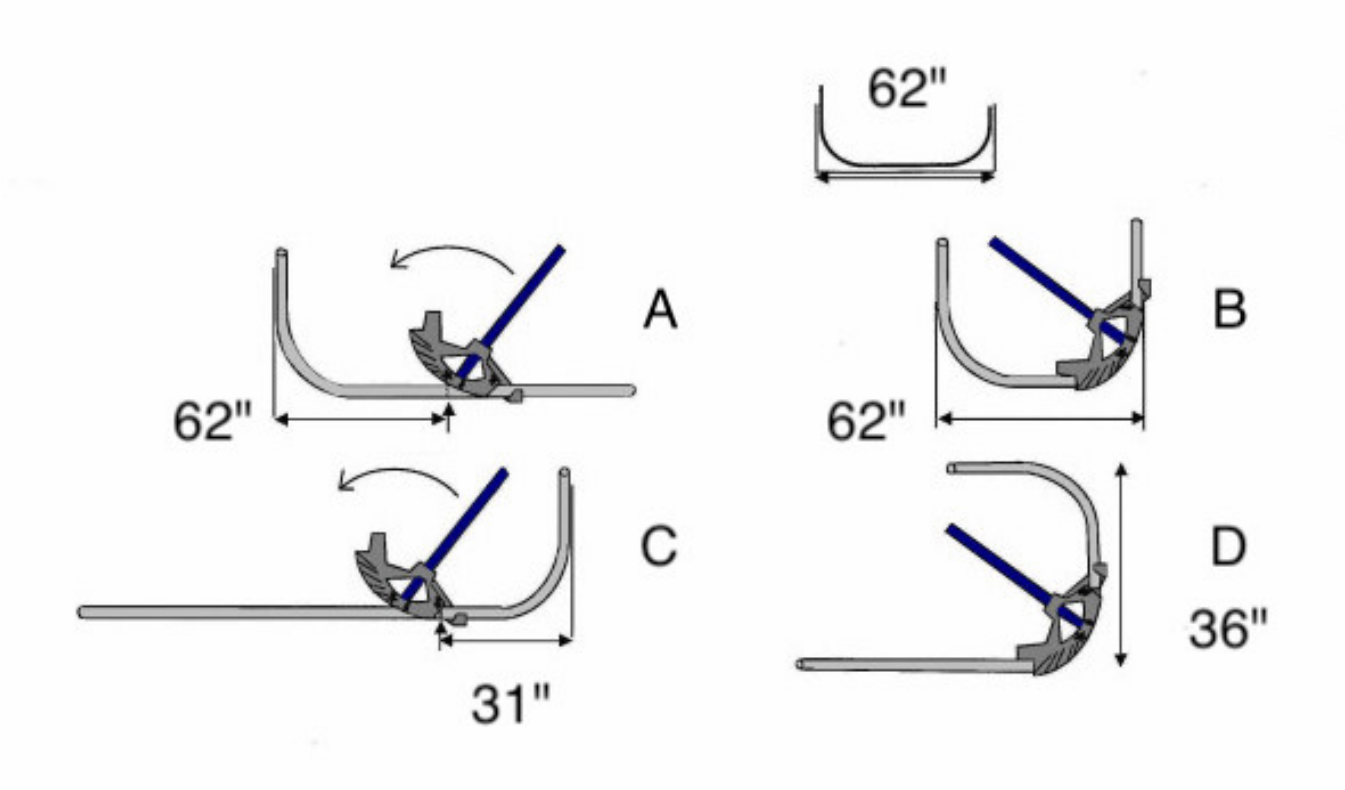
Gain and Take-up only applies to 90° bends. Gain also varies with conduit size and type.

Hint: Always subtract gain but add shrink when doing calculations.

## BACK-TO-BACK 90° BEND

Determine the width of the back-to-back bend. This is measured from the back side of the raceway at one end to the back side of the raceway at the other end. In the example below, the width is 62".

Mark the raceway at the calculated distance as shown on figure A. Place the raceway on the star and then bend the raceway up to a 90° angle. This bend is made on the star and in the direction of the




measured end of the raceway. Because there is room to bend the raceway on that side of the mark, the bend could be placed on the star.

For "short" back-to-back bends, you do not have space to bend toward the previous 90° bend. Instead, you can subtract the take-up from the distance, mark the raceway, and then bend the raceway on the arrow in the other direction as shown above in figure C and D. Here we do a 36" wide bend by measuring 31" from the end. The 31" are the 36" in width minus 5" take-up for our ½" raceway. We use the arrow mark for bending away from the first 90° bend.

## REFERENCE POINTS & MARKING

A conduit run starts and ends at a box or panel board. Each box or panel board usually has a connector, and the end of each conduit stick

has a coupler to continue the conduit run. When laying out a bend, we do all measurements relative to the start of the conduit run. In Master Bender Gold we refer to this as the last coupling. We could have picked any point on the conduit as the reference point, but it simplifies matters when we pick a well defined point like the beginning of conduit.

The direction in which you perform a bend matters. Assume you have a piece of conduit with a marking somewhere on it. You can place the bender with the arrow mark on the marking and do the bend in two ways. In one case the conduit is bend to the right of the marking; in the other case it is bend to the left of the marking. In both cases the conduit is bent, but the part of the conduit that is bent differs.

We say the bend is done **toward the last coupling** if the bent part of the conduit is on the coupling side of the marking. We say the bend is done **away from the last coupling** if the bent part of the conduit and the last coupling are on the opposite sides of the conduit marking.

Another way of remembering this is that when you bend **toward** the last coupling, you move the handle of the bender **toward** the last coupling. Likewise, when you bend **away** from the last coupling, you move the handle **away** from the last coupling.

We always start by marking the conduit with all the locations where we will do bends. We normally do not perform the bends in the order they appear. In the following sections we describe the order in which you should do the bends.

On some benders like ratchet or electric benders you can use the push-through method, where you perform each bend in sequence from the one closest to the last coupling to the one furthest away. Here you do all bends in the same direction. You can also use the push-through method with hand benders.

Master Bender Gold will compute two locations for each bend: One where you bend toward the last coupling, and one where you bend away from it. This way Master Bender Gold supports both the traditional way of bending and the push-through method.

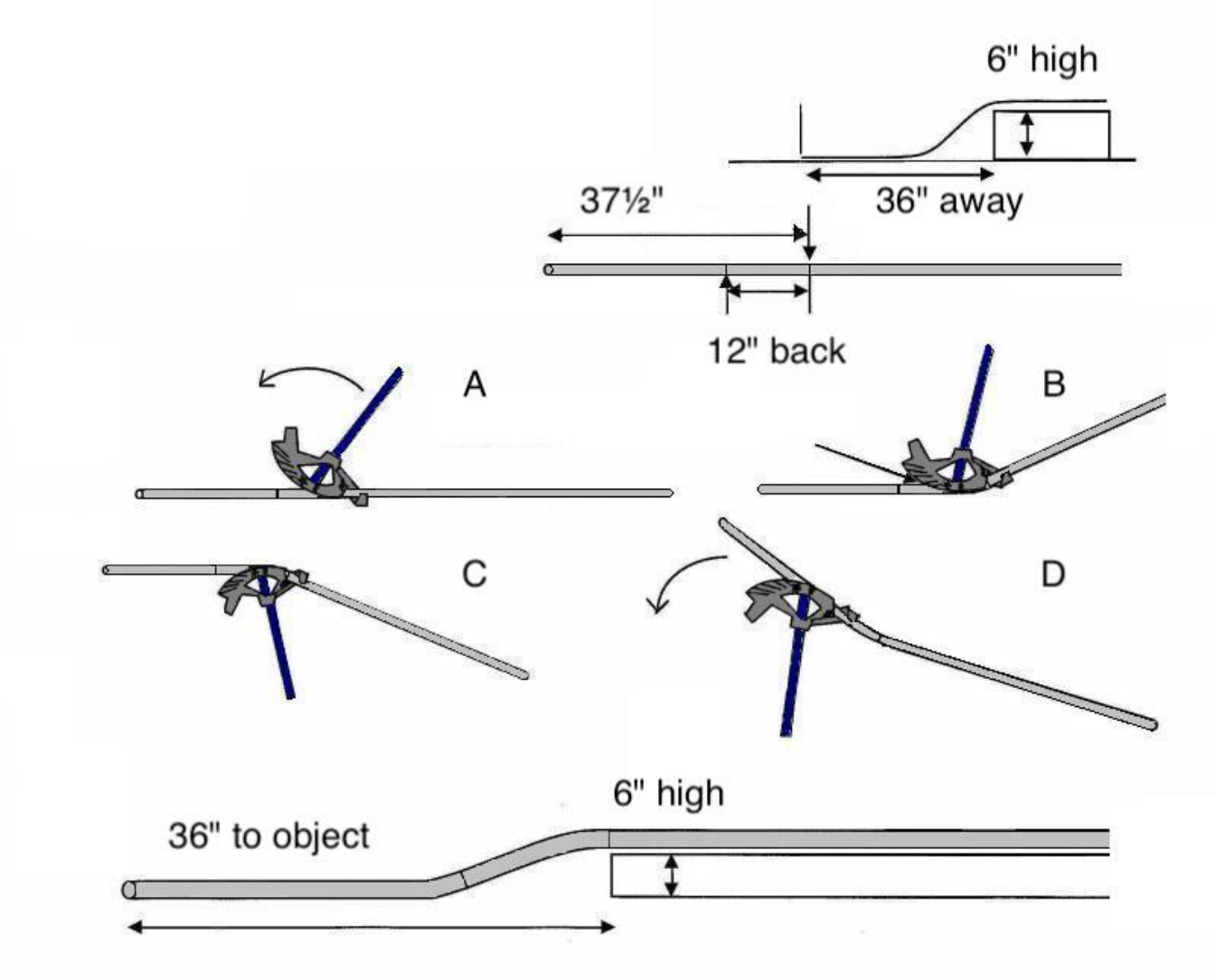
## OFFSET BEND

Determine the height of the offset and the distance from the end of the raceway. In the example below, the offset is 36" from the end of the raceway and it is 6" high. Next, determine the angle of the bends.

The two bends in an offset bend are done at the same angle. It is common to use 30°, and that is what we use in the example.

The Offset table at the back of this book shows a multiplier of 2 for 30° offset bends and a conduit length loss of ¼" per inch of offset height. This gives us a distance between bends of 12" (the 6" height times the multiplier of 2), and a shrinkage of 1½" (the 6" height times ¼" per inch loss).

Place the first mark on the raceway a distance of 36" plus the shrinkage amount of 1½". This will be 37½" away from the end of the raceway. Measure 12" back again toward the beginning of the raceway




and place the second mark there. Make sure to mark all the way around the raceway when placing marks on the raceway.

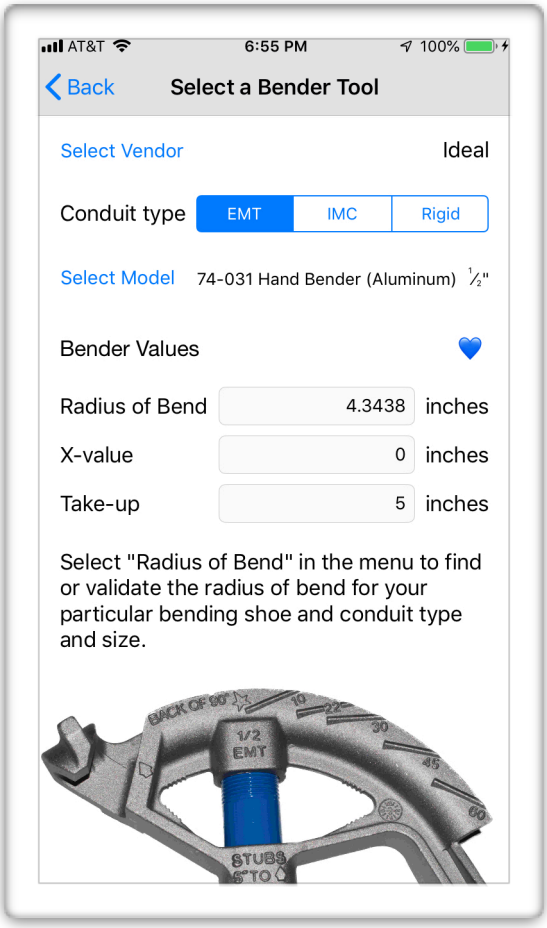
Place the arrow of the bender at the first mark, and bend toward the beginning of the raceway. Bend the conduit to 30° as illustrated in steps A and B. The 30° mark on the bender should now be located at the edge of the raceway.

Leave the bender on the raceway. Pick up both the raceway and the bender and place the bender on the floor as shown in step C. Slide the bender to the second mark, roll the raceway 180° and place the

bender's arrow on the mark. Now place your hand and armpit on the raceway bend another 30° angle on the raceway at the arrow. This should give you a 6" offset 36" away from the end of the raceway.

Offset bends at 30° are easy to remember and calculate. The distance between the bends is twice the offset depth and the shrinkage amount is a quarter of the offset depth height. Or you could say that for the distance between bends you add 2" for each inch of offset rise, and for the shrinkage amount you add ¼" for each inch of offset rise. For example: To make an 8" offset at 30°, the shrinkage amount is 2" and you need 16" between bends. The tables at the end of this book shows you the numbers for offset bends for other angles.

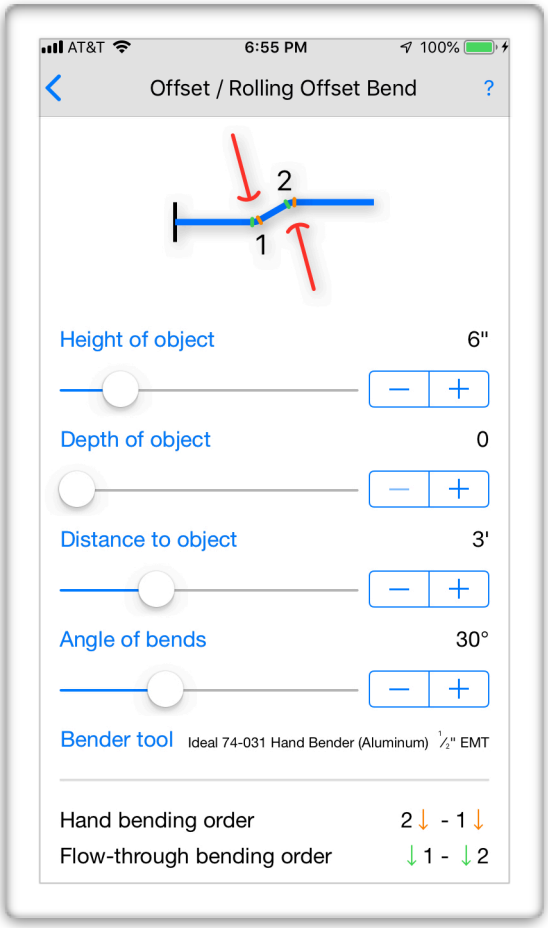
Master Bender Gold can calculate offset bends. First you select the tool and conduit size you are using. In this example we will use ½" Ideal Hand Bender. Master Bender Gold will list most tools, but if it does not list your tool, you can add it to the list as along as you know its bending radius. If you switch conduit size you must select a new tool in Master Bender Gold. Often times one does not switch much between different size conduits, and Master Bender Gold will remember the last bender you used.

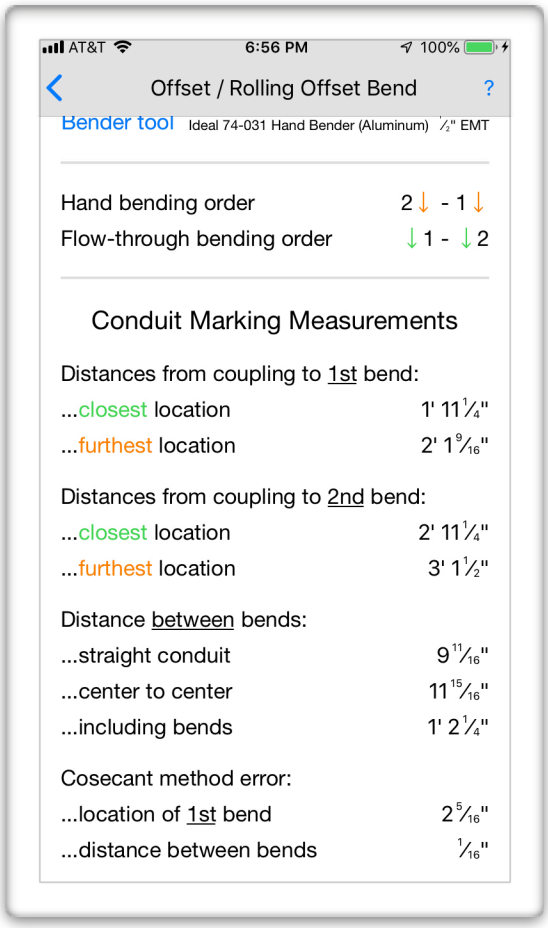



Next you select the bend parameters: Angles of the bends, offset heights, distance to offset, and for rolling

offsets you also select the horizontal offset or depth (leave at zero for normal offset bends).

Scroll down on Master Bender Gold to see the results of your bend.




Master Bender Gold lets you perform the bends in any order and in any direction. In the example above, we assumed with the co-secant method that you performed both bends toward the beginning of the raceway. Master Bender Gold computes the location of the bends as 3' 1½" or 37½" for the 2nd bend (which is the one we did first in the example above) and 2' 1-9/16" (25-9/16") for the 1st bend (which is the one we did second above). Master Bender Gold also says the distance between the bends is 11-15/16", which is close to the value of 12" we had above. Had we, however, chosen to do the bends in

different directions, the co-secant method could have been up to a couple of inches off. In our example, we are using a small angle and a conduit with a small diameter, so the difference between the co-secant approximation and the Master Bender Gold results are not very big.

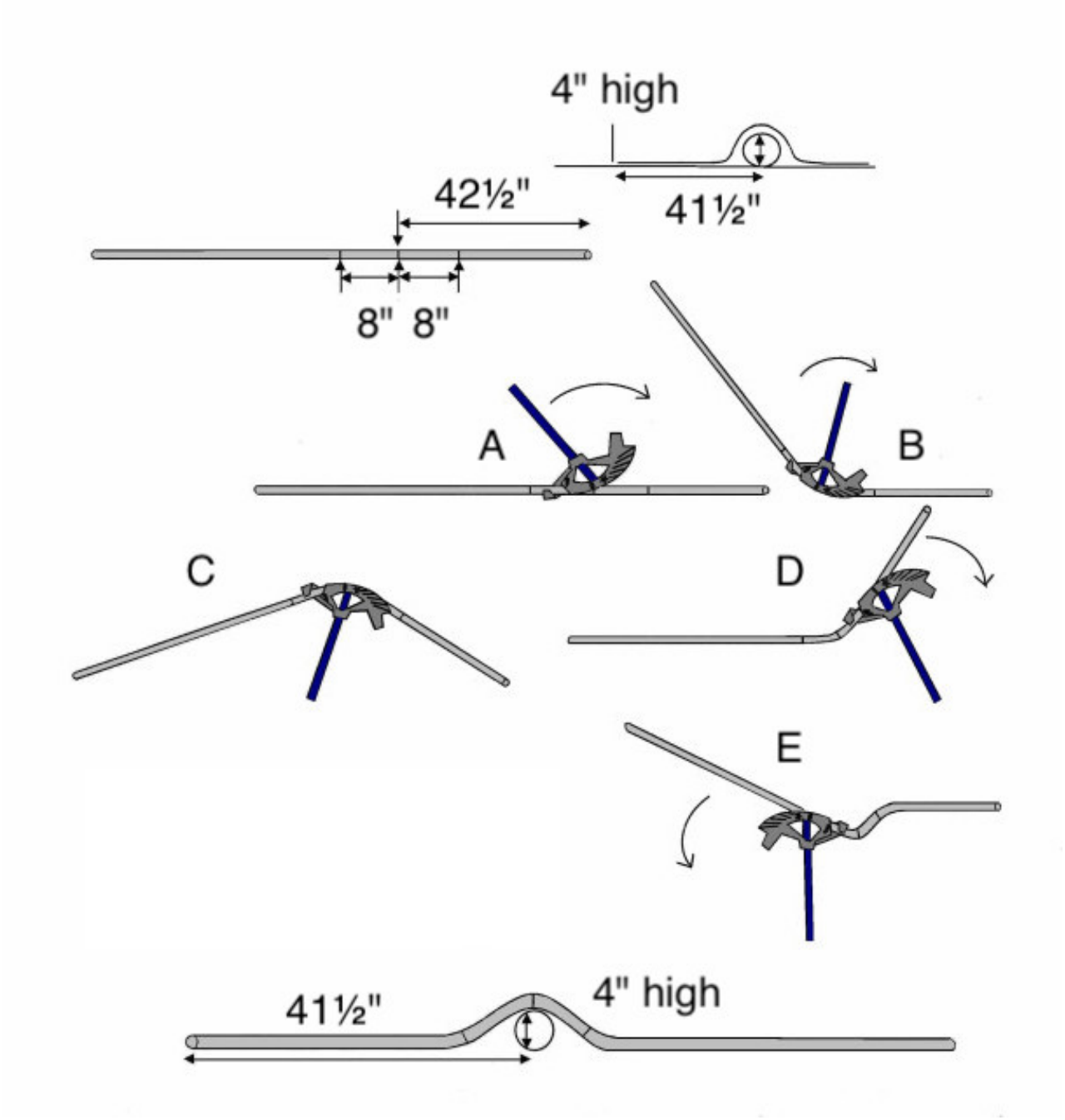
## THREE POINT SADDLE BEND

Determine the height of the obstacle. In the example, the height is 4". Determine the distance from the start of the raceway to the **center** of the obstacle. In the example, the distance is 41½". It is important to measure to the center-line and not to the front of the object.

Determine the angles you will use for the three bends. The center bend angle will be twice the other angles. In this example we will use a 60° center angle and 30° for the two outside bends, but 45° for the center bend and 22½° for the outside bends is also a common combination.

Use the table at the end of the book to determine the shrinkage and the distance between the bends. For a 30°-60°-30° three point saddle bend of height 4", the shrink is 1" and the distance between the bends is 8".

Place the first mark on the raceway a distance of 41½" plus the shrinkage amount of 1". This will 42½" away from the end of the raceway. Place the second mark 8" back from the first mark, and place the third mark 8" forward from the first mark. Be sure to mark all the way around the raceway when placing marks on the raceway.




Bend at the first mark (the mark that was placed on the raceway first, i.e., the center mark) using **rim notch** in the direction shown to 60°, where the 60° mark on the bender will be at the edge of the raceway. Leave the bender on the raceway. Pick up both the raceway and the bender and stand the handle on the floor as shown. Then slide the bender back to the second mark and roll the raceway 180°. Now place your hand and armpit on the raceway and bend a 30° angle on the

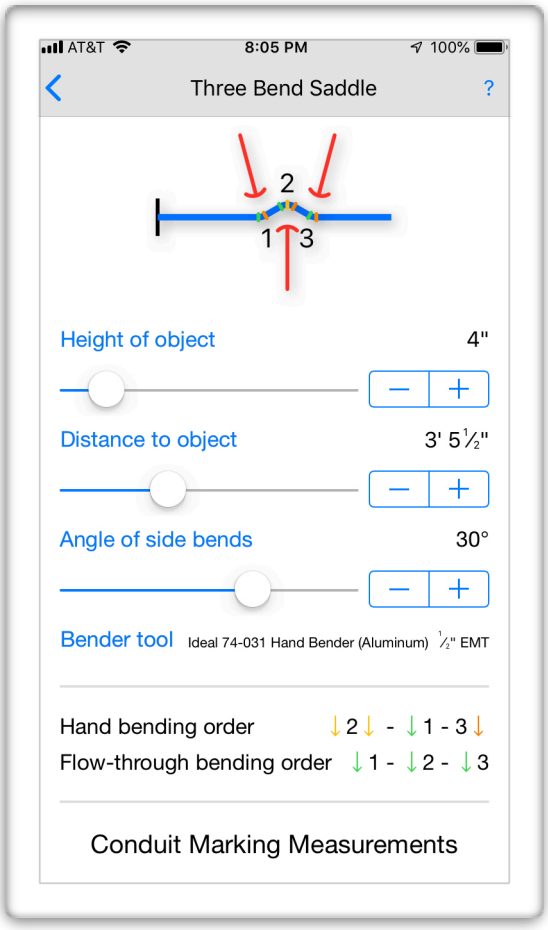
raceway at the **arrow**. Take the bender off the raceway and turn it in the opposite direction. Place the bender back on the raceway with the last mark at the arrow. For the last bend, place your hand and armpit on raceway and bend a 30° angle on the raceway at **arrow**.

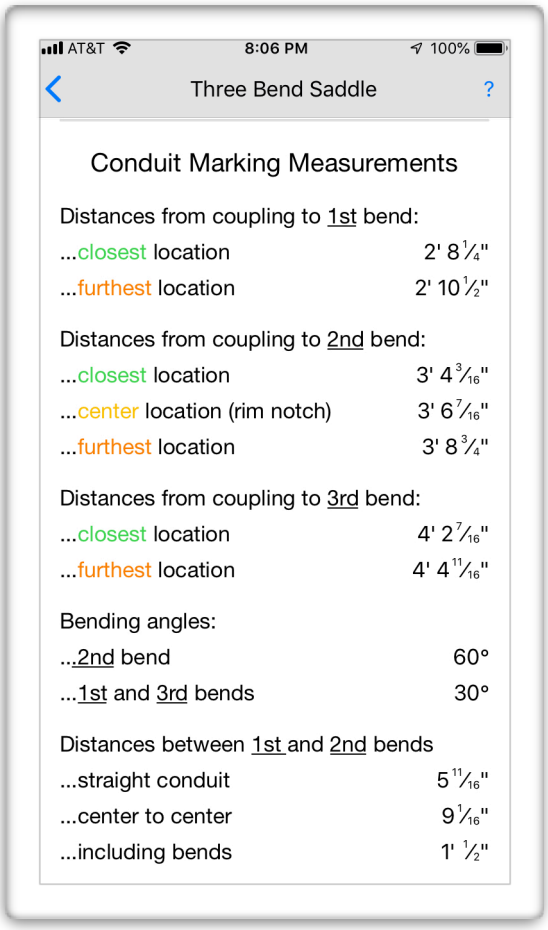
In the case of both of the outside bends, the arrow on the bender faces the center bend. This is important.

You should now have a 4" high three point saddle 41½" away from the end of the raceway. This was done using one 60° and two 30° bends. This combination is easy to remember and calculate: Distance between bends is twice the offset height, and the shrinkage amount is a quarter of the offset height. One could also say that the distance between bends is 2" for each inch of rise, and that the shrinkage amount is ¼" for each inch of rise.

Master Bender Gold can calculate three point saddle bends. Select your tool and size of conduit. We are here using the ½" Ideal Hand Bender. Enter the bend setup: The height of the object, the distance from the beginning of the raceway to the **center** of the object, and the **side** angles. Master Bender Gold will then compute the location of the three bends for you.

Master Bender Gold gives you the center of the saddle for use with the rim notch on your bender. It also gives you the location of the arrow mark for the two side bends (called 1st and 3rd bend) and for the center bend if you decide to use the arrow mark instead of the rim notch. Master Bender Gold gives two values for each arrow mark location depending on whether you are bending toward the beginning




of the raceway (called “toward the coupling”) or away from it (called “away from coupling”).

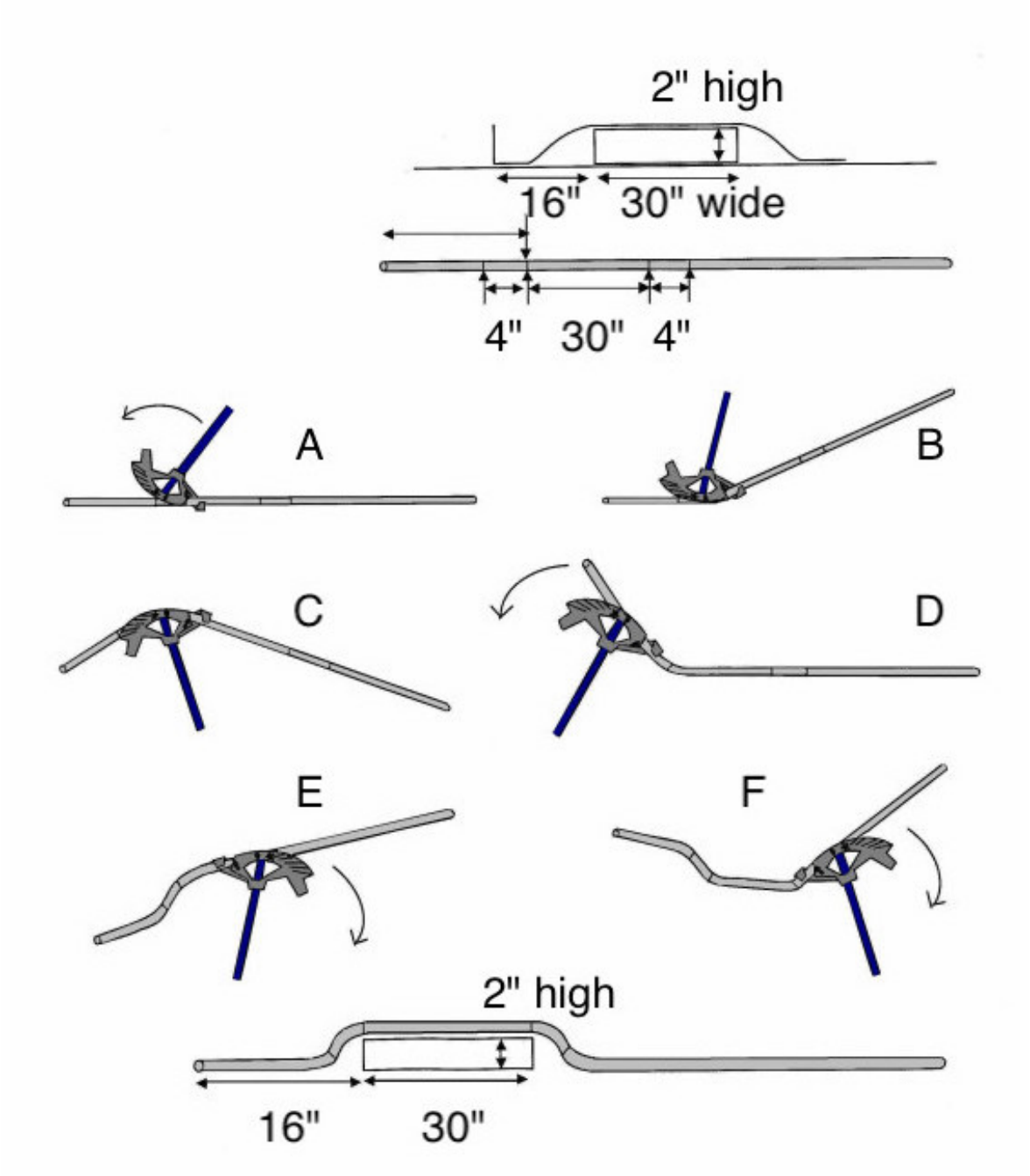
The rim notch on a hand bender indicates the center point of a 45° bend. Other benders may have more than one rim notch to indicate the center point for bends of 30° or 60°. If your bender does not have a rim notch for the center bend angle you want, you can use the arrow mark instead.

## FOUR POINT SADDLE BEND

Determine the height and width of the offset, and the distance from the beginning of the raceway to the front of the offset. In the example, the heights is 2", the width if 30", and the distance to the front of the

offset is 16". Determine the angle you will use for the four bends. You will use the same angle for all four bends. In this example, we will use 30°.

You can think of a four point saddle bend as two offset bends with the width of the object in between.



Use the tables at the back of this book to determine the shrinkage and the distance between the bends. For a 2" offset at 30°, the shrink is ½" and the distance between bends is 4".

Place the first mark on the raceway a distance of 16" plus the shrinkage amount of ½". This will be 16½" away from the end of the conduit. Place the second mark 4" back from the first mark. It is faster to measure 4" back than to subtract 4" from 16½" and place the mark at 12½". Place the third mark 30" past the first mark and the fourth mark 4" past the third mark. Be sure to mark all the way around the raceway when placing your marks.

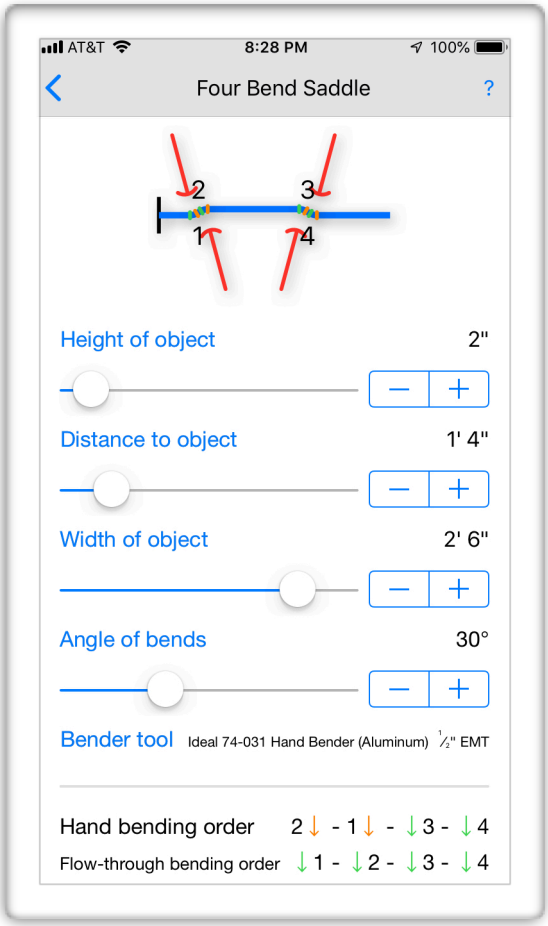
All four bends are done with the arrow mark side of the bender closest to the center of the obstacle.

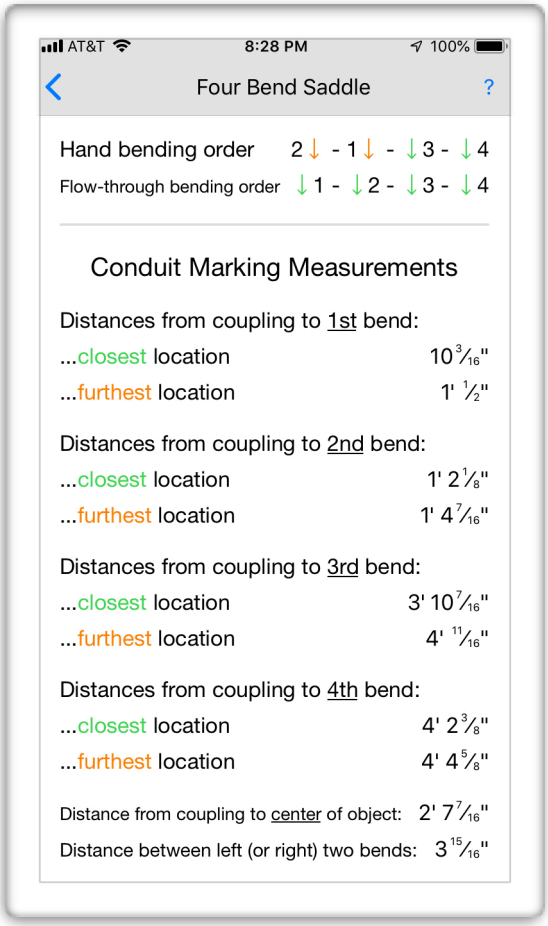
Place the bender on the raceway with the arrow at the first mark and bend the conduit to 30° as shown in figure A and B. Stop bending when the 30° mark on the bender is located at the edge of the raceway. Leave the bender on the raceway and pick up both the raceway and the bender and stand the bender handle on the floor as shown in figure C. Slide the bender back to the second mark and roll the raceway 180°. Place your hand and armpit on the raceway and bend a 30° angle on the raceway at the arrow as shown on figure D. Next, take the bender off the raceway. Turn the raceway the opposite direction and place it on the bender on the third mark at the arrow and bend it to a 30° angle as shown on figure E. Finally, slide the bender back to the fourth mark and roll the raceway 180°. Place your hand and armpit on the raceway and bend a 30° angle on the raceway at the arrow as shown

on figure F. This should give you a 2" high and 30" wide four point saddle 16" away from the end of the raceway.

This was done using 30° bends. This combination is easy to do and remember. The distance between bends is twice the height of the offset and the shrinkage amount is a quarter of the offset height. Or you could say for the distance between bends that you add 2" for each inch of offset rise, and for the shrinkage amount you add ¼" for each inch of offset rise.

Master Bender Gold can calculate four point saddle bends. Select your tool and size of conduit. We are here using the ½" Ideal Hand Bender. Enter the bend setup: The height of the object, the distance from the beginning of the raceway to the front of the object, the width of the



object, and the angle of the four bends. Master Bender Gold will then compute the location of the four bends for you.

Master Bender Gold gives you the location of the arrow mark for the four bends. Master Bender gives two values for each bend depending on whether you are bending toward the beginning of the raceway ("toward the coupling") or away from it ("away from coupling").

## MULTIPLE BENDS ON ONE RACEWAY

Often you'll need to perform multiple different bends on a conduit. For example, you may need to do an offset bend followed by a three point saddle bend. Each bend consists of multiple individual bends: The offset bend consists of two individual bends, and the three point saddle bend consists of three individual bends.

You begin by taking all the measurements for the raceway. You measure the dimensions of the objects, the distances, and you decide on angles for the bends. It can often help to make a drawing of the final raceway on a piece of paper. Even a simple sketch on the back of a napkin or scrap piece of wood can be useful.

Once you have the raceway planned out, mark the conduit for the first bend, and bend it.

Proceed to mark and bend the conduit one bend at a time.

In our example above, you would first mark and bend the offset bend. Once that is done, you will mark and bend the three point saddle bend.

Whenever multiple bends are placed on the same raceway, it is very easy to create a "dog leg," where the multiple bends do not line up with each other. The bends are not all in the same plane. This is a waste of conduit. Take your time before you make a bend. Check the alignment in all directions and make sure you have the bender placed on the correct side of the marks on the raceway.

It is often faster to slow down and do it right the first time than to hurry, make a mistake, and have to start from scratch.

## COMPARE WITH CO-SECANT

Master Bender Gold lets you chose "co-secant" as your bending tool. This way Master Bender Gold performs all calculations using the co-secant approximation method.

For offset bends, if you are not using the "co-secant" method, Master Bender Gold also compares the precise results directly to the co-secant method. This shows you how much the difference is, and essentially how much you could be off if you use the co-secant approximation.

The largest errors come from bends with large conduit diameters and large angles. Your bend could be off by inches, which can make your work look sloppy. This can be a big problem when doing exposé work.

## NEXT STEPS

If you have read this far in the book, you will now have a good understanding of the common types of bends used by electricians. The next step is to build up proficiency by trying it in practice.

As you start to bend conduit, remember the following things you have learned.

All the bends in this book are done with the marking on the raceway aligned to the bender's arrow, star, or rim notch:

- The only bend made with the **rim notch** is the center bend of a three point saddle bend.
- The only bend made with the **star** is the back-to-back bend.
- All other bends are made with the **arrow**.

Many bends can be made on the ground, but the more complicated bends must be made off the floor.

It is time to quit reading and get to bending. After you have practiced awhile, come back and re-read this book. You will be surprised at how fast you can bend. Remember: Master Bender Gold does **not** bend conduit – you do!

# TABLES

## Bender Gain Table

| Size of Conduit | 90° Gain |
|---|---|
| ½" EMT | 2½" |
| ¾" EMT | 3" |
| 1" EMT | 3 - 15/16'' |
| 1¼" EMT | 5 - 5/8" |
| ½" Rigid Steel | 3 - 1/16" |
| ¾" Rigid Steel | 3 - 13/16" |
| 1" Rigid Steel | 5 - 7/16" |

## Offset Formula

| Angle of Offset | Approximate Multiplier | Conduit Length Loss Per Inch of Depth |
|---|---|---|
| 10° | 5.67 | 1/16" |
| 22½° | 2.42 | 3/16" |
| 30° | 2.00 | ¼" |
| 45° | 1.42 | 3/8" |
| 60° | 1.15 | ½" |

## Take-Up for 90° Bends Using an EMT Bender

| Size and Type of Conduit | Take-Up |
|---|---|
| ½" EMT | 5" |
| ¾" EMT or ½" Rigid Steel | 6" |
| 1" EMT or ¾" Rigid Steel | 8" |
| 1¼" EMT or 1" Rigid Steel | 11" |

## Three Point Saddle Bend Chart

| 45° / 22½° | | | 60° / 30° | |
|---|---|---|---|---|
| **Height** | **Shrink** | **Between Bends** | **Shrink** | **Between Bends** |
| 1" | 3/16" | 2½" | ¼" | 2" |
| 2" | 3/8" | 5" | ½" | 4" |
| 3" | 9/16" | 7½" | ¾" | 6" |
| 4" | 3⁄4" | 10" | 1" | 8" |
| 5" | 15/16" | 12½" | 1¼" | 10" |
| 6" | 1-1/8" | 15" | 1½" | 12" |
| Add for each additional inch | 3/16" | 2½" | ¼" | 2" |

## 10° Offset Bend and Four Point Saddle Chart

| Offset Depth | Shrink | Distance Between Bends |
|---|---|---|
| ½" | 1/16" | 2 - 7/8" |
| 1" | 1/16" | 5¾" |
| 1½" | 1/8" | 8 - 5/8" |
| 2" | 1/8" | 11½" |
| 2½" | 3/16" | 14 - 3/8" |
| 3" | 3/16" | 17¼" |
| 3½" | ½" | 20 - 1/8" |
| 4" | ½" | 23 - 1/9" |
| 4½" | 5/16" | 25 - 8/9" |
| 5" | 5/16" | 28 - 4/5" |
| 5½" | 3/8" | 31 - 2/3" |
| 6" | 3/8" | 34 - 5/9" |
| 6½" | 7/16" | 37 - 4/9" |
| 7" | 7/16" | 40 - 1/3" |
| 7½" | ½" | 43 - 1/5" |
| 8" | ½" | 46 - 1/9" |
| 8½" | 9/16" | 48 - 8/9" |
| 9" | 9/16" | 51 - 4/5" |
| 9½" | 5/8" | 54 - 2/3" |
| 10" | 5/8" | 57 - 5/9" |
| 11" | 11/16" | 63 - 3/8" |
| 12" | ¾" | 69 - 1/8" |
| 13" | 13/16" | 74 - 7/8" |
| 14" | 7/8" | 80 - 5/8" |
| 15" | 15/16" | 86 - 3/8" |
| 16" | 1" | 92 - 1/8" |
| 17" | 1 - 1/16" | 97 - 7/8" |
| 18" | 1 - 1/8" | 103 - 2/3" |
| 19" | 1 - 3/16" | 109 - 4/9" |
| 20" | 1¼" | 115 - 1/5" |
| 21" | 5/16" | 120 - 8/9" |
| 22" | 1 - 3/8" | 126 - 2/3" |
| 23" | 1 - 7/16" | 132 - 4/9" |
| 24" | 1½" | 138 - 1/5" |
| 25" | 1 - 9/16" | 144" |

## 22½° Offset Bend and Four Point Saddle Chart

| Offset Depth | Shrink | Distance Between Bends |
|---|---|---|
| ½" | 1/8" | 1 - 1/3" |
| 1" | 1/5" | 2 5/8" |
| 1½" | 1/3" | 3 - 8/9" |
| 2" | 3/8" | 5¼" |
| 2½" | ½" | 6 - 5/9" |
| 3" | 5/9" | 7 - 4/5" |
| 3½" | 11/16" | 9 - 1/8" |
| 4" | ¾" | 10 - 7/8" |
| 4½" | 7/8" | 11¾" |
| 5" | 8/9" | 13 - 1/9" |
| 5½" | 1 - 1/9" | 14 - 3/8" |
| 6" | 1 - 1/8" | 15 - 2/3" |
| 6½" | 1¾" | 17" |
| 7" | 1 - 8/9" | 18 - 1/3" |
| 7½" | 1 - 4/9" | 19 - 5/8" |
| 8" | 1½" | 20 - 7/8" |
| 8½" | 1 - 5/8" | 22 - 1/5" |
| 9" | 1 - 2/3" | 23½" |
| 9½" | 1 - 4/5" | 24 - 4/5" |
| 10" | 1 - 7/8" | 26 - 1/8" |
| 11" | 2 - 1/9" | 28¾" |
| 12" | 2¼" | 31 - 3/8" |
| 13" | 2 - 4/9" | 34" |
| 14" | 2 - 5/8" | 38 - 5/9" |
| 15" | 2 - 4/5" | 39 - 1/5" |
| 16" | 3" | 41 - 4/5" |
| 17" | 3 - 1/5" | 44 - 4/9" |
| 18" | 3 - 3/8" | 47 - 1/9" |
| 19" | 3 - 5/9" | 49 - 5/8" |
| 20" | 3¾" | 52¼" |
| 21" | 3 - 8/9" | 54 - 7/8" |
| 22" | 4 - 1/8" | 57½" |
| 23" | 4 - 1/3" | 60 - 1/8" |
| 24" | 4½" | 62 - 2/3" |
| 25" | 4 - 2/3" | 65 - 1/3" |

# 30° Offset Bend and Four Point Saddle Chart

| Offset Depth | Shrink | Distance Between Bends |
|---|---|---|
| ½" | 1/8" | 1" |
| 1" | ¼" | 2" |
| 1½" | 3/8" | 3" |
| 2" | ½" | 4" |
| 2½" | 5/8" | 5" |
| 3" | ¾" | 6" |
| 3½" | 7/8" | 7" |
| 4" | 1" | 8" |
| 4½" | 1 - 1/8" | 9" |
| 5" | 1¼" | 10" |
| 5½" | 1 - 3/8" | 11" |
| 6" | 1½" | 12" |
| 6½" | 1 - 5/8" | 13" |
| 7" | 1¾" | 14" |
| 7½" | 1 - 7/8" | 15" |
| 8" | 2" | 16" |
| 8½" | 2 - 1/'8" | 17" |
| 9" | 2¼" | 18" |
| 9½" | 2 - 3/8" | 19" |
| 10" | 2½" | 20" |
| 11" | 2¾" | 22" |
| 12" | 3" | 24" |
| 13" | 3¼" | 26" |
| 14" | 3½" | 28" |
| 15" | 3¾" | 30" |
| 16" | 4" | 32" |
| 17" | 4¼" | 34" |
| 18" | 4½" | 36" |
| 19" | 4¾" | 38" |
| 20" | 5" | 40" |
| 21" | 5¼" | 42" |
| 22" | 5½" | 44" |
| 23" | 5¾" | 46" |
| 24" | 6" | 48" |
| 25" | 6½" | 50" |

# 45° Offset Bend and Four Point Saddle Chart

| Offset Depth | Shrink | Distance Between Bends |
|---|---|---|
| ½" | 1/5" | 1 - 1/9" |
| 1" | 3/8" | 1 - 4/9" |
| 1½" | 5/9" | 2 - 1/8" |
| 2" | ¾" | 2 - 4/5" |
| 2½" | 8/9" | 3 - 5/9" |
| 3" | 1 - 1/8" | 4¼" |
| 3½" | 1 - 1/3" | 5 - 8/9" |
| 4" | 1½" | 5 - 2/3" |
| 4½" | 1 - 2/3" | 6 - 3/8" |
| 5" | 1 - 7/8" | 7 - 1/9" |
| 5½" | 2 - 1/9" | 7¾" |
| 6" | 2¼" | 8½" |
| 6½" | 2 - 4/9" | 9 - 1/5" |
| 7" | 2 - 5/8" | 9 - 7/8" |
| 7½" | 2 - 4/5" | 10 - 5/8" |
| 8" | 3" | 11 - 1/3" |
| 8½" | 3 - 1/5" | 12" |
| 9" | 3 - 3/8" | 12¾" |
| 9½" | 3 - 5/9" | 13 - 4/9" |
| 10" | 3¾" | 14 - 1/8" |
| 11" | 4 - 1/8" | 15 - 5/9" |
| 12" | 4½" | 17" |
| 13" | 4 - 7/8" | 18 - 3/8" |
| 14" | 5¼" | 19 - 4/5" |
| 15" | 5 - 5/8" | 21 - 1/5" |
| 16" | 6" | 22 - 5/8" |
| 17" | 6 - 3/8" | 24 - 1/9" |
| 18" | 6¾" | 25 - 4/9" |
| 19" | 7 - 1/8" | 26 - 7/8" |
| 20" | 7½" | 28 - 1/3" |
| 21" | 7 - 7/8" | 29 - 11/16" |
| 22" | 8¼" | 31 - 1/8" |
| 23" | 8 - 5/8" | 32½" |
| 24" | 9" | 33 - 8/9" |
| 25" | 9 - 3/8" | 35 - 3/8" |

# 60° Offset Bend and Four Point Saddle Chart

| Offset Depth | Shrink | Distance Between Bends |
|---|---|---|
| ½" | ¼" | 9/16" |
| 1" | ½" | 1 - 1/8" |
| 1½" | ¾" | 1¾" |
| 2" | 1" | 2 - 5/16" |
| 2½" | 1¼" | 2 - 7/8" |
| 3" | 1½" | 3 - 7/16" |
| 3½" | 1¾" | 4 - 1/16" |
| 4" | 2" | 4 - 5/8" |
| 4½" | 2¼" | 5 - 3/16" |
| 5" | 2½" | 5¾" |
| 5½" | 2¾" | 6 - 3/8" |
| 6" | 3" | 6 - 15/16" |
| 6½" | 3¼" | 7½" |
| 7" | 3½" | 8 - 1/16" |
| 7½" | 3¾" | 8 - 11/16" |
| 8" | 4" | 9¼" |
| 8½" | 4¼" | 9 - 13/16" |
| 9" | 4½" | 10 - 5/8" |
| 9½" | 4¾" | 11" |
| 10" | 5" | 11 - 9/16" |
| 11" | 5½" | 12 - 11/16" |
| 12" | 6" | 13 - 7/8" |
| 13" | 6½" | 15" |
| 14" | 7" | 16 - 3/16" |
| 15" | 7½" | 17 - 5/16" |
| 16" | 8" | 18½" |
| 17" | 8½" | 19 - 5/8" |
| 18" | 9" | 20 - 13/16" |
| 19" | 9½" | 21 - 15/16" |
| 20" | 10" | 23 - 1/8" |
| 21" | 10½" | 24¼" |
| 22" | 11" | 25 - 3/8" |
| 23" | 11½" | 26 - 9/16" |
| 24" | 12" | 27 - 11/16" |
| 25" | 12½" | 26 - 7/8" |

# Fractional / Decimal Conversion

| 8th | 16th | 32nd | 64th | Decimal | From | - | To |
|---|---|---|---|---|---|---|---|
| | | | 1/64 | 0.016 | 0.008 | - | 0.023 |
| | | 1/32 | 1/32 | 0.031 | 0.024 | - | 0.039 |
| | | | 3/64 | 0.047 | 0.040 | - | 0.055 |
| | 1/16 | 1/16 | 1/16 | 0.063 | 0.056 | - | 0.070 |
| | | | 5/64 | 0.078 | 0.071 | - | 0.086 |
| | | | 3/32 | 0.094 | 0.087 | - | 0.102 |
| | | | 7/64 | 0.109 | 0.103 | - | 0.117 |
| 1/8 | 1/8 | 1/8 | 1/8 | 0.125 | 0.118 | - | 0.133 |
| | | | 9/64 | 0.141 | 0.134 | - | 0.148 |
| | | 5/32 | 5/32 | 0.156 | 0.149 | - | 0.164 |
| | | | 11/64 | 0.172 | 0.165 | - | 0.180 |
| | 3/16 | 3/16 | 3/16 | 0.188 | 0.181 | - | 0.195 |
| | | | 13/64 | 0.203 | 0.196 | - | 0.211 |
| | | 7/32 | 7/32 | 0.219 | 0.212 | - | 0.227 |
| | | | 15/64 | 0.234 | 0.228 | - | 0.242 |
| 1/4 | 1/4 | 1/4 | 1/4 | 0.250 | 0.243 | - | 0.258 |
| | | | 17/64 | 0.266 | 0.259 | - | 0.273 |
| | | 9/32 | 9/32 | 0.281 | 0.274 | - | 0.289 |
| | | | 19/64 | 0.297 | 0.290 | - | 0.305 |
| | 5/16 | 5/16 | 5/16 | 0.313 | 0.306 | - | 0.320 |
| | | | 21/64 | 0.328 | 0.321 | - | 0.336 |
| | | 11/32 | 11/32 | 0.344 | 0.337 | - | 0.352 |
| | | | 23/64 | 0.359 | 0.353 | - | 0.367 |
| 3/8 | 3/8 | 3/8 | 3/8 | 0.375 | 0.368 | - | 0.383 |
| | | | 25/64 | 0.391 | 0.384 | - | 0.398 |
| | | 13/32 | 13/32 | 0.406 | 0.399 | - | 0.414 |
| | | | 27/64 | 0.422 | 0.415 | - | 0.430 |
| | 7/16 | 7/16 | 7/16 | 0.438 | 0.431 | - | 0.445 |
| | | | 29/64 | 0.453 | 0.446 | - | 0.461 |
| | | 15/32 | 15/32 | 0.469 | 0.462 | - | 0.477 |
| | | | 31/64 | 0.484 | 0.478 | - | 0.492 |
| 1/2 | 1/2 | 1/2 | 1/2 | 0.500 | 0.493 | - | 0.508 |
| | | | 33/64 | 0.516 | 0.509 | - | 0.523 |
| | | 17/32 | 17/32 | 0.531 | 0.524 | - | 0.539 |

| 8th | 16th | 32nd | 64th | Decimal | From | - | To |
|---|---|---|---|---|---|---|---|
| | | | 35/64 | 0.547 | 0.540 | - | 0.555 |
| | 9/16 | 9/16 | 9/16 | 0.563 | 0.556 | - | 0.570 |
| | | | 37/64 | 0.578 | 0.571 | - | 0.586 |
| | | 19/32 | 19/32 | 0.594 | 0.587 | - | 0.602 |
| | | | 39/64 | 0.609 | 0.603 | - | 0.617 |
| 5/8 | 5/8 | 5/8 | 5/8 | 0.625 | 0.618 | - | 0.633 |
| | | | 41/64 | 0.641 | 0.634 | - | 0.648 |
| | | 21/32 | 21/32 | 0.656 | 0.649 | - | 0.664 |
| | | | 43/64 | 0.672 | 0.665 | - | 0.680 |
| | 11/16 | 11/16 | 11/16 | 0.688 | 0.681 | - | 0.695 |
| | | | 45/64 | 0.703 | 0.696 | - | 0.711 |
| | | 23/32 | 23/32 | 0.719 | 0.712 | - | 0.727 |
| | | | 47/64 | 0.734 | 0.728 | - | 0.742 |
| 3/4 | 3/4 | 3/4 | 3/4 | 0.750 | 0.743 | - | 0.758 |
| | | | 49/64 | 0.766 | 0.759 | - | 0.773 |
| | | 25/32 | 25/32 | 0.781 | 0.774 | - | 0.789 |
| | | | 51/64 | 0.797 | 0.790 | - | 0.805 |
| | 13/16 | 13/16 | 13/16 | 0.813 | 0.806 | - | 0.820 |
| | | | 53/64 | 0.828 | 0.821 | - | 0.836 |
| | | 27/32 | 27/32 | 0.844 | 0.837 | - | 0.852 |
| | | | 55/64 | 0.859 | 0.853 | - | 0.867 |
| 7/8 | 7/8 | 7/8 | 7/8 | 0.875 | 0.868 | - | 0.883 |
| | | | 57/64 | 0.891 | 0.884 | - | 0.898 |
| | | 29/32 | 29/32 | 0.906 | 0.899 | - | 0.914 |
| | | | 59/64 | 0.922 | 0.915 | - | 0.930 |
| | 15/16 | 15/16 | 15/16 | 0.938 | 0.931 | - | 0.945 |
| | | | 61/64 | 0.953 | 0.946 | - | 0.961 |
| | | 31/32 | 31/32 | 0.969 | 0.962 | - | 0.977 |
| | | | 63/64 | 0.984 | 0.978 | - | 0.992 |
| 1 | 1 | 1 | 1 | 1.000 | 0.993 | - | 1.000 |

# APPS FOR ELECTRICIANS

We have written a number of apps for electricians. They can be downloaded from Apple's App Store for your iOS or iPadOS devices.

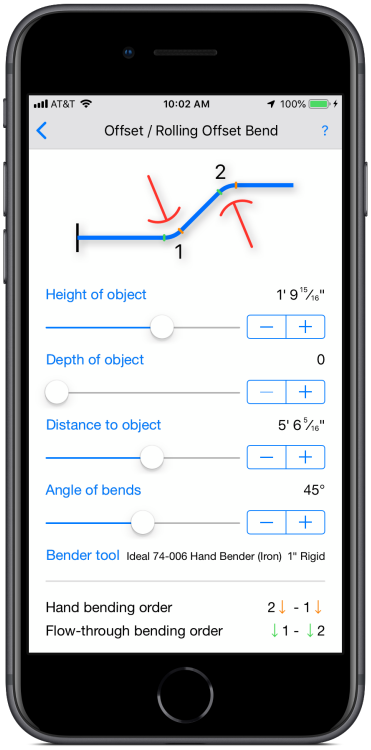
See www.MasterSparky.com for details.

## MASTER BENDER GOLD

### Bending Guide for Electricians

**Master Bender Gold** is not just a bending calculator but a complete bending guide. We are the industry's leading and most precise conduit bending app since 2007. Are you using the best conduit bending app?

Master Bender Gold is the industry's leading and most precise conduit bending app.




Master Bender Gold is a conduit bending calculator for electricians. Master Bender Gold can also be used by plumbers and pipe fitters, who can enter their own tools into the app.

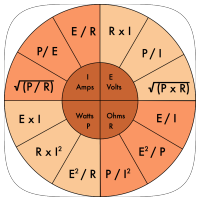
Master Bender Gold aids you in bending conduit raceways. It takes the math out of bending and allows you to concentrate on the task at hand.

Master Bender Gold supports the following types of bends: offset bends and rolling offset

bends, three and four point saddle bends, parallel bends, segment bends, concentric bends, gain/take-up, and 90 degree bends around a round, square, and rectangular object. It supports both cosecant and precision bending formulas using the centerline radius of the bend.

## MASTER ELECTRICIAN REFERENCE

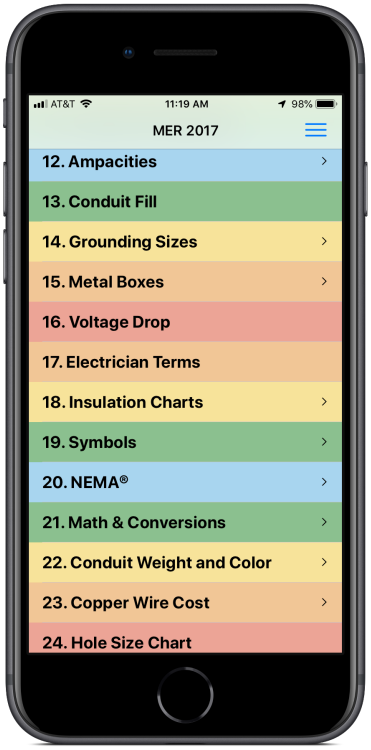
### Reference Book for Electricians




Many States are now using 2017 NEC, so make sure you get **Master Electrician Reference 2017** today. It is **the** handbook for electricians — and it costs less than most paper handbooks.

Master Electrician Reference (or MER for short) is your electronic pocket electrician reference guide.

MER is for electrical designers, engineers, installers, contractors, facility managers, inspectors, exam candidates, apprentices, electricians, journeymen, architects, and technicians. MER is for people doing residential, industrial, and commercial work. Simply, if you are a Master Sparky or work with electricity in any way, this reference guide is for you!



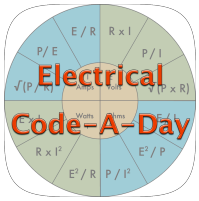

Have you ever lost pages or had damaged pages in your pocket electricians reference? The solution is here: Use MER to keep the most

important information easily accessible on your phone or tablet. MER will even do calculations for you; something your old pocket reference book can't do.

MER contains the answers to many of the questions in the Electrical Code-A-Day app.

## ELECTRICAL CODE-A-DAY

### Quiz for Electricians (free)




Electrical Code-A-Day has an electrical code question for each day in the year. Take a minute a day to answer a question, or answer as many as you can in one go. How you do it is up to you!

This quiz app contains basic electrician questions written by a real electrician.

This app is for apprentices, journeymen, and masters. Whether you are learning the code or just need a refresher, this is the app for you.

Can you beat the Master? See how many of the 366 questions you can answer correctly!