

# Welding Math Packet

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## HOW TO USE THIS PACKET

This packet is meant to be used as a reference guide and a learning tool. It contains nearly all of the math worksheets that were developed for the *Math on Metals Project* which have been interspersed throughout all of the welding packets. The worksheets have been collected, edited, and rearranged in an order that we hope will be helpful to all welding students, whether you are taking just a few classes for welding skills upgrade or you are a degree or certificate seeking student.

When compiling this math reference packet, care was taken to build on skills, starting from the most basic (whole number, addition, subtraction, multiplication, division) moving on quickly to fractions, decimals, ratios, percentages, formulas and geometry. Throughout the math worksheets and this packet, applications of the skills have been tied directly to the welding projects and problems you will encounter in the classroom and on the job.

Although the skills build in a logical order, this reference guide is not necessarily meant to be started at the beginning and moved through on a step-by-step basis, but rather it is intended to be used to fill in math knowledge gaps and to provide examples of math applications that would be helpful to welders.

Using the detailed table of contents you should be able to locate the specific math application and also the background theory that you may need in order to gain a thorough understanding of any math related problem you encounter. An example might be that you are having trouble understanding how to calculate heat input on a welding job. You could go to the heat input section found in the table of contents. If all you need is a refresher on the formula it is located there. If you discover that you also need more information on how to solve formulas, then you would look to the formula section for more explanation on how to use a formula and order of operation.

At the end of each application worksheet you will find a list of other worksheets contained in this packet that may be helpful for a fuller understanding of the application worksheet.

Although the math in this packet is meant for the most part to be both self explanatory and self paced, you may encounter problems in using this packet. Please ask your instructor for clarification. Some answers have been provided in the math packet itself, your instructor will have separate detailed answer sheets that they can make available to you at their discretion.

# **WHOLE NUMBERS**

## **ADDING, SUBTRACTING, MULTIPLYING & DIVIDING**

Applications:

- All welding applications
- Measurement
- Blueprint reading

## READING NUMBERS

### Understanding the Decimal Point

The most important part of any number is the decimal point. Every number is written around a decimal point. Whole units are located to the left of it, and anything less than a whole unit is located to the right of it. The decimal point may be considered as a point of reference, identifying each digit by its relative position. For example, the following number (1,534.367) is read: one thousand, five hundred thirty-four and three hundred sixty-seven thousandths. This means there are 1,534 whole units, plus  $367/1000$  of one unit. When you see a decimal point in a number, you read it as **and**. The number 36.55 is read thirty six **and** fifty five hundredths. To learn more about reading decimals and what they mean turn to the section on decimals.

The following are examples of numbers and how they are read:

12,978,543.896	Twelve million, nine hundred seventy-eight thousand, five hundred forty-three and eight hundred ninety-six thousandths.
1,423,601.78	One million, four hundred twenty-three thousand, six hundred
670,809.9	Six hundred seventy thousand, eight hundred nine and nine tenths.
56,206	Fifty-six thousand, two hundred six.
7,000	Seven thousand.
3,980	Three thousand, nine hundred eighty.



## ADDITION AND SUBTRACTION OF WHOLE NUMBERS

**Addition** is the process of combining two or more numbers to obtain a number called their sum or total.

The numbers being added are **Addends**.

43.89 **Addend**

17.98 **Addend**

The result is the **Sum**.

61.87 **Sum**

To prove the accuracy of your addition, you merely reverse the order and add again.

**Subtraction** is the process of finding the difference between two numbers.

The number from which another is to be subtracted is the **Minuend**.

The number to be subtracted from another is the **Subtrahend**.

The result is the **Difference** or **Remainder**

890 **Minuend**

-78 **Subtrahend**

812 **Difference**

To prove the accuracy of your subtraction, you add the Difference to your Subtrahend and the result should be the same as your Minuend.

812 difference

+78 Subtrahend

890 Sum

**Note:** when using your calculator to add numbers you can enter the numbers (addends) in any order. Example;  $5 + 2 = 7$  or  $2 + 5 = 7$ .

When you subtract using the calculator be sure and enter the Minuend first (even if it is a smaller number) then enter the subtrahend in order to get the difference.

Example:  $7 - 2 = 5$

If you enter  $7-2$  incorrectly (entering the 2 first) you will get a negative number (-5) that is an incorrect answer.

# MULTIPLICATION OF WHOLE NUMBERS

Multiplication is repeated addition.

The number to be multiplied is the **Multiplicand**.

The number by which another is multiplied is the **Multiplier**.

The result of the multiplication is the **Product**.

Although the multiplicand and multiplier are  
Inter-changeable, the product is always the same.

$$\begin{array}{r} 1245 \text{ **Multiplicand** } \\ \times 19 \text{ **Multiplier** } \\ \hline 11,205 \\ 1245\text{ } \\ \hline 23655 \text{ **Product** } \end{array}$$

If one number is larger than the other, the larger number is usually used as the multiplicand.

**Note:** You can use your calculator to solve multiplication numbers. You can enter the Multiplicand and the multiplier in any order **but it is a good idea to enter the numbers as they are written from left to right or top to bottom**. This will make it less confusing when you are solving more complicated problems.

$$\text{Example: } 1245 \times 19 = 23,655$$

## DIVISION OF WHOLE NUMBERS

Division is repeated subtraction.

The number to be divided by another is the **Dividend**.

The number by which another is divided is the **Divisor**.

The result of the division is the **Quotient**.

Any part of the dividend left over when the quotient is not exact is the **Remainder**.

50/10 The 50 is the Dividend and the 10 is the Divisor

50÷10 = 5      5 is the **Quotient**

The division sign (/) means "divided by." However, a division problem may be set up in several acceptable ways. For example,

$\frac{50}{10}$    or   50 ÷ 10   or   50/10   all mean the same thing

**You can use your calculator to solve division problems. Remember to put the top number or the divisor into the calculator first, then follow with the division symbol (÷) and then the bottom number or dividend.**

**Example: 50 ÷ 10 = 5.**

If you enter it wrong (putting the bottom number or the dividend in first) you will not get the correct answer on the calculator.

To prove the accuracy of your division, multiply the Quotient by the Divisor and add the Remainder, (if there is one) to the result. The final product should be the same figure as your Dividend.

Proof      5    Quotient  
          x 10    Divisor  
          50    Dividend

# SCIENTIFIC CALCULATOR

Applications:

- Solving formulas
- Adding, subtracting, multiplying and dividing fractions
- Combining fractions and decimals
- Converting fractions to decimals
- Converting decimals to fractions

# USING YOUR SCIENTIFIC CALCULATOR

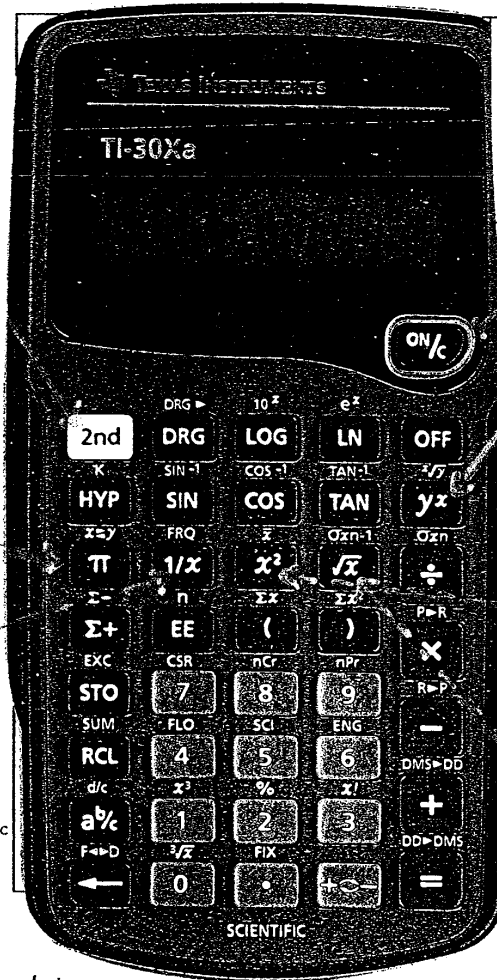
## Tooling around on your TI-30Xa

This yellow "2<sup>nd</sup>" button is like the shift key on a keyboard. You use it with another key to get the function written in yellow above the other key.

Here is the pi key  $\approx 3.14$

1/x is used for reciprocals, esp. in parallel circuits

These bottom 2 keys are for fractions; a b/c and above the backspace key  $\leftarrow$ , the 2<sup>nd</sup> function of F $\leftrightarrow$ D to convert fractions to decimals and vice versa.



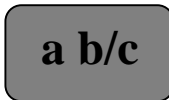
You can use the "On/C" button not only to turn your new tooltoy on, but also to clear the last number (even multiple digit numbers) you entered. Pressing it 2x will clear everything

The "y<sup>x</sup>" button is used for powers of 3 or more, like 5<sup>4</sup> and 10<sup>6</sup>. You use it just like the fraction key; put the base number then press "y<sup>x</sup>", then press the exponent followed by "=".

The "x<sup>2</sup>" button is to get the squares of numbers, i.e. 5<sup>2</sup> gets you 25, done in the same way as the "y<sup>x</sup>" key; Press 5 then the x<sup>2</sup>.

The  $\sqrt{x}$  key gives you square roots; Press 36 then  $\sqrt{x}$ , and you get 6.

# OPERATING THE FRACTION KEY ON A TI-30Xa



Your calculator has been programmed to do fractions, but they appear on the display in an unusual way:

$\frac{1}{2}$  looks like 1  $\downarrow$  2

$\frac{5}{16}$  looks like 5  $\downarrow$  16

$9\frac{3}{4}$  looks like 9 \_ 3  $\downarrow$  4

**Can you identify these?**

$$\begin{array}{lcl} 7\_1 \downarrow 4 & = & \underline{\hspace{2cm}} \\ 11 \downarrow 16 & = & \underline{\hspace{2cm}} \end{array} \qquad \begin{array}{lcl} 14\_1 \downarrow 8 & = & \underline{\hspace{2cm}} \\ 23\_5 \downarrow 8 & = & \underline{\hspace{2cm}} \end{array}$$

Here's how to enter fractions and mixed numbers on your calculator:

To enter  $\frac{3}{4}$  :

Press 3

Press 

Press 4

*It should read:* 3  $\downarrow$  4

To enter  $15\frac{6}{8}$ :

Press 15

Press 

Press 6

Press 

Press 8



*It should read:* 15 \_ 6  $\downarrow$  8

To reduce to lowest terms, press  . Did you get 15 \_ 3  $\downarrow$  4?

F« D

To change to a decimal number, press  and  at the same time.

Did you get 5.75?

To switch back to the fraction form, press  and  to

## MAKING SURE YOUR ANSWER IS CORRECT WHEN USING A CALCULATOR

If we are to rely on the calculator instead of doing numbers on paper or in our heads, we need to do/know two things.

- (1) We need to run every problem through the calculator twice to be sure that we didn't push any unwanted keys or skip wanted ones.
- (2) We need to have an understanding of what size of number we should get as an answer. Should it be smaller than our original number or larger? Should it be less than one, under ten, in the thousands, or a negative number?

To help out with (2), it is important to understand some things about multiplying and dividing numbers.

- Multiplying and dividing are related operations. Multiplying by two is the "opposite" of dividing by two, just like adding and subtracting are opposites.
- Multiplying by a number/fraction is the same as dividing by its reciprocal. For example, multiplying by  $\frac{1}{2}$  is the same as dividing by  $\frac{2}{1}$  or 2. Dividing by  $\frac{3}{4}$  is the same as multiplying by  $\frac{4}{3}$ . Multiplying by 8 is the same as dividing by  $\frac{1}{8}$ .

$$2 \times 8 = 16 = 2 \div \frac{1}{8}$$

This last one makes sense if you think of cutting up pizza. If you cut your 2 pizzas into eight slices (dividing them into eighths ( $\frac{1}{8}$ 's)) per pie, you are multiplying the number of pizzas by 8 to get 16 slices. You can check this using your calculator and fraction key.

- Multiplying a number by a number greater than one will make your answer larger than the **original number**, like when we multiply  $7 \times 2 = 14$ . Dividing a number by a number greater than one will make your answer smaller than the **original number**, like when we calculate  $10 \div 2 = 5$ . Multiplying or dividing by one will not change anything. This is what we were taught in elementary school.
- However, multiplying a number by a number **less than one** will get us an answer that is smaller than our original number. Why? Because when we multiply a number by something less than one, we are saying



that we want less than the whole (100%) value of that original number, just like when we multiply by  $\frac{1}{2}$  to get half of something, a smaller number or size. This works, also, with multiplying two numbers both less than one. Notice how  $\frac{1}{2}$  of  $\frac{1}{2} = \frac{1}{4}$ , which is smaller than both of the original numbers.

- By the same weird and wonderful logic, when we divide a number by something smaller than one, we will get a larger number -- like with the pizza slices. We are chopping our quantities into smaller pieces, less than their whole original size, and therefore, we will get more pieces than we started with.
- *More useful information: multiplying by .5 is taking  $\frac{1}{2}$* 
  - *multiplying by .25 is taking  $\frac{1}{4}$*
  - *multiplying by .75 is taking  $\frac{3}{4}$*
  - *multiplying by .33 is taking  $\frac{1}{3}$*

For the following problems, use your head only, no paper, pen, slide rule or calculator to answer the questions. First circle whether the number is smaller than . . . or larger than . . . , and then use the multiple choice to choose the number closest to the answer. Then use your calculator to check your answers.

1. Which of the following is the **closest** to the answer for  $103 \div \frac{1}{5}$  ?  
*Circle one:      larger than 103                      smaller than 103*  
(a) 500  
(b) 21  
(c)  $103/5$   
(d) .002
2. Which of the following is the **closest** to the answer for  $.5 \times 78$  ?  
*Circle one:      larger than 78                      smaller than 78      {Hint: same as  $78 \times .5$ }*  
(a) 400  
(b) 40  
(c) .4
3. Which of the following is the **closest** to the answer for  $47 \div \frac{1}{8}$  ?  
*Circle one:      larger than 47                      smaller than 47*  
(a) 10  
(b) 40  
(c) 400

4. Which of the following is the **closest** to the answer for  $256 \times .9$   
Circle one:    larger than 256       very close to 256       smaller than 256  
                  {Hint: use rounding to get an approximate answer}

- (a) 25
- (b) 2500
- (c) 250
- (d) 3

# FRACTION

Applications:

- measuring
- using a ruler
- reading blueprints
- choosing the correctly sized tools
- determining tolerances
- layout
- fabrication

## UNDERSTANDING FRACTIONS

The welding fabrication industry requires the everyday use of fractions. Besides simple tape rule measurement, it is often necessary to add, subtract, multiply and divide fractions. Before practicing performing these kinds of calculations, it's a good idea to know a few other fraction skills.



Look at this bar. Notice that it has 4 sections. Three of the sections are shaded, the fourth is white

Take a look at this fraction:  $3/4$

The number on the bottom always represents the number of parts that an object has been divided into. In this case it is 4

The number on the top tells you how many parts you are concerned with. In this case 3.

An inch on a ruler may be divided into 8 parts, 16 parts or 32 parts. Sometimes they are divided into 64 parts.

If your inch is divided into 8 parts, then each fraction of that inch will have an 8 on the bottom. Examples are  $1/8$ ,  $3/8$ ,  $5/8$ ,  $6/8$

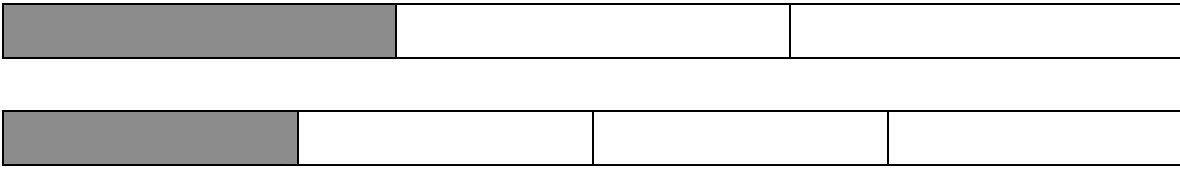


This bar represents  $5/8$ ths, because 5 of the 8 sections are shaded

If your inch is divided into 16 parts then each fraction of that inch will have 16 on the bottom. Examples are  $4/16$ ,  $8/16$ ,  $11/16$

In each case the numbers on the top of the fraction let you know how many parts of the whole thing that you have. If you had  $8/8$  or  $16/16$ ths, you would have the whole thing or one (1). If you had  $4/8$  or  $8/16$ ths you would have half ( $1/2$ ) of the whole thing.

If you have two bars that are the same size and one is divided in thirds, 3 pieces, and the other is divided into 4ths, 4 pieces, which is bigger  $\frac{1}{3}$  or  $\frac{1}{4}^{\text{th}}$ ?



# RELATIVE SIZE OF FRACTIONS

## Which is Smaller, Which is Bigger

Answer the following to see if you understand the relative size of common fractions used in measuring. Check your answers at the bottom of the page

**Circle the fraction in each pair that is larger**

1.  $\frac{3}{8}$  or  $\frac{5}{8}$

2.  $\frac{5}{16}$  or  $\frac{3}{8}$

3.  $\frac{3}{4}$  or  $\frac{7}{8}$

4.  $\frac{1}{3}$  or  $\frac{1}{2}$

5.  $\frac{4}{16}$  or  $\frac{1}{4}$

**Re-order the fraction from smallest to largest**

6.  $\frac{7}{8}$ ,  $\frac{5}{32}$ ,  $\frac{32}{64}$ ,  $\frac{2}{3}$ ,  $\frac{9}{16}$

7.  $\frac{3}{4}$ ,  $\frac{2}{3}$ ,  $\frac{5}{8}$ ,  $\frac{52}{64}$ ,  $\frac{1}{8}$ ,  $\frac{1}{3}$

8.  $1\frac{3}{4}$ ,  $\frac{15}{16}$ ,  $\frac{9}{10}$ ,  $\frac{2}{3}$ ,  $\frac{28}{32}$

**Circle the fraction in each pair that is smaller**

9.  $\frac{1}{3}$ ,  $\frac{1}{4}$

10.  $\frac{3}{16}$ ,  $\frac{4}{32}$

11.  $\frac{3}{64}$ ,  $\frac{1}{32}$

12.  $\frac{9}{16}$ ,  $\frac{8}{32}$

13.  $\frac{3}{8}$ ,  $\frac{1}{4}$

Answers: 1.  $\frac{5}{8}$ , 2.  $\frac{3}{8}$ , 3.  $\frac{7}{8}$ , 4.  $\frac{1}{2}$ , 5. same, 6.  $\frac{5}{32}$ ,  $\frac{32}{64}$ ,  $\frac{9}{16}$ ,  $\frac{2}{3}$ ,  $\frac{7}{8}$ , 7.  $\frac{1}{8}$ ,  $\frac{1}{3}$ ,  $\frac{5}{8}$ ,  $\frac{2}{3}$ ,  $\frac{3}{4}$ ,  $\frac{52}{64}$ , 8.  $\frac{2}{3}$ ,  $\frac{28}{32}$ ,  $\frac{9}{10}$ ,  $\frac{15}{16}$ ,  $1\frac{3}{4}$

**Need more help? See the following worksheets: Understanding fractions, converting fractions to decimals**

## REDUCING FRACTIONS TO LOWEST TERMS

A fraction such as  $\frac{6}{8}$  is often easier to read on the tape measure if you reduce it to its simplest terms:  $\frac{3}{4}$ ; there are fewer lines to count for reduced fractions. For this reason, the first fraction skill we will review is how to reduce fractions to lowest terms.

The first thing to really know and understand about reduced fractions is that they are no different in value or size than their non-reduced counterparts. For instance,  $\frac{2}{4}$ " and  $\frac{1}{2}$ " (its reduced fraction) are exactly equal in size. The same is true for  $\frac{4}{8}$  and  $\frac{1}{2}$ ; and also  $\frac{4}{16}$  and  $\frac{1}{4}$ . When you reduce fractions, you should never change their value or size, just the way they look.

The next thing is to know *when* fractions can be reduced. Fractions need to be reduced when there is some integer greater than 1 {2, 3, 4, 5 . . .} which can be evenly divided into both the bottom and the top of the fraction.

Examples:  $\frac{14}{16}$  can be reduced because both 14 and 16 can be divided by 2.

{Note: with measurements in inches, 2 is the first number you should always try to reduce your fraction by}

$\frac{12}{16}$  can also be reduced because both 12 and 16 can be divided by 2. Better yet, they can both be divided by 4, but we'll get to that later.

$\frac{7}{8}$  cannot be reduced as there is no integer other than 1 which will divide evenly into both 7 and 8.

**Exercise:** Circle the numbers below which can be reduced:

<b>30/32</b>	<b>4/16</b>	<b>5/8</b>	<b>3/8</b>	<b><math>\frac{1}{4}</math></b>
<b>11/16</b>	<b>48/64</b>	<b>2/3</b>	<b>3/5</b>	<b>4/4</b>

*Hint: you should have circled exactly five of these fractions.*  
Use your calculator fraction key to check your answers.

Finally, we need to know how to reduce. Because we have the fraction key which will do this conversion for us, this part of the packet reading is for those who want to review the skill without the calculator. When doing the exercises, you may choose to do them 'by hand' and then check them by calculator, or just use the calculator. As always, should you choose to do them only by the calculator, it is a good idea to do each problem twice to eliminate input or "typing" errors.

Let's take the example of  $12/16$  ". We know that both 12 and 16 can be divided by 2 (at least), so it must be reducible. If we divide both the top and bottom by 2, we get  $6/8$ . But  $6/8$  is also reducible; both 6 and 8 can also be divided by 2 to get  $3/4$ . This is fine and a perfectly correct way to do it, but it's not the fastest way. It's always good to check to see if 2 will divide evenly into both top and bottom, but if it can, you should see if a bigger number like 4 or 8 (or 3 or 5 if you're not just talking about inches) can divide into them. In the case of  $12/16$ , we divided by 2 twice, when we could have just divided by 4 once. If we divide 12 and 16 both by 4, we get  $3/4$ , which is our final answer from the slower method. The lesson learned from this is to choose not just any number which will divide evenly into both top and bottom, but the ***largest*** number which will divide into both of them.

Exercises: Reduce the following fractions to lowest terms. This is also called simplifying. If it cannot be reduced, just copy the number.

<i>Example: <math>6/8 = 3/4</math></i>
--

1.  $2/8$  \_\_\_\_\_

2.  $13/16$  \_\_\_\_\_

3.  $9/32$  \_\_\_\_\_

4.  $6/16$  \_\_\_\_\_

5.  $16/64$  \_\_\_\_\_

6.  $10/16$  \_\_\_\_\_

**Need more help? See the following worksheets: Using the fraction key on your calculator**



## CHANGING IMPROPER FRACTIONS TO MIXED NUMBERS AND VICE VERSA

Sometimes, when fractions are added or subtracted, your answer ends up being an improper number, like  $11/4$ . This is not the kind of number you want to have to find on our standard tape measure. Therefore, it is important to be able to convert improper fractions to mixed numbers, for example  $11/4$  to  $2 \frac{3}{4}$ . You also will need to be able to change mixed number measurements to their improper fraction counterparts in order to be able to perform calculations without the calculator. The fraction key (together with the yellow '2<sup>nd</sup>' function key) on your calculator handles improper fractions and mixed numbers equally well. Again, you may choose to do all exercises using your calculator.

Improper fractions are fractions in which the top is larger than the bottom:  $5/4$ ,  $9/8$ , etc.

Mixed numbers include both a whole number and a fraction:  $3 \frac{1}{2}$ ,  $7 \frac{3}{4}$ ,  $19 \frac{5}{8}$ , etc.

Starting from improper fractions, note that the bottom number of the fraction represents how many pieces your whole items are cut up or divided into. A fraction with 8 on the bottom represents something which is cut or divided up into 8 equal pieces. The top number tells you how many of those pieces you have or you are working with. So  $9/8$  is talking about items cut up into 8 equal pieces, and you are working with 9 of those pieces. This would lead you to suspect you have more than one whole item's worth.

Think pizza! Each pizza is cut into 8 slices, and you have 9 slices.

The way to convert improper fractions to mixed numbers without the calculator is to divide the bottom number into the top, note how many whole times it goes in, and then subtract to find the remainder and make it the new top of the fraction. The bottom of the fraction (the denominator) should remain the same.

So,  $9/8$ : 8 goes into 9 once = 1, with 1 left over. We write this  $1 \frac{1}{8}$ . Remember: the bottom of the fraction remains the same.

With this method: we can convert the following examples:

$13/4$ :  $13 \div 4 = 3$  ( $3 \times 4 = 12$ ), with **1** left over ( $13 - 12 = 1$ ), giving us  **$3 \frac{1}{4}$**  (much easier to read on the tape measure than  $13/4$  !)

$20/8$ :  $20 \div 8 = 2$  with 4 left over ( $2 \times 8 = 16$ ; then  $20 - 16 = 4$ )  $\Rightarrow 2 \frac{4}{8}$  or  $2 \frac{1}{2}$

$20/4$ :  $20 \div 4 = 5$  (Here, you see that a fraction is just a division problem)

*Note: if the top divides evenly into the top, there is only a whole number Answer.*

**Exercises:** Convert the following improper fractions to mixed numbers. Reduce fractions, if possible, to lowest terms. Check your answers with your calculator's fraction key.

1.  $33/16$  \_\_\_\_\_

2.  $9/2$  \_\_\_\_\_

**Example:**  $15/2 = \underline{7 \frac{1}{2}}$

3.  $19/16$  \_\_\_\_\_

4.  $24/8$  \_\_\_\_\_

5.  $54/8$  \_\_\_\_\_

6.  $18/4$  \_\_\_\_\_

Now, let's work on going in the reverse direction:

To convert mixed numbers to improper fractions, which will be necessary if you want to multiply or divide fractions "by hand," you need to do the exact opposite of what you did above:

Instead of dividing, you multiply.

Instead of subtracting, you add.

To convert  $5 \frac{1}{8}$  to an improper fraction, you first multiply the whole number by the bottom of the fraction (the denominator).

$$5 \times 8 = 40$$

Then you add that number to the number on top of the fraction (the numerator).

$$40 + 1 = 41$$

And as always, put that new number, the sum, on top of the old denominator. Usually when you are converting to an improper fraction, you are doing it because you want to perform some calculations. It is not usually necessary to do any reducing.

**Answer:**      **$\frac{41}{8}$**

**Exercises:** *Give the improper fraction equivalent of these mixed numbers. Check them with your calculator's fraction key. It is not necessary to reduce to lowest terms.*

1.      $3 \frac{1}{8}$      \_\_\_\_\_

2.      $9 \frac{3}{4}$      \_\_\_\_\_

**Example:**      $5 \frac{1}{4} = \frac{21}{4}$

3.      $4 \frac{5}{16}$      \_\_\_\_\_

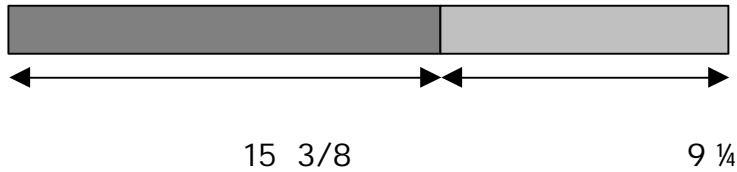
4.      $7 \frac{1}{2}$      \_\_\_\_\_

5.      $11 \frac{3}{8}$      \_\_\_\_\_

With these skills in hand, now move on to adding and subtracting fractions, which comes in very useful when welding parts together or in calculating and obeying industrial tolerances. From now on, all exercises can be done using the fraction key and explanations for "by hand" calculations are not included. Please see your instructor for additional help if you want to review how to add and subtract fractions by hand.

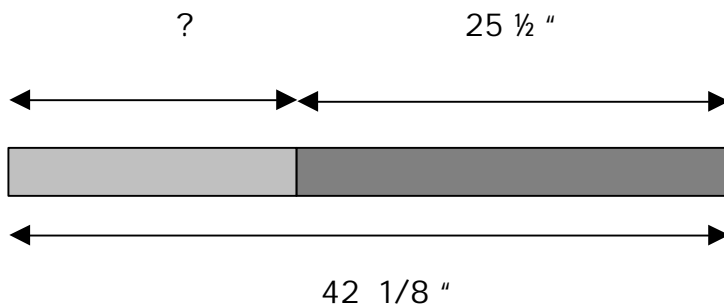
## ADDING AND SUBTRACTING FRACTIONS AND MIXED NUMBERS

Suppose you had two pieces of steel that needed to be welded together, and you wanted to find the total length.



Use your calculator's fraction key to find the total length. Did you get  $24 \frac{5}{8}$  inches? Can this be reduced?

Now suppose that you have one long piece of steel and you want to cut it where the vertical line is. How long is the smaller piece?

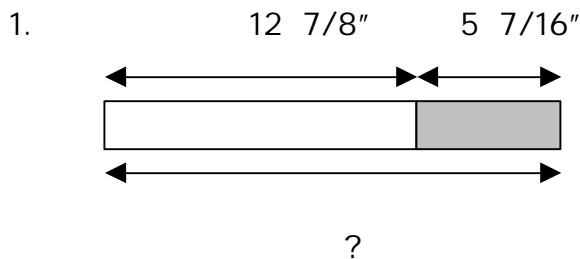


Now you have to subtract the shorter length from the longer:  $42 \frac{1}{8} - 25 \frac{1}{2}$

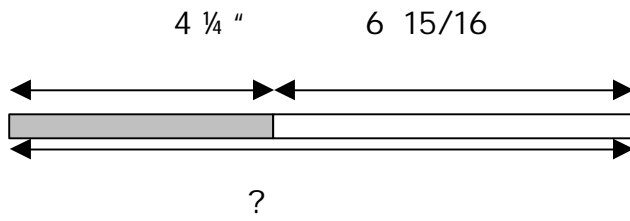
Did you get  $16 \frac{5}{8}$  "? How could you use your calculator in a different way to check your answer?

### **Exercises:**

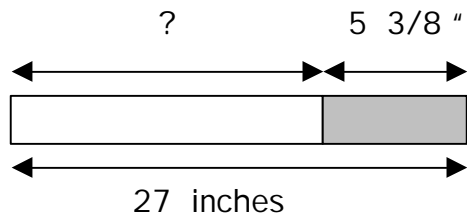
Now try to find the missing length in the pictures below:



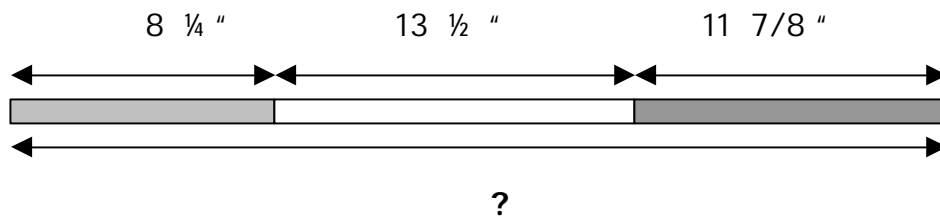
2. Find the total length of this one, too:



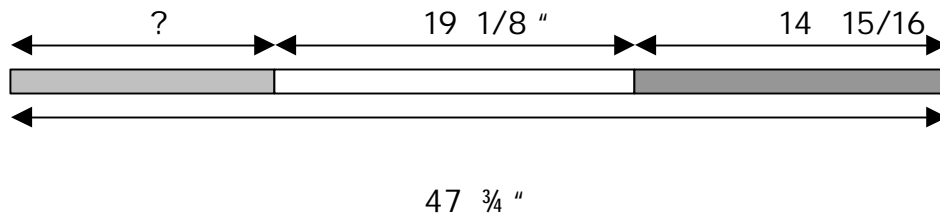
3.



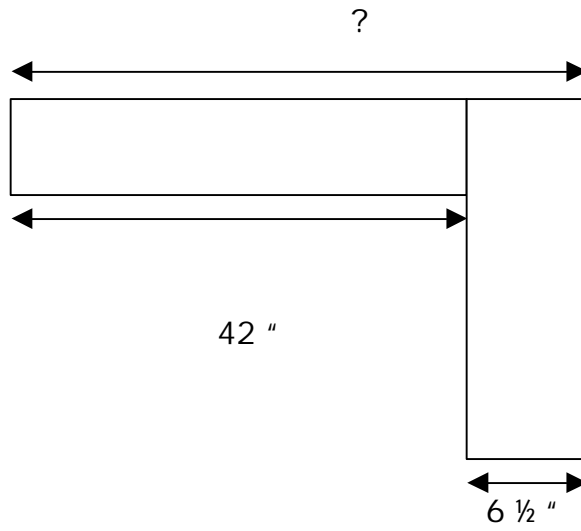
4.



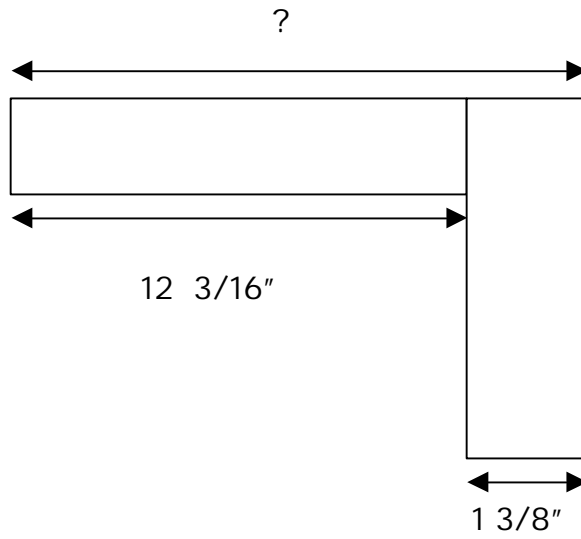
5.



6.



7.



**Need more help? See the following worksheets: Using the Fraction key on your calculator**

# MULTIPLYING FRACTIONS

For fractions, not mixed numbers . . .

Rule #1: Multiply the top numbers (numerators) together

Rule #2: Multiply the bottom numbers (denominators) together

Example 1:  $\frac{1}{4} \times \frac{3}{4} = \frac{1 \times 3}{4 \times 4} = \frac{3}{16}$

Example 2:  $\frac{3}{16} \times 5 = \frac{3}{16} \times \frac{5}{1} = \frac{3 \times 5}{16 \times 1} = \frac{15}{16}$

Try these:

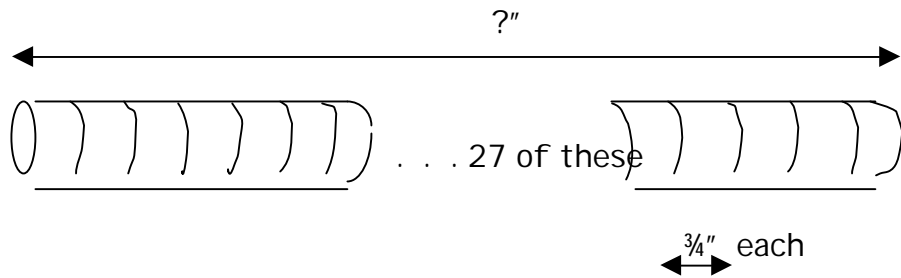
1.  $\frac{1}{2} \times \frac{5}{8} = \underline{\hspace{2cm}}$

2.  $\frac{3}{8} \times \frac{7}{8} = \underline{\hspace{2cm}}$

3.  $\frac{29}{16} \times \frac{1}{4} = \underline{\hspace{2cm}}$

4.  $\frac{5}{32} \times 6 = \underline{\hspace{2cm}}$  (note:  $6 = 6/1$  and *Reduce!*)

5. You need to cut 27 small pieces of steel tubing. Each piece is  $\frac{3}{4}$  " long. How long a length of tubing must you buy? *Note:  $27 = 27/1$*



For mixed numbers . . .

Convert all mixed numbers to improper fractions and do as above.

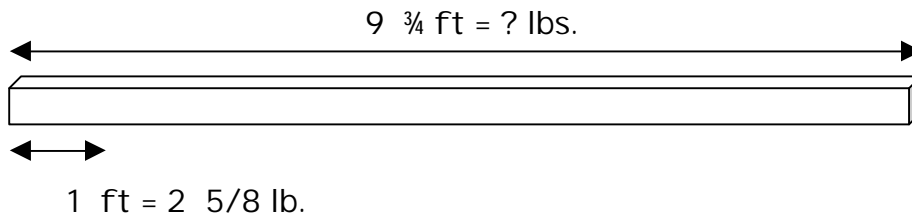
If answer is improper fraction, convert to mixed number for ease in measurement.

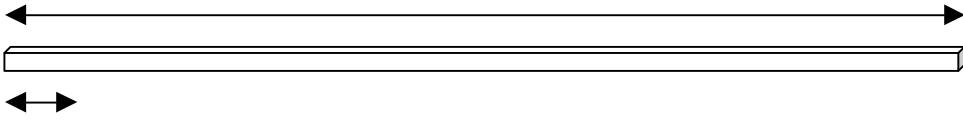
$$\text{Example 1: } 3 \frac{1}{2} \times \frac{3}{4} = \frac{7}{2} \times \frac{3}{4} = \frac{21}{8} \\ = 2 \frac{5}{8}$$

This kind of multiplication comes into play when you are trying to figure out total weight of a piece of metal, given the length of it and its weight per foot in pounds.

For the following exercises, you may use your fraction key on your calculator. But remember to do the calculation twice to see if you get the same answer each time. It is very easy to push the wrong buttons or push too hard or too gently.

1. A  $9 \frac{3}{4}$  foot long piece of quarter inch steel weighs  $2 \frac{5}{8}$  lb/ft. Find the total weight of the piece.



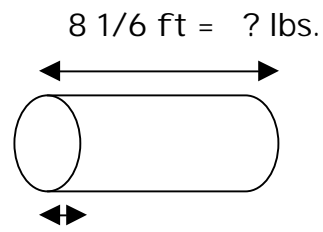
2. 

$12 \frac{5}{12} \text{ ft} = ? \text{ lbs.}$

$1 \text{ ft} = 1 \frac{7}{16} \text{ lb.}$  Find the total weight of this length of steel.



3.



$1 \text{ ft} = 2 \frac{3}{4} \text{ lb.}$

Find the total weight of this length of pipe.

**Need more help? See the following worksheets: Using the fraction key on your calculator**

## DIVIDING FRACTIONS

*Rule #1: Convert any whole numbers to fractions by putting a "1" underneath them Rule #2: Convert any mixed numbers to improper fractions*

*Rule #3: Keeping the first fraction exactly like it is, flip the second fraction, so that the top is now on the bottom, and the bottom number is now on top: numerator now on bottom, denominator now on top.*

*Rule #4: Multiply fractions like you always do. (across the top, across the bottom)*

*Rule #5: Reduce the resulting fraction to lowest terms*

*Example 1:*  $\frac{1}{4} \div \frac{1}{8} = \frac{1 \times 8}{4 \times 1} = \frac{8}{4} = 2$

*Example 2:*  $1\frac{3}{4} \div 2 = \frac{7}{4} \div \frac{2}{1} = \frac{7}{4} \times \frac{1}{2} = \frac{7 \times 1}{4 \times 2} = \frac{7}{8}$

*Try these: (Remember to reduce when you can!)*

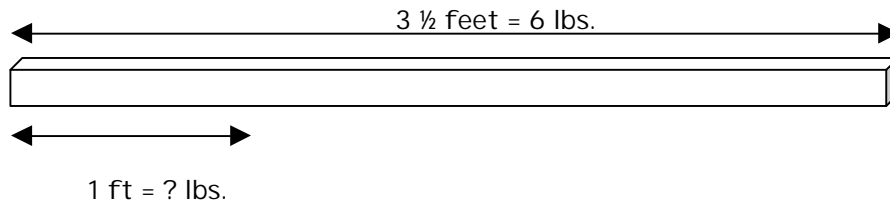
1.  $5 \div \frac{5}{8} = \underline{\hspace{2cm}}$

2.  $\frac{3}{16} \div \frac{1}{4} = \underline{\hspace{2cm}}$

3.  $7\frac{7}{8} \div \frac{1}{4} = \underline{\hspace{2cm}}$  *Convert answer to mixed number.*

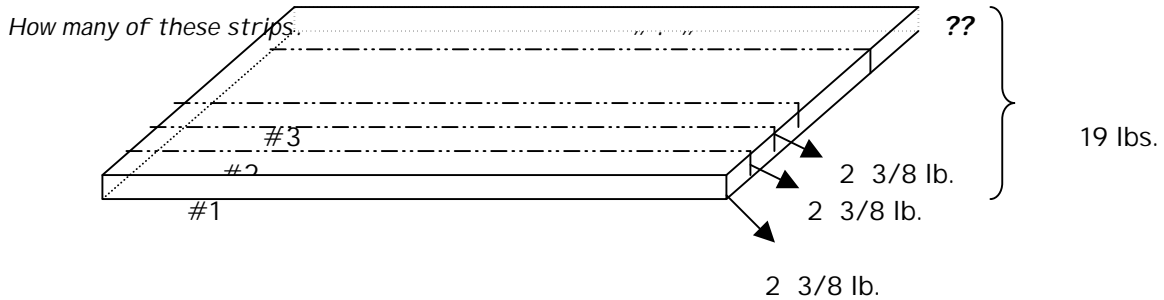
4.  $2\frac{1}{2} \div 8 = \underline{\hspace{2cm}}$  (note:  $8 = 8/1$ )

5. You have a 6 lb pc of steel that is  $3\frac{1}{2}$  feet long. How much does it weight per ft.?

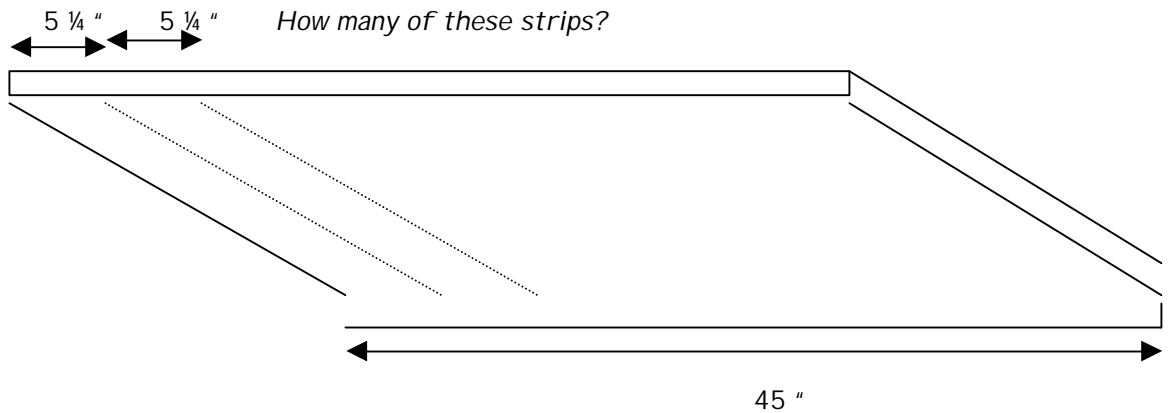


Try doing the following problems, either by hand or using your calculator:

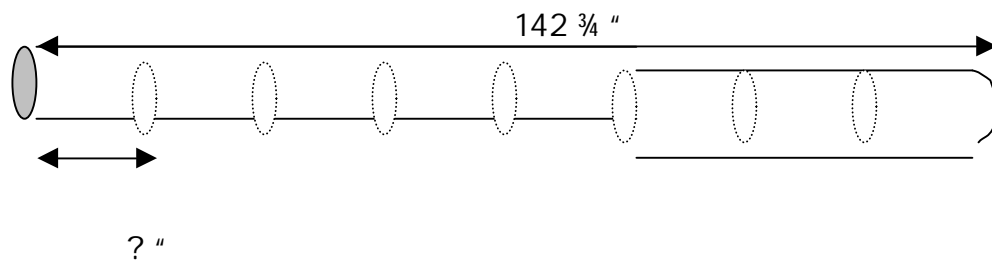
1. A sheet of metal weighs 19 lbs. In a shearing operation, the sheet is cut into strips weighing  $2 \frac{3}{8}$  lb. each. **How many** strips of metal are produced?



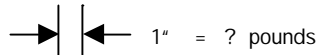
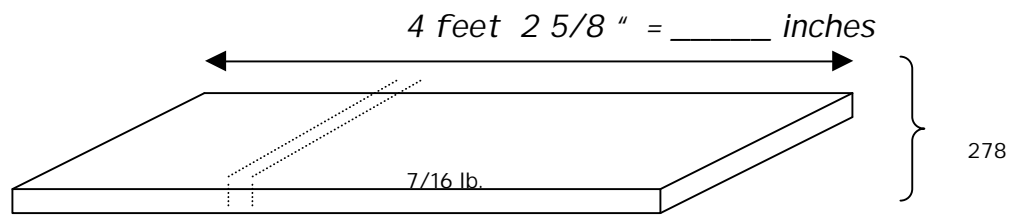
2. How many  $5 \frac{1}{4}$  inch strips can be sheared from a thin piece of sheet metal 45 inches long? If there is any left over after your cuts, see if you can figure out exactly what length will be left over.



3. A piece of  $6 \frac{7}{8}$ " diameter tubing 142  $\frac{3}{4}$  inches long is being cut into 8 pieces of equal length. How long is each piece?



4. How much does one inch length of steel plate weigh, if the 4 ft 2 5/8" plate weighs a total of 278 7/16 lbs? *Note that 9/16 = 9 ounces out of the 16 ounces that make up one pound.*



**Need more help? See the following worksheets: Using the fraction key on your calculator**

## CONVERTING FRACTIONS TO DECIMALS

This is going to be a real quick lesson. **A fraction is a division problem.** A fraction is a division problem that reads from top to bottom.  $\frac{1}{2}$  can also be stated: "1 divided by 2." Note that if you input that into your calculator (**Don't forget to press "=" !!**), you will get what you already know is true, which is that  $\frac{1}{2}$  equals .50 or .5, as in 50 cents or 5 tenths, etc. Now, this is the hard part. You must believe that all fractions work this way. If you divide the top by the bottom, you get the decimal equivalent. Try it for  $\frac{3}{4}$  and  $\frac{1}{4}$  and  $\frac{1}{8}$ . You will get: .75, .25, and .125 respectively. Are you a believer yet?! Think of it this way. What you are saying is that 3 out of every 4 dollars is the same as 75 out of every 100 dollars, and that 1 out of every 8 people is the same as 125 out of every 1000 people.

$$\frac{3}{4} : \quad 3 \quad \boxed{\div} \quad 4 \quad \boxed{=} \quad "$$

Be sure to try your fraction key also on this. Use the 2<sup>nd</sup> function key and the key with  $F \leftrightarrow D$  above it on the TI 30 Xa. For some calculators, you just need to push the "=" key one or two times.

So what does this have to do with you? Well, it comes in real handy when we talk about ratios and proportion, which we'll do later. It also is important to know and be able to do when we talk about wire diameter sizes.

Have you ever seen the Inner Shield Wire labeled size "068" ? Do you know what this means? It means that this wire is 0.068 or 68 thousandths of an inch in diameter. But how does that compare with some of the common fractional inch diameter sizes? Convert the fractional inch diameter sizes below to decimal sizes and circle the one which you think is closest to "068."

**Exercise:**

$$5/32" = \underline{\hspace{2cm}}$$
$$5/64" = \underline{\hspace{2cm}}$$
$$3/32" = \underline{\hspace{2cm}}$$
$$1/16" = \underline{\hspace{2cm}}$$
$$1/8" = \underline{\hspace{2cm}}$$

You need to be able to convert fractions to decimals so that when you read prints with different modes of recording diameter sizes, you can relate them to each other, fractions to decimals and vice versa. *Then, it may be possible to substitute a 1/16" wire for a ".068" in some circumstances.* Even though it is not exact, there may be times when it is close enough. But how will you know if you cannot convert them?

Reading decimals, which we did in WLD 141, helps you to have an understanding of just how big they are. In this class, we will work on comparing decimals, which you will also use when comparing fractions. If you cannot tell which fraction is bigger, you can convert the fractions to decimals and then compare more easily.

To convert decimal inches to fractional inches is a little more work, but you already have all the skills. You've already done it to convert to the most accurate decimal, but it might be useful to convert to the nearest 1/16 inch: *(We'll also look at this in WLD 131)*

Let's say that you want to know what .068 inch is to the closest 1/16 of an inch.

If there is a whole number in front of it, record it and drop it. (Example: for 4.32, write down 4 inches and use only the .32 part of the number). We don't have a whole number here, so we don't have to worry about it.

Input the part of the number which begins with the decimal point: **".068"**

*This number tells you what part of an inch, in this case, how many 1000ths you are working with*

**Multiply by 16** to "cut" it into sixteenths, which is what you want.

*This is the amount of 16ths you have in .068 = 1.088*

**Round** the resulting number on your calculator to the nearest whole number.

*This is the whole number of 16ths you have in .068 = 1*

*And there you have it!*                       $\frac{1}{16}$

To convert it to 32<sup>nds</sup>, you just multiply it by 32, instead of 16.

To convert it to 64<sup>ths</sup>, you just multiply by 64.

Exercise:

Convert the following decimals to the nearest 32<sup>nd</sup> or 64<sup>th</sup> of an inch; reduce as needed:

$$.035 = \frac{\quad}{32}$$

$$.045 = \frac{\quad}{32}$$

$$.035 = \frac{\quad}{64}$$

$$.045 = \frac{\quad}{64}$$

Why would it be good to convert .035 and .045 to 64<sup>ths</sup> instead of 32<sup>nds</sup>?

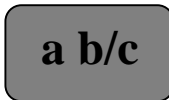
$$.090 = \frac{\quad}{32}$$

$$.025 = \frac{\quad}{32}$$

Which one of the above is closest to "hog wire" = 3/32" DIA? Circle it.



## OPERATING THE FRACTION KEY ON A TI-30Xa



Your calculator has been programmed to do fractions, but they appear on the display in an unusual way:

$\frac{1}{2}$  looks like  $1 \cdot \bar{2}$

$\frac{5}{16}$  looks like  $5 \bar{16}$

$9\frac{3}{4}$  looks like  $9 \_ 3 \bar{4}$

Can you identify these?

$7 \_ 1 \bar{4}$  = \_\_\_\_\_       $14 \_ 1 \bar{8}$  = \_\_\_\_\_

$11 \bar{16}$  = \_\_\_\_\_       $23 \_ 5 \bar{8}$  = \_\_\_\_\_

Here's how to enter fractions and mixed numbers on your calculator:

To enter  $\frac{3}{4}$  :

Press 3

Press 

Press 4

***It should read:***       $3 \bar{4}$

To enter  $15\frac{6}{8}$ :

Press 15

Press 

Press 6

Press 

Press 8

***It should read:***       $15 \_ 6 \bar{8}$

To reduce to lowest terms, press  . Did you get  $15 \_ 3 \bar{4}$ ?

To change to a decimal number, press **2nd** and **F $\leftarrow$ D** at the same time.  
Did you get 5.75?

To switch back to the fraction form, press **2nd** and  **$\leftarrow$**  together again.

# DECIMALS

Applications:

- Measuring
- Blueprint reading
- Fabrication
- Tolerances
- Metric Measurements

## COMPARING DECIMALS AND FRACTIONS

### How Decimals and Fractions are the Same

Decimal Inches	Fractions of an Inch
A decimal inch is an inch divided into many parts. When measuring a decimal inch it can be divided into ten parts, a hundred parts, a thousand parts or even ten thousand parts.	A fraction is an inch divided into many parts. When measuring a fraction of an inch it is usually divided into sixty-fourths, thirty-seconds, sixteenths, eights, quarters, and halves.
Decimals when not combined with whole numbers are always less than 1 inch.  .1, .01, .001, .0001	Fractions when not combined with whole numbers are always less than 1 inch.  $1/32, 1/16, 1/8, 1/4, 1/2$
You can combine a decimal with a whole number to make a number greater than one inch.  1.5, 5.25, 7.125, 3.2501	You can combine a fraction with a whole number to make a number greater than one inch.  $1 \frac{3}{16}, 5 \frac{2}{3}, 7 \frac{3}{4}, 3 \frac{1}{2}$

<p>Decimals are always written with a decimal point followed by digits to the right of the decimal point. The name of the last column to the right of the decimal point tells you how many parts your inch is divided into.</p> <p>.250 one thousand parts .5 ten parts .01 one hundred parts</p>	<p>Fractions are always written with a numerator and a denominator. The bottom number tells you how many parts the inch is divided into</p> <p><math>\frac{1}{4}</math> four parts <math>\frac{1}{2}</math> two parts <math>\frac{1}{8}</math> eight parts <math>\frac{1}{100}</math> one hundred parts</p>
All decimals can be converted into fractions.	All fractions can be converted into decimals.

### HOW DECIMALS AND FRACTIONS ARE DIFFERENT

Decimal Inches	Fractions of an inch
Micrometers, dial indicators and calipers are usually used to measure decimal inches.	Rulers and tape measures are usually used to measure fractions of an inch.
Decimals are also used to express numbers less than 1 in the metric system. Don't confuse this with decimal inches. They are not the same thing.	Fractions are not used in the metric system.

## HOW TO READ AND WRITE A DECIMAL

$1000^s$	$100^s$	$10^s$	$1^s$	?	$10^{ths}$	$100^{th}$	$1000^{ths}$	$10,000^{ths}$
----------	---------	--------	-------	---	------------	------------	--------------	----------------

### The four steps to reading a decimal:

1. Say the number to the left of the decimal point as it's written without using the word "and";
2. Say the word "and" to indicate the decimal point;
3. Say the number to the right of the decimal point as it's written;
4. Then say the name of the place value of the last digit to the right.

**Example:** 372.681  
Step 1. three hundred seventy-two  
Step 2. and  
Step 3. eight hundred sixty-one  
Step 4. thousandths

This number is read: three hundred seventy-two and eight hundred sixty-one thousandths.

If there is only a zero or no digit at all to the left of the decimal point, then you only need to follow steps 3 and 4 above.

**Example:** 0.02  
Step 3. two  
Step 4. hundredths

This number is read: two hundredths.  
(The same would be true if the number were written as just .02).

## READING AND WRITING - PRACTICE

In which place is the underlined digit?

1. 1.74      Hundredth      2. 96.582      \_\_\_\_\_

3. 7.2975      \_\_\_\_\_      4. 813.96      \_\_\_\_\_

5. 327.845      \_\_\_\_\_      6. 84.215      \_\_\_\_\_

**Write in words.**

7.    3.45  
\_\_\_\_\_

8.    0.583  
\_\_\_\_\_

9.    100.01  
\_\_\_\_\_

10.   0.028  
\_\_\_\_\_

11.   400.1  
\_\_\_\_\_

12.   0.004  
\_\_\_\_\_

13.   0.019  
\_\_\_\_\_

14.   80.022  
\_\_\_\_\_

## READING AND WRITING - PRACTICE

**Write the number.**

15. Four tenths

---

16. Nineteen thousandths

---

17. Fourteen and three thousand eighty-six ten-thousandths

---

18. Fifty-nine hundredths

---

19. Three thousandths

---

20. Twelve and five tenths

---

21. Thirty-eight and one hundred twenty-two thousandths

---

22. Eight and six hundredths

---

23. Eight and six thousandths

---

24. Nine hundred five ten-thousandths

---

25. Nine and one hundred thirteen thousandths

---



26. One and forty-five hundredths

---

27. Three hundred fifteen thousandths

---

## DECIMAL SIZE

Select the decimal size that you think is appropriate (all decimal sizes are in inches).

1. The thickness of a human hair  
nickel

- a. .020
- b. .200
- c. .002

2. The diameter of a

- a. .850
- b. .085
- c. .150

3. The size of this period.  
letter "H"

- a. .711
- b. .090
- c. .012

4. The width of the

- a. .010
- b. .345
- c. .090

5. The diameter of a dime  
piece of paper

- a. .710
- b. .220
- c. .099

6. The thickness of this

- a. .004
- b. .090
- c. .190

7. The height of your fingernail  
fingernail

- a. .099
- b. .610
- c. .009

8. The thickness of your

- a. .723
- b. .050
- c. .005

9. The diameter of a quarter  
pencil

- a. .412
- b. .099
- c. .950

10. The width of a #2

- a. .025
- b. .250
- c. .100

## COMPARING DECIMAL SIZE

### Which is Larger? Which is Smaller?

When comparing decimals, you read from left to right, as with a book. And remember, not all decimal numbers have a decimal point. For example, 214 is a decimal number, but since it has no nonzero digits after the decimal point, there is no need to include the point.  $214.00 = 214$ .

Look at the digit furthest to the left of each decimal number. (A digit is any of the whole numbers from 0 through 9, including zero). Determine which decimal place it is in i.e. thousands, tens, ones, hundredths, etc. If one number has a digit in a higher decimal place than the other, then it is automatically larger. Another way of saying that is that if one number has more digits to the left of the decimal point than the other, then it is larger. [It is not so to the right of the decimal point.

**Example:** 1024 is greater than 988 [0.5478 is not greater than 0.60]

If they both have the same number of digits before the decimal point, then we need to look at each decimal place, starting from the left. If they both have a digit in the hundreds place, and not the thousands place, then we compare the digits in the hundreds place. If one is higher, then that number is greater. If both digits are the same, then we look to the tens place and compare those digits, and so on to the next digit to the right.

After the decimal point, the system is much the same. Just keep in mind that counting digits on the right side will not be useful. Tenths are greater than hundredths, which are greater than thousandths, which are greater than ten-thousandths, etc. So, we continue to look at the decimal places left to right.

**Example:** Which is greater? 0.5803 or 0.0906?

Well, the right one looks longer, but if we look at the first decimal place, the tenths, the left number has a digit in it, but the right number does not. Therefore, the left number is greater. Tenths are greater than hundredths.

**Example:** Which is greater? 0.4683 or 0.470?

In this example, the left one looks longer...and therefore larger. However, let's take it step by step. They both begin with a "4" in the tenths place, so they are even so far, but when we look at the hundredths place, we see that

the left number has a "6" while the right number has a "7" there. Therefore, the right number is greater.

We could add a "0" to the end of 0.470 without changing how large the number is, making it 0.4700. Now it is easier to compare with 0.4683, which also has four digits after the decimal point. This is a perfectly acceptable and foolproof method of comparing decimals. But remember, 0's can only be added to the right side of the decimal point, and there, only to the right of all other digits.

**Example:** Which is greater? 27.045 or 27.00981 ?

If we just add enough (in this case 2) zeros to the right side of the left number, so that both numbers have 5 digits after the decimal point, we get 27.04500. Now, looking at the digits only to the right of the decimal, we can see that on the left we have 4500 (hundred thousandths) and on the right we have only 981 (hundred thousandths).

**Example:** Which is greater? 33.0764 or 33.07639?

Again, we compare from left to right. The digits before the decimal point are exactly the same, so we move on the right of the decimal point. In the tenths place, they both have a "0". So, we move to the hundredth's place to compare digits, and we see that they both have a "7". Then we move to the thousandths place and see that they have a "6". And when we get to the ten-thousandths place, they finally differ. The left number has a "4". and the right number has a "3". Which one is greater?

**Example:** Which one is greater? .3 or .303?

Add two zeros after the "3" of the left number. Now you have .300 and .303 to compare, the same numbers you had before, but in a form easier to compare. Which one is greater?

*[Note: you can only add zeros to the right hand end of a number. For example, you can change .04 to .040, but you cannot change 21 to 210, or 53.7 to 53.07].*

Decimal	Correct	Incorrect
0.033	0.0330 or 0.03300	.0033
10.24	10.240	10.204 or 10.024
1,099	1,099.0 or 1,099.000	10990.10099.etc, or 01099, this latter mostly because it would be confusing; it looks like it is a small number missing its decimal point.

**Example:** Which one is greater? .2 or .179? Change .2 to .200 and compare. Which one do you say is greater?

## COMPARING DECIMALS

Which is larger?

- |                 |       |                     |
|-----------------|-------|---------------------|
| 1. 3 or .29     | _____ | 6. .7 or .074       |
| 2. .04 or .004  | _____ | 7. .156 or .1561    |
| 3. .91 or .893  | _____ | 8. .29 or .899      |
| 4. 1.47 or .278 | _____ | 9. .28 or 2.8       |
| 5. .63 or 4.5   | _____ | 10. 4.504 or 4.5035 |

Which is smaller?

- |                  |       |                      |
|------------------|-------|----------------------|
| 1. .89 or .9     | _____ | 6. 4.1 or 3.010      |
| 2. .2 or .21     | _____ | 7. 5.06 or 1.059     |
| 3. .50 or .05    | _____ | 8. 1.638 or .5376    |
| 4. .36 or .4     | _____ | 9. 2.0439 or 2.04395 |
| 5. .0051 or .006 | _____ | 10. 9.3 or 8.754     |

Arrange in descending order (largest first)

1. .01, .001, .1, .0001
2. 2.25, .253, .2485, 2.249
3. .38, 1.5, .475, .0506
4. .006, 5.02, .503, .1483
5. .98, .89, .934, .9

Arrange in ascending order (smallest first)

1. .201, .19, 1.2, .21
2. .465, .4053, .47, 4.5
3. .51, .583, .60, .5126
4. .04, 1.25, .156, 2.3
5. .76, .7, .076, .0710

## ROUNDING DECIMALS

When rounding numbers to the nearest tenth, hundredth, thousandth or any other decimal place unit, follow the procedure and examples outlined below:

**Example 1** Round 2.29148 to the nearest thousandth.

- Step 1.** Find the number that is in the thousandth's place.  
(In this example, it is the number four)
- Step 2.** Look at the digit that is immediately to the right of that number. (In this example, the digit is 8)
- Step 3.** If the digit is less than five, then the number stays the same. If the digit is 5 or greater, then add on to the number ("round up")  
(In this example, the 4 rounds up to 5)

*Answer:* 2.915

**Example 2** Let's round the same number, 2.9148, to the nearest tenth.

- Step 1.** The number in the tenth's place is 9
- Step 2.** The digit to its immediate right is 1
- Step 3.** Since the digit 1 is smaller than 5, the number 9 stays as is

*Answer:* 2.9

What would have happened in Example 2 if the number to the right of the 9 had been 5 or greater? This is what you do.

**Example 3** Lets round the number 23.4999 to the nearest thousandth.

**Step 1.** The number in the thousandth's place is 9

**Step 2.** The digit to its immediate right is 9

**Step 3.** Since the digit is 5 or greater, we must round the 9 up to 10. Replace the 9 with 0 in the thousandth's place and carry the one over to the hundredth's place. That gives us 10 in the hundredth's place, also. So, we put a 0 in the hundredth's place and carry the 1 over to add to the 4 in the tenth's place.

*Answer:* 23.500



## ROUNDING DECIMALS PRACTICE

**Round to the nearest tenth.**

1. 1.534 \_\_\_\_\_

2. 21.919 \_\_\_\_\_

3. 378.751 \_\_\_\_\_

4. 48.993 \_\_\_\_\_

5. 57.098 \_\_\_\_\_

6. 20.05 \_\_\_\_\_

**Round to the nearest hundredth.**

1. 0.025 \_\_\_\_\_

2. 5.166 \_\_\_\_\_

3. 9.1448 \_\_\_\_\_

4. 28.997 \_\_\_\_\_

5. 129.713 \_\_\_\_\_

6. 789.554 \_\_\_\_\_

**Round to the nearest thousandth.**

1. .00629 \_\_\_\_\_

2. .0197 \_\_\_\_\_

3. 4.0099 \_\_\_\_\_

4. 280.04145 \_\_\_\_\_

5. 14.71852 \_\_\_\_\_

6. 16.03049 \_\_\_\_\_

## HOW TO CONVERT A DECIMAL TO A FRACTION

There are three steps in converting a decimal to a fraction

1. **Say** aloud the name of the decimal
  - a. use the proper name, not shop slang
2. **Write down** what you say, putting the number on the top and place name on the bottom
3. **Reduce** the fraction if necessary

Example: .125

**Say:** 'One hundred twenty-five thousandths'

**Write:**  $\frac{125}{1000}$

**Reduce:**  $\frac{1}{8}$

**Note:** to quickly reduce the fraction, enter it into your calculator using the fraction key. Enter 125/1000 as **125 a b/c 1000 =**

$\frac{1}{8}$  will show up on your display

Need more help? See the following worksheets: Reducing fractions, operating the fraction key on your calculator

## DECIMAL TO FRACTION CONVERSIONS TO PRACTICE

Convert the following decimals to fractions and reduce them to their lowest terms.

1.  $0.125 =$

2.  $4.3 =$

3.  $2.500 =$

4.  $1.75 =$

5.  $0.250 =$

6.  $0.375 =$

7.  $0.5625 =$

8.  $4.860 =$

9.  $2.3125 =$

10.  $6.875 =$

**Need more help? See the following worksheets: [reducing fractions](#), [Operating the fraction key on your calculator](#)**

## ADDING DECIMALS

Sometimes, print or metal dimensions or other measurements may come in decimal rather than fraction form. We can usually use a calculator, but we should be able to add and subtract decimals in a pinch. Try working these problems by hand and then check them by calculator. Better yet, make an educated guess of approximately how big the answer will be before you do any calculations!

When adding decimals, these are the things to keep in mind:

1. The decimal points must line up.
2. A whole number has a decimal point at its right.
3. You may add zeros to the right of the decimal point as placeholders to help keep the columns straight and decimal places lined up correctly
4. The decimal point in the answer goes directly below the other decimal points.

**Example:** Add  $3 + 5.94 + 2.08 =$

	3.00
	5.94
	<u>2.08</u>
	11.02

Add, then check your answers with a calculator.

1.  $.8 + .095 + .47 =$

2.  $5.6 + 25 =$

3.  $99 + 3.1 + 6.002 =$

4.  $9.04 + 2.085 =$

5.  $0.273 + 10.9084 =$

6.  $46.395 + .0005 =$

7.  $28 + .087 + 5.92 =$

8.  $22.19 + .003 =$



$$5. \quad .70 - .054 =$$

$$6. \quad 89 - .0003 =$$

$$7. \quad 1 - .036 =$$

$$8. \quad 4.45 - .0025 =$$

# TOLERANCES

Applications:

- Blueprint reading
- Understanding specifications
- Quality Issues



## BILATERAL AND UNILATERAL TOLERANCES

Places where we frequently find decimal notation in the shop are blueprints and "spec" sheets. Dimensions and tolerances are often in decimal notation.

There are two different kinds of tolerances which are used: bilateral and unilateral. Bilateral tolerances are just what they sound like: **two-sided tolerances**.

An example of a dimension with an attached bilateral tolerance is 1.15 mm ± .005 mm. Notice that the .005 mm can be either added to get 1.155 for the upper limit (maximum) of acceptable measure, or it can be subtracted to get 1.145 for the lower limit (minimum) of what would be considered an acceptable measure.

A **unilateral tolerance** is just what it sounds like. It is a tolerance on only one side. In other words, the little bit of leeway allowed in measurement **is in only one direction, either larger or smaller**.

For example, a dimension with unilateral tolerance may read like this:

$$\begin{array}{r} .45 \text{ in.} \quad + \quad 0 \text{ inch} \\ \quad \quad \quad - \quad .0025 \text{ inch} \end{array}$$

What the notation means is that the dimension can be .0025 inch less than 0.45 inch, but cannot be any greater than .45 inch. Its maximum measure is 0.45 inch. Its minimum measure is  $.45 - .0025 = 0.4475$  inch.

So, what does the tolerance notation below mean?

$$\begin{array}{r} 30.75 \text{ mm} \quad + \quad .002 \text{ mm} \\ \quad \quad \quad - \quad 0 \text{ mm} \end{array}$$

What is its minimum measure? What is its maximum measure?

Try completing the following chart with minimum and maximum measurements, given the bilateral or unilateral tolerance:

MEASUREMENT + TOLERANCE	MINIMUM	MAXIMUM
3.50 ± 0.015 mm		
28.01 ±.001 inch		
35.6 mm + 0 -.025		
3.375 in. +.0008 -0		
4.625 in. + 0 -.005		

## FRACTIONAL TOLERANCES

This is probably a good time to review fractional tolerances. Remember to add and subtract fractions, they need to have the same denominator (the number on the bottom of the fraction). The GOOD news is that this is pretty easy to find with the denominators we associate with inches: 1/16, 1/8, 1/4, 1/2, etc. The trick is to always choose the larger or largest denominator and change all the other fractions so that they have that largest denominator. When we do this, we must remember to maintain proportionality. We do this by making sure that whatever we have to multiply the bottom of the fraction to get the new denominator is the same number we multiply the top by. *Notice the larger denominator is circled.*

$\frac{1}{\textcircled{16}} + \frac{7}{8} = ?$	+	$\frac{1}{16}$	+	$\frac{1}{16}$	<p>Try this fractional tolerance:</p> <p>1. <math>3 \frac{1}{4} \pm 1/16</math></p> <p style="margin-left: 40px;">Minimum = _____</p> <p style="margin-left: 40px;">Maximum = _____</p>
		$\frac{7_{x2}}{8_{x2}}$		$\frac{14}{16}$	
		$\frac{1}{16}$		$\frac{14}{16}$	
				$\frac{15}{16}$	
				$\frac{16}{16}$	

The other trick you should remember is that when you are subtracting, sometimes you have to borrow. When you have to do this, it is good to imagine you are cutting one of the whole inches into sixteenths or eighths (whatever the common denominator is) and adding to the fractional part of the mixed number. It will often be the only fractional part. **see below**

*Remember that one inch has 16 sixteenths*

*one inch has 8 eighths*

*one inch has 4 fourths, etc.*

$$7" \pm 1/16"$$

To add is very simple here:  $7 + 1/16 = 7 \frac{1}{16}"$

To subtract takes a little more work and trickery:

$$\begin{array}{r} 6 \\ \cancel{7} \quad \frac{16}{16} \\ - \quad \frac{1}{16} \\ \hline 6 \quad \frac{15}{16} \end{array}$$

Try this fractional tolerance:

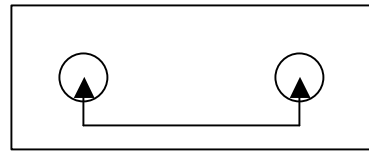
2.  $24 \pm 1/8"$  Minimum = \_\_\_\_\_

Maximum = \_\_\_\_\_

Need more help? See the following worksheets: [All fractions worksheets](#)

## DECIMAL TOLERANCES

Now we are going to do for decimals what we did for fractions. We are going to calculate tolerances. If you didn't take WLD 113 recently, you might have missed that lesson, so we'll review it here.



23.35 ± .002

Blueprints almost always have tolerances printed on them.\* They look something like this:

**23.35 ± .002 inches.**

This expression is usually attached to a particular dimension\*, like a diameter or length or thickness of an object or, as above, the distance between the centers of two holes.

*So what does this "tolerance" expression mean . . . ?*

Think of the first number, 23.35, as the ideal number, the best number possible for that dimension of your object. This number represents your goal as you fabricate/weld/cut your piece.

The next symbol, "±," means "plus or minus" -- just what it looks like top-to-bottom.

The last part, the second number, is the amount your actual measured dimension can differ from the first number, how far it can be from your ideal or goal dimension. So, . . . **our expression reads: "23.35 plus or minus 2 thousandths (.002) of an inch."**

Notice that in this tolerance our desired measurement can be either a little bit more than the ideal or a little bit less than the ideal. This is called a bilateral, or two-sided, tolerance. A tolerance that only has tolerance on one side, either plus or minus, is a unilateral tolerance. We find unilateral tolerances with such dimensions as screw holes, where the ideal is as close as possible to the screw size, but any tighter is impossible for the screw. Most tolerances, however, are bilateral and look like the ones shown on this page.

Once we are given a tolerance, we can calculate the range of possible measurements that dimension can take, ranging from the smallest or minimum size



Tolerance	Minimum	Maximum	Given measurement	Yes/No Is this measurement w/in tolerance?
3.450 ± .0005			3.453	
12.000 ± .003			12.098	
39.055 ± .0002			39.0551	
0.5 ± .001			0.49	
22 ± .01			21.095	
18.875 ± .005			18.880	

**Need more help? See the following worksheets: All decimal worksheets**

## ANGULAR TOLERANCE

Most protractors that you will use are only accurate to the nearest degree. This means when you are measuring you can not be more accurate than +/- 1 degree. Most of your blueprints tell you to be accurate to +/- 5 degrees.

Suppose that you are required to make an angle that measures 55 +/- 5 degrees. To calculate the acceptability range you would do the following:

$$55 - 5 = 50 \quad \text{to} \quad 55 + 5 = 60$$

The angle can be any size between 50 and 60 degrees and still be within tolerance.



# HANDS ON PRACTICE IN CALCULATING JOINT PREPARATION TOLERANCES AND DETERMINING IF YOUR WELD IS WRITTEN WITHIN TOLERANCE -WLD 224

## Joint Preparation

Your packet states that:

A joint shall be acceptable by visual inspection if:

1. The root opening does not vary from the specified dimension more than  $\pm 1/16"$ .
2. The included angle does not exceed the specified dimension more than  $\pm 5^\circ$ .

**For this lab look at the drawing entitled 'Butt Joint Horizontal (2G)'**

Given the above tolerances:

1. Calculate the range of the root opening in both fractional and decimal inches. Enter your calculations below.
2. Calculate the acceptable range of the included angle. Enter your calculations below.
3. Inspect and measure each joint after it has been prepared.
4. Record the actual dimensions of your joint in the space provided.
5. Determine if the actual dimensions are within tolerance.

Note: If you have forgotten how to calculate ranges and tolerances see the math reference packet.

## Butt Joint Horizontal (2G)

Root opening range (in **fractional inches**) \_\_\_\_\_ to \_\_\_\_\_

What is the actual measurement of the root opening? \_\_\_\_\_ Is your weld within tolerance? Y/N

Root opening range (in **decimal inches**) \_\_\_\_\_ to \_\_\_\_\_

What is the actual measurement of the root opening? \_\_\_\_\_ Is your weld within tolerance? Y/N

Included angle range \_\_\_\_\_ to \_\_\_\_\_

What is the actual measurement of the included angle? \_\_\_\_\_ Is your weld within tolerance? Y/N

**Need more help? See the following worksheets: tolerances: fractional, decimal, angle**

## MEASURING TOOLS

Applications:

- Layout
- Fabrication
- Measuring lines, angles and circles with accuracy

## MEASURING WITH FRACTIONS

When we measure with a measuring tape or ruler of some kind, we need to be able to read the marks on the tape or rule correctly. If we are counting the marks that divide the inch into 8 equal slices, we are counting "eighths." If we are counting the marks that divide the inch into 16 equal slices, we are counting "sixteenths," and so on. It is easier to measure and to visualize eighths and sixteenths than it is with 32nds and 64ths. Therefore, if we get something in 32nds that can actually be simplified to eighths, we jump on the chance. The next practice sheet "Reducing Common Fractions" deals with exactly that.

The 2<sup>nd</sup> practice sheet, called "Expressing Common Fractions in Higher Terms" works with doing the exact opposite of reducing fractions. We often need to "expand" fractions in order to be able to add them together or subtract them from each other, a skill that is frequently needed when figuring layout. Follow the examples and see how easy it is to convert those fractions back and forth to lower and higher terms.

The pages following these first two practice sheets deal with actually reading the tape measurer or ruler. The first of these pages shows an expanded one inch ruler with equivalent (equal) fractions for  $1/4$ " ( $2/8$  and  $4/16$ ),  $1/2$ " ( $2/4$ ,  $4/8$ , and  $8/16$ ) and other common fractions. The second of these pages shows a ruler marked off in sixteenths. For each letter A - O, count off how many 16ths or how many whole inches\* and how many additional sixteenths. Then, if they can be simplified, use your reducing skills to write these measurements in inches with fractions of lowest terms.

*\*Note: Make sure that if the top number of your fraction is larger than the bottom number, you simplify it. Fractions with a larger top number are called improper fractions, and they are hard for people to read and even harder to measure off on metal! Make that one inch and  $5/16$  - or --  $1 \frac{5}{16}$  inches.*

## REDUCING COMMON FRACTIONS

Example 1: Express  $30/32$  in lowest terms.

Solution: Find the largest number that will go into each number. Divide that number into each number of the fraction.

$$\underline{30} \div 2 = 15$$

$$32 \div 2 = 16 \quad \text{Ans.} = 15/16$$

Example 2: Express  $12/16$  in lowest terms.

The largest number that will go into each number is 4.

$$12 \div 4 = 3$$

$$16 \div 4 = 4 \quad \text{Ans.} = 3/4$$

Notes: **If both numbers are even, the fraction is always reducible by 2.**

In example 2, what if you could not see that 4 was the largest number and you reduced by 2?

$$\underline{12} \div 2 = 6$$

$$16 \div 2 = 8 \quad \text{Ans.} = 6/8$$

They are both still even and must be reduced again.

$$\underline{6} \div 2 = 3$$

$$8 \div 2 = 4 \quad \text{Ans} = 3/4$$

# EXPRESSING COMMON FRACTIONS IN HIGHER TERMS

Example 1 Express  $\frac{3}{8}$  as 16ths  $\frac{3}{8} = ?/16$

Solution: Divide the smaller denominator (bottom #) into the larger denominator.

$$\frac{3}{8} = ?/16 \quad 16 \div 8 = 2$$

Multiply that answer times the first numerator (top #) and place over the larger denominator.

$$2 \times 3 = 6 \quad = 6/16$$

## Practice

1.  $\frac{3}{4} = ?/16$                       2.  $\frac{5}{8} = ?/16$

## Practic

1.  $\frac{4}{8}$                                       2.  $\frac{8}{16}$   
3.  $\frac{14}{16}$                                   4.  $\frac{8}{32}$   
5.  $\frac{6}{16}$                                       6.  $\frac{2}{8}$   
7.  $\frac{2}{4}$                                         8.  $\frac{6}{8}$   
9.  $\frac{10}{16}$                                       10.  $\frac{24}{32}$   
11.  $\frac{16}{32}$                                       12.  $\frac{4}{16}$

13.  $3/4=?/32$

14.  $7/8=?/16$

15.  $1/2=?/8$

16.  $1/4=?/16$

17.  $3/4=?/8$

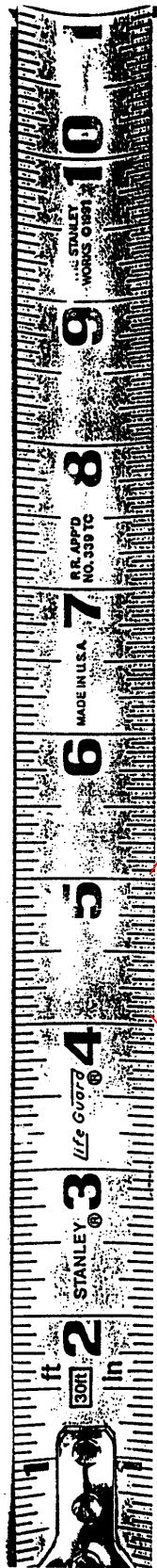
18.  $1/2=?/16$

19.  $1/4=?/8$

20.  $1/2=?/16$

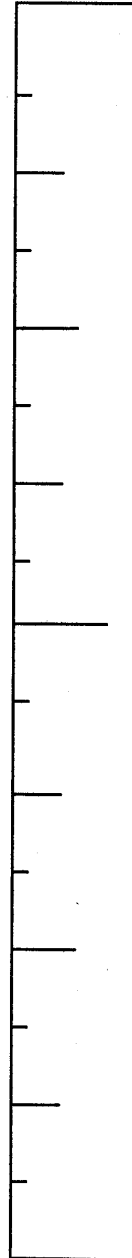
21.  $3/8=?/16$

22.  $1/8=?/16$



One Inch

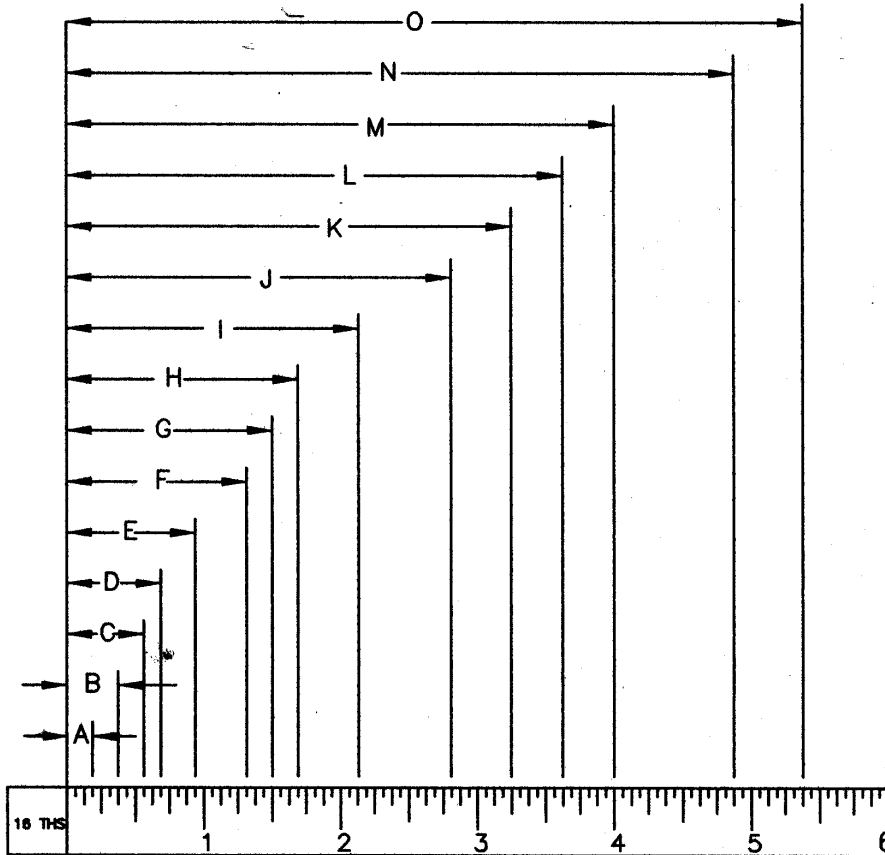
0" 1"



$\frac{1}{16}$ "	$\frac{1}{8}$ "	$\frac{3}{16}$ "	$\frac{1}{4}$ "	$\frac{5}{16}$ "	$\frac{3}{8}$ "	$\frac{7}{16}$ "	$\frac{1}{2}$ "	$\frac{9}{16}$ "	$\frac{5}{8}$ "	$\frac{11}{16}$ "	$\frac{3}{4}$ "	$\frac{13}{16}$ "	$\frac{7}{8}$ "	$\frac{15}{16}$ "	$\frac{1}{2}$
	$\frac{2}{16}$		$\frac{2}{8}$		$\frac{6}{16}$		$\frac{2}{4}$		$\frac{10}{16}$		$\frac{6}{8}$		$\frac{14}{16}$		$\frac{4}{4}$
			$\frac{4}{16}$				$\frac{4}{8}$				$\frac{12}{16}$		$\frac{8}{8}$		$\frac{16}{16}$
							$\frac{8}{16}$								



Drawn below is a 6 inch rule, divided into 1/16 inch increments. You need to correctly identify the distances indicated by the arrows, and place your answers in the proper space below. Example: The distance indicated by the arrows marked "M" is 4 inches. Place 4" in the space below marked "M".



ANSWERS:

A \_\_\_\_\_  
 B \_\_\_\_\_  
 C \_\_\_\_\_  
 D \_\_\_\_\_  
 E \_\_\_\_\_  
 F \_\_\_\_\_  
 G \_\_\_\_\_

H \_\_\_\_\_  
 I \_\_\_\_\_  
 J \_\_\_\_\_  
 K \_\_\_\_\_  
 M \_\_\_\_\_  
 N \_\_\_\_\_  
 O \_\_\_\_\_



Portland Community College  
 Welding Technology

Tolerance (Unless otherwise Specified)  
 Dimensional  $\pm$  1/32" Angle  $\pm$  5'

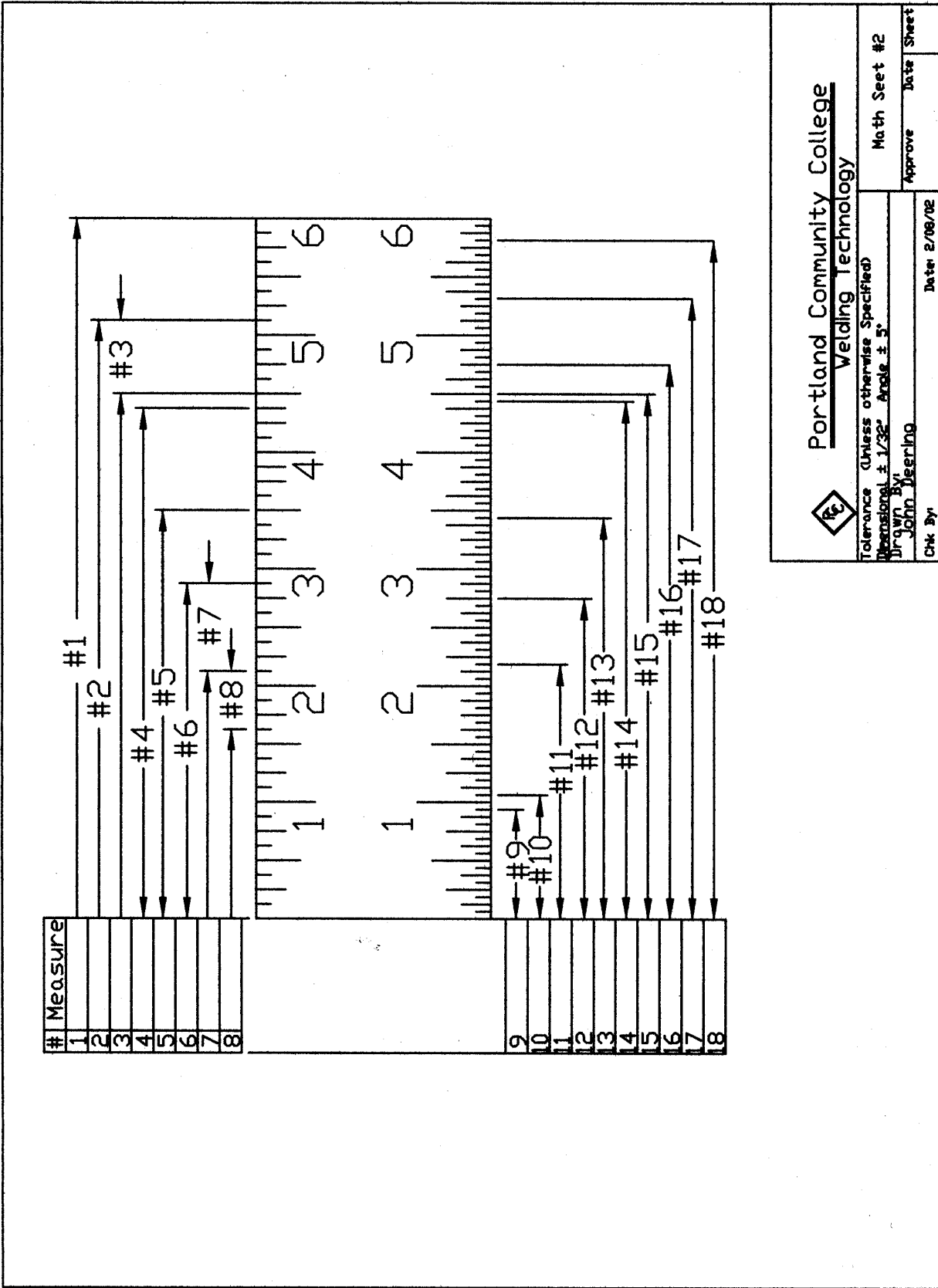
Drawn By:  
 John Deering

Chk By:

Date: 1/08/02

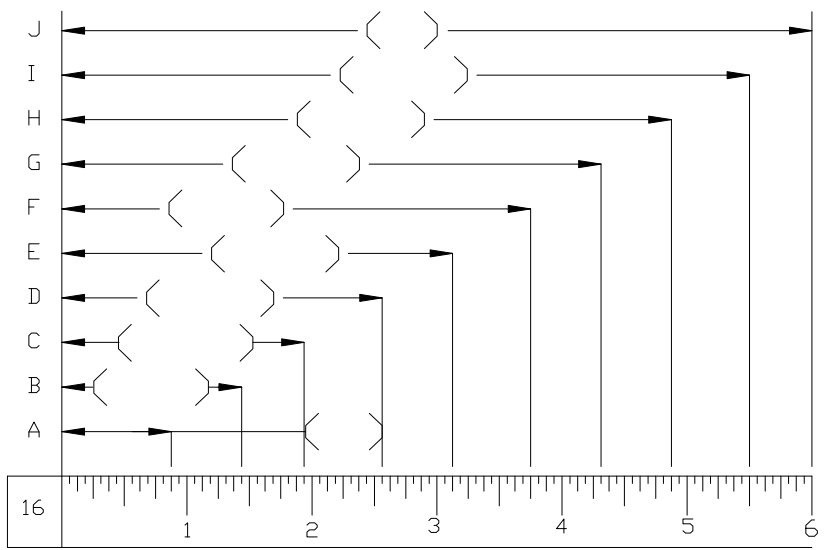
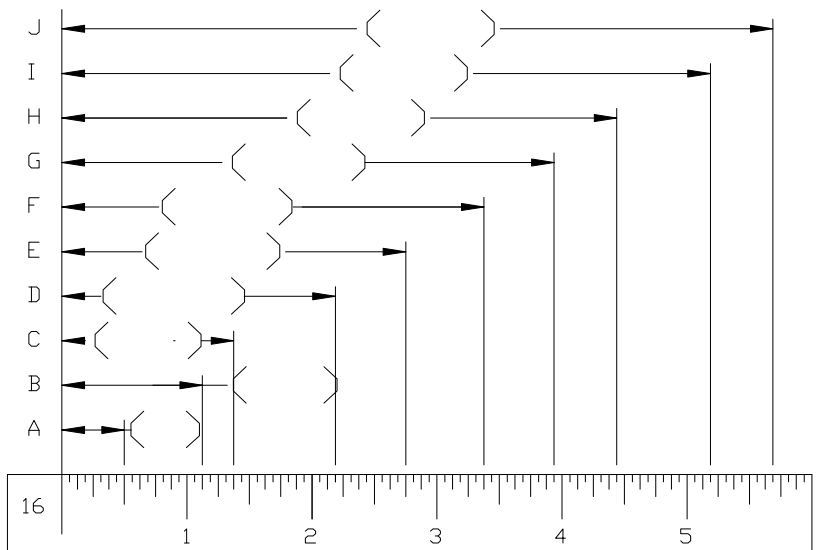
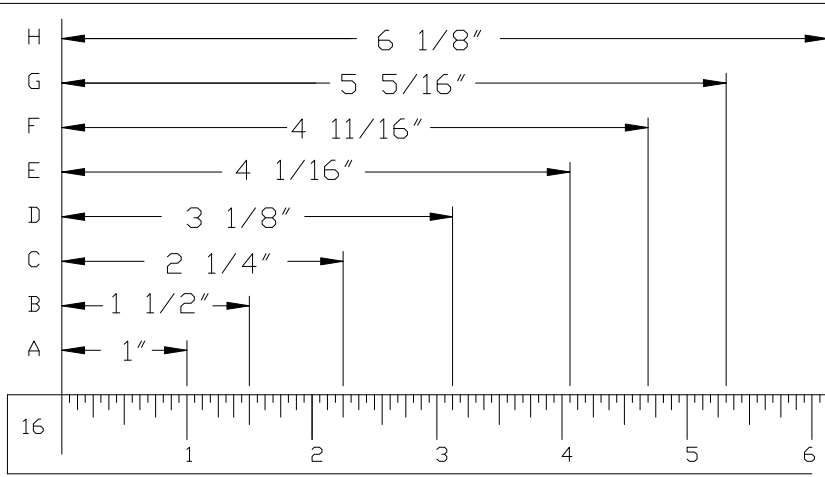
Approve \_\_\_\_\_  
 Date \_\_\_\_\_  
 Sheet #1


Math Sheet #1




**Portland Community College**  
**Welding Technology**

Tolerance (Unless otherwise Specified)		Math Seet #2
Dimensional $\pm 1/32"$ Angle $\pm 5^\circ$		Approve _____ Date _____ Sheet _____
Designed By: John Deering		
Chk By:		Date: 2/08/02



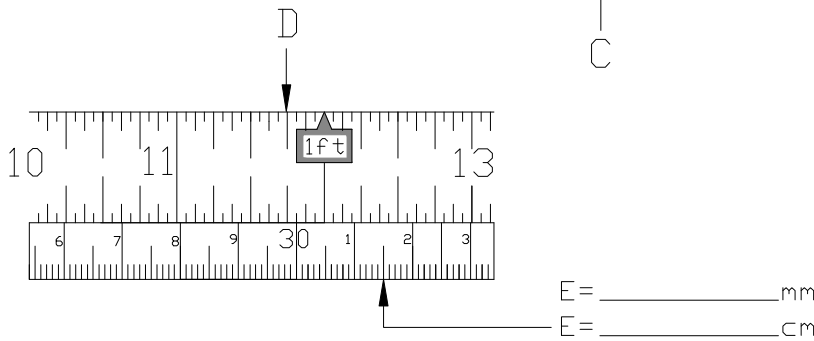
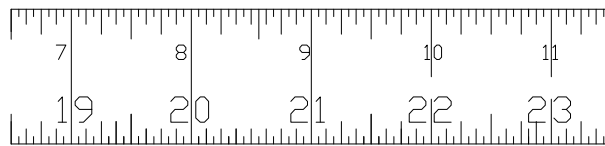
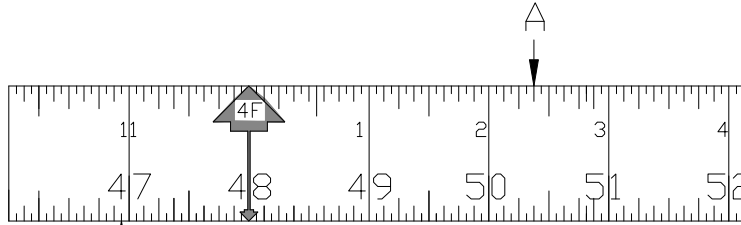
 Portland Community College Welding Technology	Math Seet #3	Date	Sheet
	Tolerance (Unless otherwise Specified) Dimensional ± 1/32" Angle ± 5° Drawn By: JOHN DEERING	Approve	Date
Date: 3/04/03		Chk By:	

Name: \_\_\_\_\_ Date: \_\_\_\_\_

## English and Metric Linear Measure

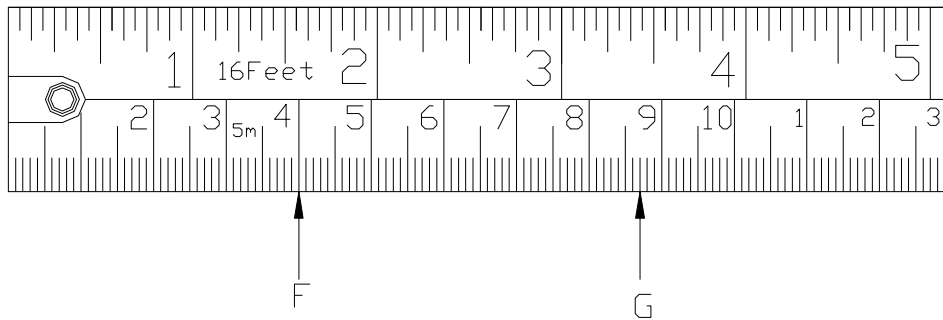
Write the English (inches/fraction of inch) measurement for the points A-D on the tape rules below.

A = \_\_\_\_\_ ft \_\_\_\_\_ inches      C = \_\_\_\_\_ ft \_\_\_\_\_ inches  
 B = \_\_\_\_\_ ft \_\_\_\_\_ inches      D = \_\_\_\_\_ ft \_\_\_\_\_ inches



Write the Metric (centimeters or millimeters as indicated) measure for the point E above and the points F & G on the tape rules below.

F = \_\_\_\_\_ mm      G = \_\_\_\_\_ mm  
 F = \_\_\_\_\_ cm      G = \_\_\_\_\_ cm



 Portland Community College Welding Technology	Math Seat #5	Date	Sheet
	Tolerance (Unless otherwise Specified) Dimensional ± 1/32"(5mm) Angle ± 5°	Approve	Date: 4/23/02
Drawn By: John Deering Chk By:			

Need Help? See the metric system section for further instruction.

## CONVERTING DECIMAL INCHES TO THE NEAREST SIXTEENTH OF AN INCH

Sometimes you need to convert decimal inch measurement to inches and sixteenths of an inch:

For example: Suppose you want to convert a measurement of 2.25" in a dimension manual to a measurement of inches and sixteenths of an inch.

To do that you

- (1) Write **2** down on your paper as the number of whole inches;
- (2) then you enter the rest of the number **.25** into your calculator.

**Remember to put in the decimal point!**

.25

- (3) Multiply this number by 16; this is the number of 16<sup>th</sup>s of an inch that you have.

**.25 x 16 = 4**      or    **4/16.**    **Reduce to ¼.**    *Put it together with the 2" to get **2 ¼"** !*

**Try the following problems, converting the measurement to the nearest 1/16 of an inch:**

1.    0.875 inches = \_\_\_\_\_
2.    8.4375 inches = \_\_\_\_\_
3.    9.0625 inches = \_\_\_\_\_
4.    1.5625 inches = \_\_\_\_\_

The following is an example of a number that isn't quite so neat as the ones above. It will not come out evenly to a whole number of sixteenths, so you will have to do one more step . . .

**Convert 7.395":** (1) Write **7** down on your paper as the number of whole inches; then

(2) Enter the rest of the number in your calculator as

**.395 (without the 7! BUT WITH THE DECIMAL POINT!)**

Notice that this number is not quite so predictable and neat as ".25"

(3) Multiply this number by 16\* **and round your answer off to the nearest whole number**; this is the number of 16<sup>th</sup>s of an inch that you have.

$$.395 \times 16 = 6.32 = \text{approx. } \mathbf{6} \quad \text{or} \quad \mathbf{6/16}$$

(4) If possible, reduce this fraction to eighths or fourths, etc. and include the whole number of inches with the answer: **7 3/8 inches**

5. 25.445 inches = \_\_\_\_\_                      7. 48.07 inches = \_\_\_\_\_

6. 36.955 inches = \_\_\_\_\_                      8. 13.62 inches = \_\_\_\_\_

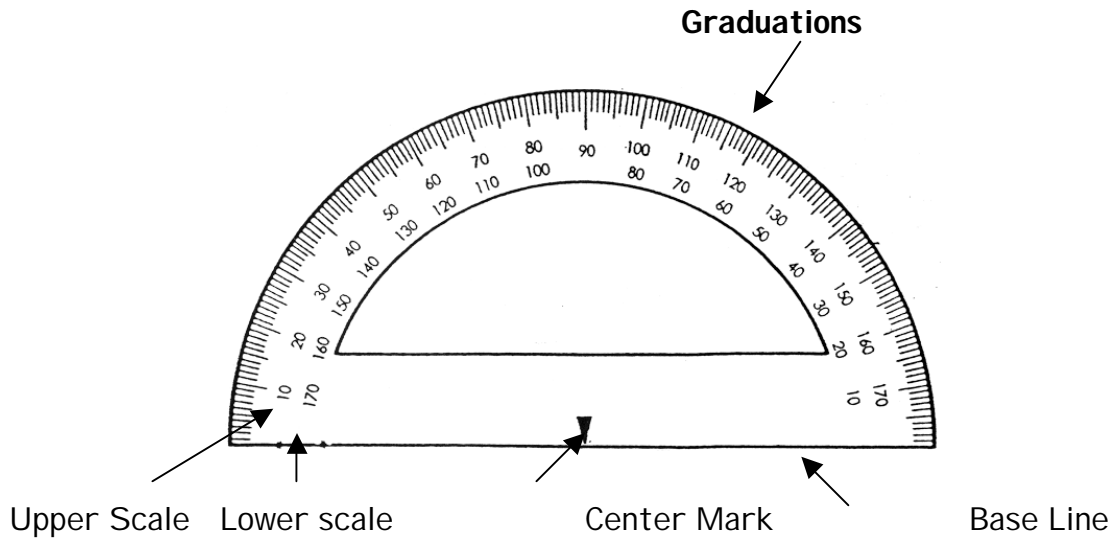
\*Note that if you wanted to convert to the nearest 1/8 instead of 1/16, you would multiply by 8 instead of 16, and if you wanted a finer measurement of 32nds, you would multiply by 32 instead of 16. It's that easy!

**Need more help? See the following worksheets: reducing fractions**

# USING A PROTRACTOR TO MEASURE ANGLES

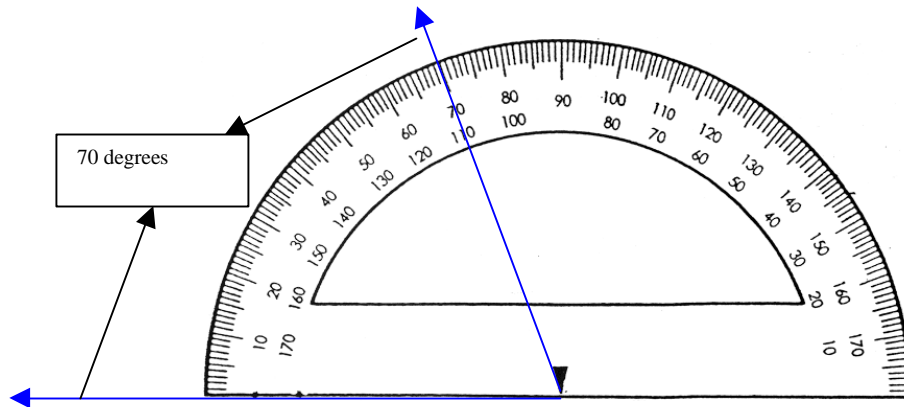
You can measure an angle using a tool called a protractor. A protractor is half a circle and is divided into 180 degrees. Each graduation on the protector equals one degree. A number marks every ten degrees.

Look at the parts of the protractor pictured below.



## HOW TO USE A PROTRACTOR

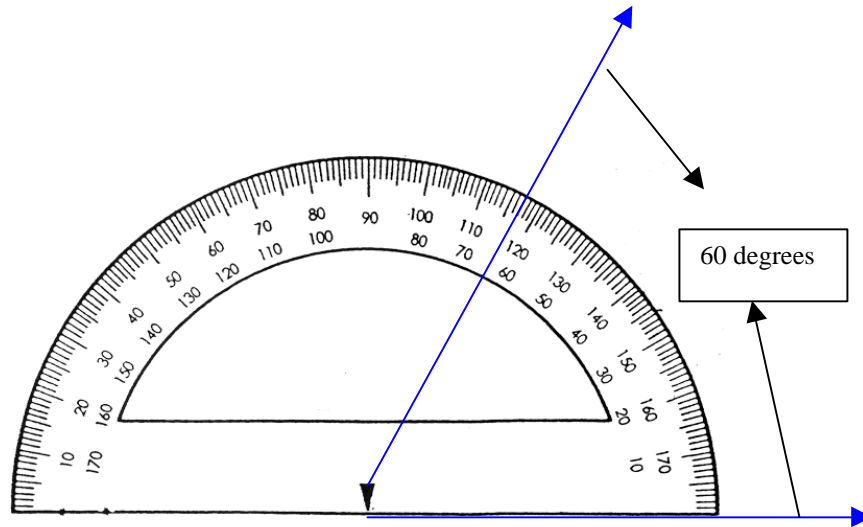
Line the base of the protractor up with one side of the angle you want to measure. Place the center mark, located at the base of the protector, at the point where the two lines of the angle come together (this is known as the vertex). If you have done this correctly, one arm of the angle will intersect a graduation on the scale of the protractor. This will tell you the size of your angle. See example below.



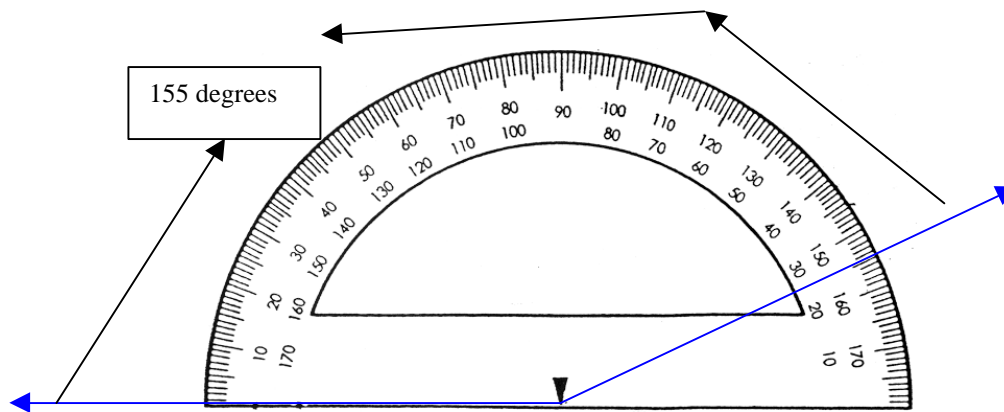
Note that this angle can sometimes be referred to as an *Acute Angle* since it measures between 0 and 90 degrees.

Notice that many protractors have two rows of numbers, an upper scale and a lower scale. You use the upper scale to measure angles when one side of the angle is lined up with the base line to the left of the center mark. You use the lower scale when one side of the angle is lined up with the base line to the right of the center mark. The two scales make it easy to read angles facing different directions.





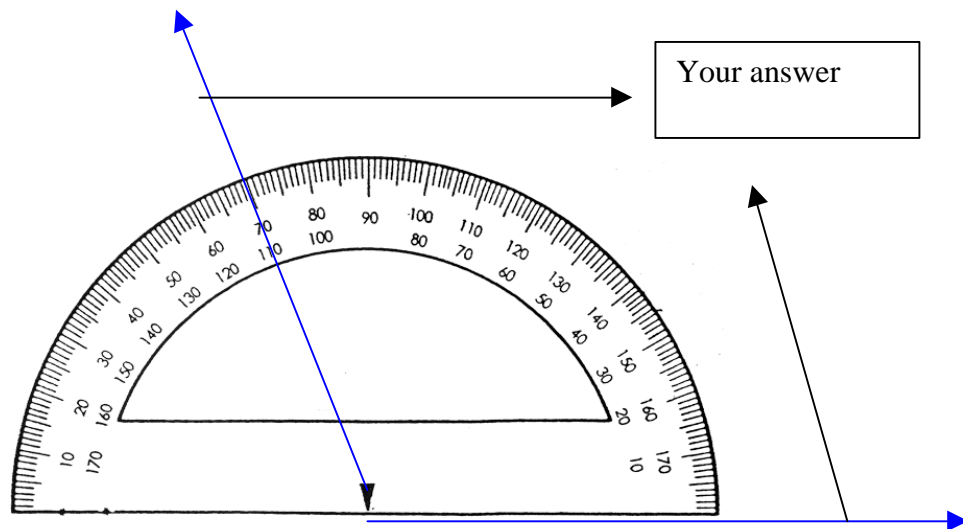
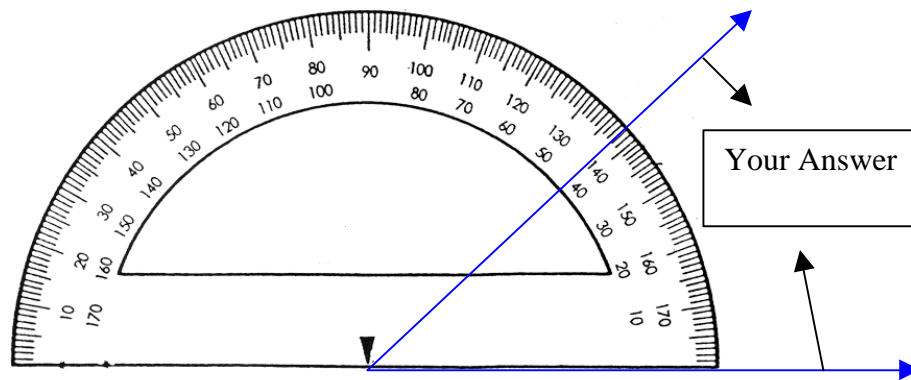
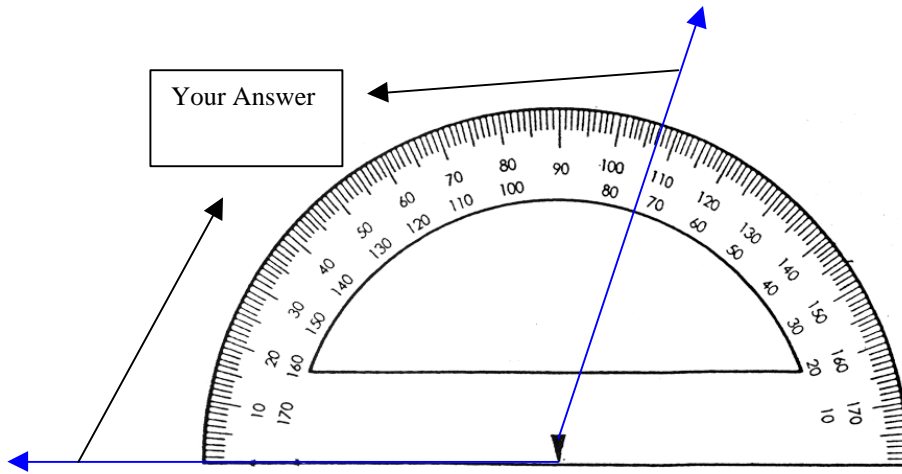
60 degrees is an *Acute Angle*



**Note that this is referred to as an *Obtuse Angle* because it measures greater than 90 degrees and less than 180 degrees.**

To check to see if your measurements are correct remember that the angle you measure plus the outside supplemental angle must equal 180 degrees. In the first example above  $60 + 120 = 180$  and in the lower example above  $155 + 25 = 180$ .

Look at the following protractor and determine the angular measurement.

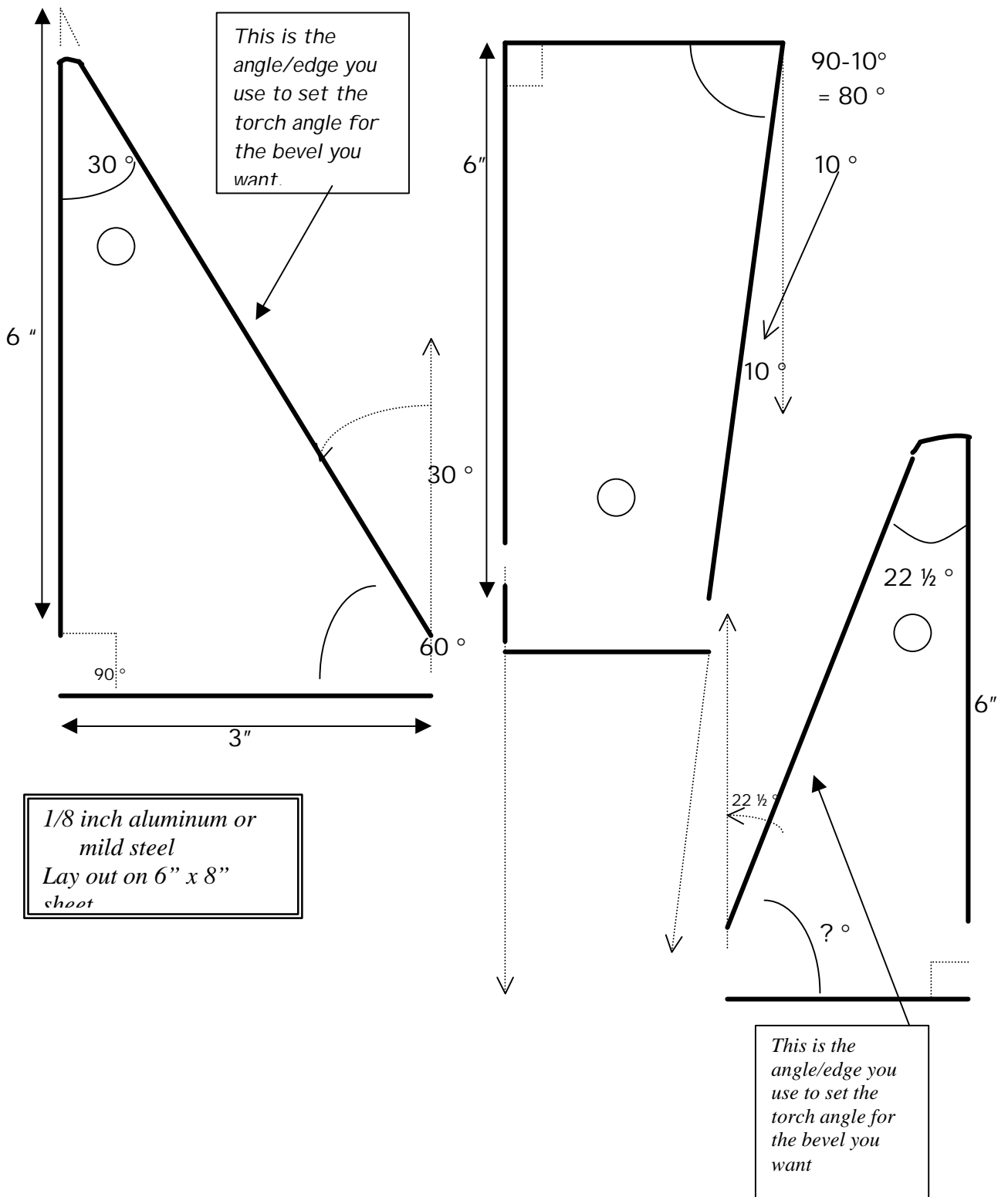


## CONSTRUCTION OF A BEVEL (ANGLE) FINDER

The purpose of this practical exercise is to get experience in measuring, laying out and cutting various standard angles and to construct some useful tools in the process. It is very important that you read the previous page in order to understand why these bevel finders are constructed the way they are.

Use the measurements below to construct three bevel finders: one each for  $10^\circ$ ,  $22\frac{1}{2}^\circ$ , and  $30^\circ$ . Please be sure to measure these with accurate measuring tools such as a protractor before cutting. Do NOT use the sketches below or the templates from the tool room as patterns.

Remember: You are making tools for yourself and want them to be as accurate as possible. Use the punch to make the  $\frac{1}{4}$ " DIA hole in one corner of each. This hole should indicate which corner is the specified angle, and it can also be used for hanging on a peg or on a ring to keep them together.

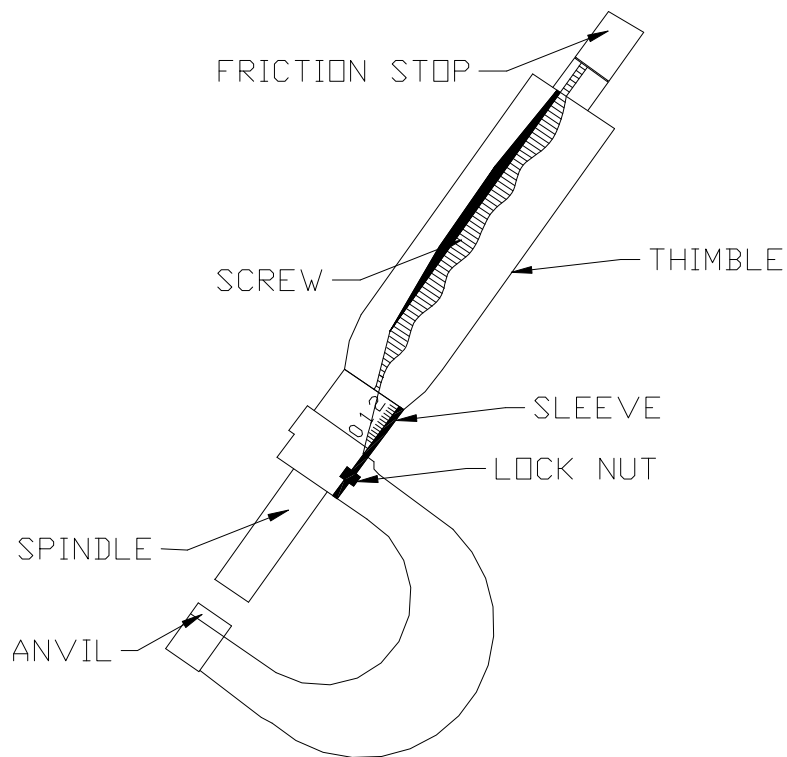


## READING A MICROMETER

Micrometers are often used to measure smaller parts. Micrometers are used when you want to be extremely accurate. For most purposes as a welder you will use a micrometer that is accurate to the nearest .001 of an inch. These step-by-step instructions will teach you to read these micrometers as well as a micrometer that is accurate to the nearest .0001 of an inch.

Place the object that you wish to measure between the anvil and the spindle. Snug the spindle down until you have the 'correct feel'. Your instructor will help you to determine the 'correct feel'.

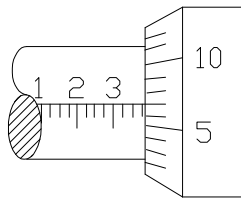
Start by learning the names of the parts of the micrometer.



You will find numbers on a standard micrometer that will tell you:

Total number of inches:	noted on the u-shaped piece
Number of tenths of an inch:	numbers found on the sleeve
Number of .025 of an inch:	graduations found on the sleeve
Number of .001 of an inch:	graduations found on the thimble

When you add up all of these numbers you will have determined the measurement of an object that you have placed between the anvil and the spindle.



$$\langle C. \rangle \quad \underline{.382}$$

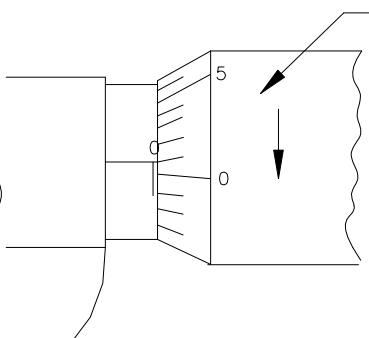
$$.3 + .075 + .008 = .382$$

$$\text{SLEEVE} + \text{THIMBLE} = .382$$

<p><b>Step #1</b> Look at your micrometer and determine the number of whole inches it measures. You will find this information on the 'U' shaped piece that connects the anvil to the spindle. If it is a 0-1" micrometer the maximum distance it can measure is 1 inch. If it is a 2"-3" micrometer the minimum it can measure is two inches, the maximum is 3 inches. In this case the micrometer is a 0-1" micrometer and it is not fully opened so it measures less than 1 inch. Write down '0' inches.</p>	<p>0.00 inches</p>
---	--------------------

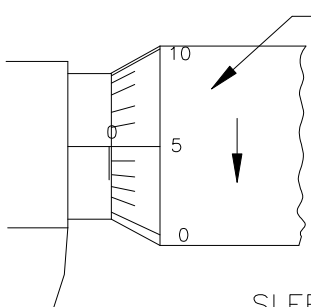
<p><b>Step #2</b> Look at the numbers on the sleeve to determine how many tenths of an inch (.1) are included in your measurement. Choose the number written on the sleeve that is closest to the thimble. In this case it is 3. So I write down 0.3</p>	<p>0.3</p>
<p><b>Step #3</b> Look at the little lines on the sleeve. These are called graduations. Each graduation represents .025 of an inch. Notice that there are 3 graduations between each number. For example between the numbers 1 and 2 you have .125, .150 and .175 then you have .200.</p> <p>To measure with the micrometer, count the number of graduations between the number closest to the thimble (3) and the thimble. In this case there are 3 graduations showing between the 3 and the thimble. Multiply the number of graduations by .025. <math>3 \times .025 = .075</math> Write this number down.</p>	<p>0.075</p>
<p><b>Step #4</b> Look at the index line on the sleeve. Determine which graduation on the thimble lines up with the index line. In this case it is lining up with the 7<sup>th</sup> graduation. Write this down as .007</p>	<p>0.007</p>
<p><b>Step #5</b> Add up all the numbers you have written down. Be sure to keep the decimal points lined up.</p> <p>Adding up these numbers will give you the correct measurement.</p>	<p>0.000  INCHES  0.3  0.075  + <u>0.007</u>  0.382  INCHES</p>

Here are five more examples on how to read a micrometer. Can you follow the logic behind this measuring instrument? See your instructor if you need assistance.

(A) 

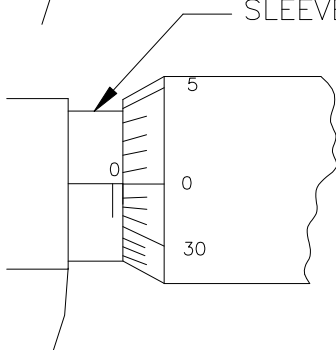
NOTE:  
EACH MARK ON THIMBLE  
EQUALS 1/1000

.001"

(B) 

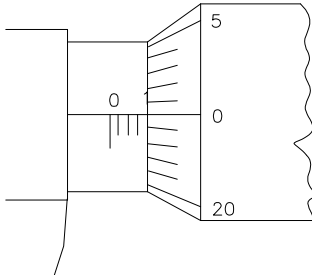
(5 x .001 = .005")

.005"

(C) 

EACH MARK ON BARRELL  
EQUALS .025" (1ST MARK)

.025"

(D) 

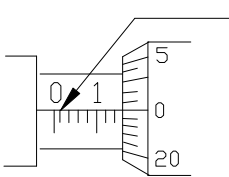
4 x .025 = .1

.100"

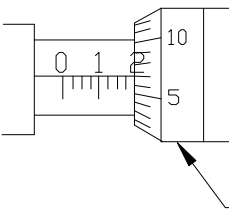


# PROBLEM SET #1

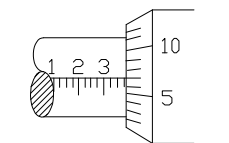
Complete the following questions by interpreting what the micrometer is measuring at and writing your answer in the space provided.

(A.)  EACH MARK ON SLEEVE EQUALS .025

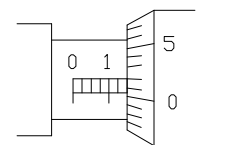
(A.) \_\_\_\_\_

(B.)  THIMBLE, EACH MARK=.001

(B.) \_\_\_\_\_

(C.) 

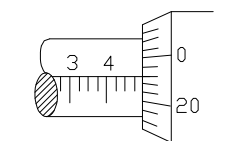
(C.) \_\_\_\_\_

(D.) 

(D.) \_\_\_\_\_

(E.) 

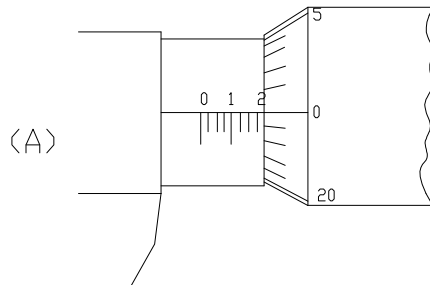
(E.) \_\_\_\_\_

(F.) 

(F.) \_\_\_\_\_

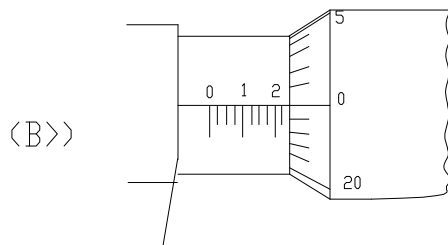
## PROBLEM SET #2

Complete the following questions by interpreting what the micrometer is measuring at and writing your answer in the space provided.

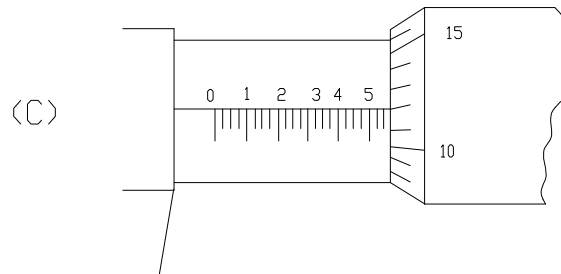


ANSWERS

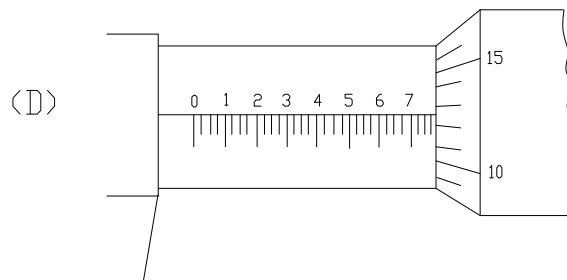
A. \_\_\_\_\_



A. \_\_\_\_\_

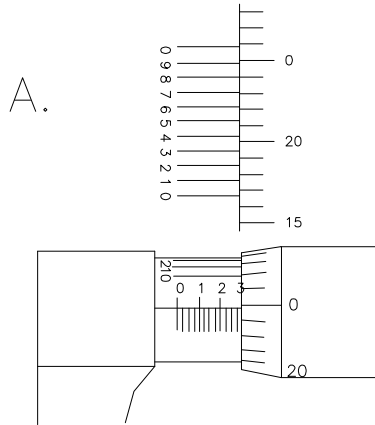


A. \_\_\_\_\_



A. \_\_\_\_\_

In order to read a micrometer that measures to the nearest .0001" you follow all the same steps and then you add one additional step.



Answers

.2 SLEEVE  
 .075 SLEEVE  
 .024 THIMBLE  
 .0008 SLEEVE  
 .2998

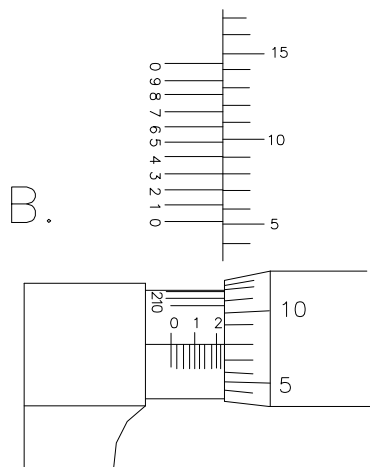
A.         .2998        

<p><b>Step #1</b> Look at your micrometer and determine the number of inches it measures. You will find this information on the 'U' shaped piece that connects the anvil to the spindle. If it is a 0-1" micrometer the maximum distance it can measure is 1 inch. If it is a 2"-3" micrometer the minimum it can measure is two inches, the maximum is 3 inches. In this case the micrometer is a 0-1" micrometer and it is not fully opened so it measures less than 1 inch. Write down '0' inches.</p>	<p>0.00 inches</p>
<p><b>Step #2</b> Look at the numbers on the sleeve to determine how many tenths of an inch (.1) are included in your measurement. Choose the number written on the sleeve that is closest to the thimble. In this case it is 2. So I write down 0.2</p>	<p>0.2</p>

<p><b>Step #3</b> Look at the little lines on the sleeve. These are called graduations. Each graduation represents .025 of an inch. Notice that there are 3 graduations between each number. For example between the numbers 1 and 2 you have .125, .150 and .175 then you have .200.</p> <p>To measure with the micrometer, count the number of graduations between the number closest to the thimble (2) and the thimble. In this case there are 3 graduations showing between the number 2 and the thimble. Multiply the number of graduations by .025  <math>2 \times .025 = .075</math> Write this number down.</p>	0.075
<p><b>Step #4</b> Look at the index line on the sleeve. Determine which graduation on the thimble lines up with the index line. In this case it is lining up with the 24<sup>th</sup> graduation. Write this down as .024</p>	0.024
<p><b>Step #5</b> On micrometers that are accurate to the nearest .0001 there is a second set of graduations running lengthwise located on the sleeve. Each of these marks represents .0001 Find the graduation on the sleeve that most nearly lines up perfectly with a graduation on the thimble. Note the number by the graduation on the sleeve. Write this number down.</p>	0.0008
<p><b>Step #5</b> Add up all the numbers you have written down. Be sure to keep the decimal points lined up. Adding up these numbers will give you the correct measurement.</p>	0.000 INCHES 0.2 0.075 0.024 + 0.0008 <hr style="width: 10%; margin-left: 0;"/> 0.2998 "

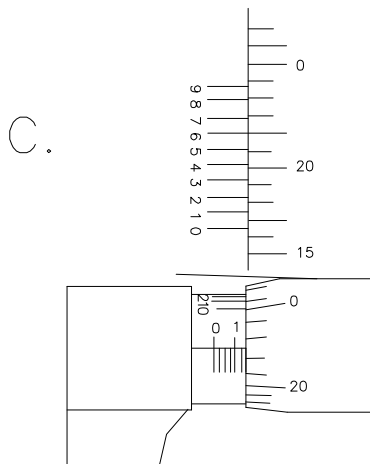
## PROBLEM SET #3

Complete the following questions by interpreting what the micrometer is measuring at and writing your answer in the space provided.



SLEEVE  
SLEEVE  
THIMBLE  
SEEVE

B. \_\_\_\_\_



SLEEVE  
SLEEVE  
THIMBLE  
SEEVE

C. \_\_\_\_\_

**Need more help? See the following worksheets: Reading and understanding decimals, adding decimals, relative size of decimals**

## COMPARING WIRE DIAMETER

### Applications:

- Choosing the correct wire size when wires are sized in both decimals and fractions

## COMPARING WIRE DIAMETER: FRACTIONAL AND DECIMAL INCH

There are times when it is important to compare wire diameter sizes, and this is a little trickier when they are recorded both in decimal inch sizes and in fractional inch sizes. But now that you have practiced converting fractions to decimals and comparing decimals, there is nothing more to learn. All we have to do is apply all that knowledge.

*On #'s 1 and 2, make a guess:*

1. Which is **bigger** in diameter, the .045 wire or the 1/16" wire?
  
2. Which is **bigger** in diameter, the 3/32 wire or the .035" wire?
  
3. Convert the following wire/stick diameter sizes into decimal numbers:

1/16" \_\_\_\_\_

3/32" \_\_\_\_\_

1/8 " (stick only) \_\_\_\_\_ *Were you right on #1 and #2?*

4. Now make a chart of the following 6 common wire/stick sizes. Put the smallest sizes first and the largest sizes on the bottom. Write them as they are normally written; in other words, do not write the decimal equivalent for the fractions.

	<b><i>Smallest to Largest:</i></b>
3/32	
1/16	
.025	
.035	
.045	
1/8	

5. What is the smallest size you use of these most commonly used wires?
  
6. What is the largest size you use of these most commonly used **wires**?
  
7. What is the wire size closest to a 1-millimeter DI A (.03937 inch)?

**Need more help? See the following worksheets: Converting fractions to decimals, converting decimals to fractions, using the fraction key on your calculator**



# RATIO AND PROPORTION

Applications:

- Converting units
  - Examples
    - Inches and feet
    - square inches and square feet
    - English measurements to metric measurement
    - Seconds ?Minutes
  
- Understanding relationships between different numbers
  - Examples
    - Time and money
    - Money and material
    - Materials and coverage

# RATIO AND PROPORTION

A ratio is the relationship between two numbers. The following are ratios:

- 5 out of 7 cars
- 1 of every 4 people
- $\frac{3}{4}$  foot
- 1:10 inches
- 1" for every 12 inches

As you can see, there are many ways of representing ratios. You can use words or symbols. The most commonly used symbolic representations are two numbers with a colon in-between them (1:2) and fractions ( $\frac{1}{2}$ ). That's right; all fractions are ratios. Fractions relate two numbers.

A proportion is most commonly represented by setting two fractions equal to each other, like  $\frac{3}{4} = \frac{6}{8}$ . We also see it in countless "everyday" kinds of math problems:

- If 3 cans of tuna cost \$1.00, how much would 5 cans of tuna cost?
- If a gear with a certain tooth size and 6-inch diameter has 42 teeth.

- How many teeth of the same size will an 8-inch diameter gear have?
- If 30 feet of wire costs \$.85, how much will 200 feet cost?
- If it took me 3.5 hours to weld 20 pieces from one blueprint, how many can I get done in 8 hours?

As you may remember, there is a neat trick that works with two fractions that are equal to each other. It is especially useful if you have three out of the four numbers.

$$\frac{3}{4} = \frac{6}{8}$$

AND

$$\frac{1}{3} = \frac{4}{12}$$

Notice that if the fractions are equal and you multiply both pairs of numbers diagonal from each other, the product of these multiplications are equal . . .  
 $3 \times 8 = 4 \times 6$  (Both equal 24) AND  $1 \times 12 = 3 \times 4$  (Both equal 12). This is useful, because it means that if you have three of the numbers, you can multiply the two diagonal from each other, and divide that answer by the third number. Remember the two products equal each other, so that means

that if we multiply one set of diagonals and divide by a third number, we will get the fourth number. Try it with the fraction proportions we just looked at.

3	?
÷ 4	8

$(3 \times 8) \div 4 = 6$

÷ 1	4
3	?

$(3 \times 4) \div 1 = 12$

This method of solving proportions is called appropriately: The Box Method.

Suppose we wanted to solve our problem on **how many identically welded pieces we could finish in 8 hours if it took us 3.5 hours to complete 20 pieces**. All you need to do is decide the two categories of numbers in the problem: "hours" and "pieces." Use these to label the columns and insert the numbers in their appropriate columns, making sure that the 3.5 hours is on the same row or line as 20 pieces. These two must be on the same line as they are paired together, just as 8 hours will be paired with your answer. **See below.** *You should be able to complete 45-46 pieces in 8 hours given the rate you are going.*

Hours	Pieces
8	←
÷ 3.5	20

$= (8 \times 20) \div 3.5 = 45.7 \approx 45 \text{ or } 46 \text{ pieces}$

Another use for proportions is in converting metric measures to standard English measures and vice versa. If you listen carefully to the way the following question is phrased, you may recognize that it is a question of proportion.

If 1 inch equals 25.4 mm, how many inches long is a steel plate measuring 1200 mm?

The Box Method works wonderfully for these kinds of problems, also. Decide your categories of measuring units. In our case above, the categories are inches and mm (millimeters – a millimeter is about the thickness of a dime). Then you can set up the box.

The secret to setting up a box to do conversions, just like with other proportions is . . .

1. Choose and label your 2 categories of units for your numbers
2. Find the two numbers which represent measurements equal to each other, just like **1 in. = 25.4 mm**, and be sure that these are in the **same row** and under appropriate category headings. *See below. This will ensure that 1200 mm will be paired with its equivalent in inches.*
3. Put the third number, 1200, in the top row under the appropriate category heading. *Note: you cannot put 1200 **mm** under the "inches" column heading.*
4. Cross-multiply where you have numbers diagonal to each other and then divide by the third number, the number you did not use.

Inches	mm
» 47.24	1200
1	÷ 25.4

# PERCENTAGES

Applications:

- Costing out projects
- Determining pay and benefits
- Reducing waste
- Maximizing efficiency

## CALCULATING PERCENTS

If you took Welding 121, you practiced recognizing and calculating proportional problems. Calculating percents is just one special instance of calculating proportions. When we calculate proportions in the following lessons, we will use the Box Method that we used before, and the only difference will be that one category of number data will always be “percents,” and because of that, we will always be working with a ratio of some number to 100.

The word “percent” means “for every” (per) “one hundred” (cent).  $\frac{\quad}{100}$   
 $\quad:100$

This means that when we set up our box, we will always have a “%” column, AND “100” will always be under that column.

We are also going to set up the box in a way that is easy and clear:

*The top row will be a part or portion, not the total:*

#	%
#	%
	100

*The bottom row will represent the (original) total or 100%:*

Part of the total	Partial %
Total #	100%

*A hint for which number is the total (or original total) number in the problem is to look for the number following the word “of.” The number paired with the partial percent should be inserted into the same top row. If a problem says that a number ‘is’ some partial % (less than 100), this is your cue to put these two numbers on the top row together.*

Once set up, the percent box works just like all the other proportion boxes: Cross-multiply the numbers diagonal to each other and then divide by the number you didn’t use.

The most wonderful thing about this method is that it works the same exact way for all different kinds of percent problems. Here are three examples:

Example A: What is 5% **of** 40?

#'s	%
? = 2	5
40	÷ 100

$(40 \times 5) \div 100$   
 $= 200 \div 100 = 2$

Example B: 32 **is** what percent **of** 80?

#'s	%
32	?
÷ 80	100

$= (32 \times 100) \div 80$   
 $= 40\%$

Example C: 10 **is** 5% **of** what? You find the answer on this one.

#'s	%
10	÷ 5
? =	100

What is really great about this method is that normally you would have to use three different methods to solve these three example problems A - C, including trying to remember when to divide, when to multiply, and when and how far to move the decimal point. With this method, you do the same exact thing each time and you do absolutely NOTHING with the decimal. The most difficult part of this method is making sure you put the numbers in the write cells of the Box!

*By the way, did you get **200** as your original total?*

So, let's practice a little on finding some percent answers. You will be amazed how quickly you can calculate them.

1. You are ordering tape measures for the shop, and they are generally \$19.98 but now are on a 30% off discount. How much are you saving per tape? How much are you paying?

\$	%
	100%

2. You are welding 300 of the exact same piece. Your foreman informs you that you shouldn't have more than a 2% defect rate. You finish the order and count the pieces you had to toss into recycling; there are 4 bad pieces. What was your percentage of bad pieces? Is your foreman going to be satisfied?

bad pcs	
	100%

**Need more help? See the following worksheets: Ratio and Proportion**



# ACCURATE SETTINGS AND ADJUSTMENTS

Applications:

- Setting dials and calculating amperage ranges on different machines
- Calculating wire feed speed
- Understanding Wire feed speed as it relates to amperage

## REDUCE THE AMOUNT OF AVAILABLE CURRENT BY DIFFERING PERCENTAGES

Look at the chart printed below. It is reprinted from welding packet WLD 23 entitled "DATA FOR WELDING OF STAINLESS STEEL".

Notice that these current values are for flat position only. Reduce the following ranges by 10% for vertical welds and 20% for overhead welds.

**Calculate the correct ampere ranges for vertical welds and overhead welds.**

D.C.S.P. Welding current Flat amperes	10% ampere reduction for vertical welds	20% ampere reduction for overhead welds
80-100	72-90	64-80
100-120		
90-100		
110-130		
120-140		
130-150		
200-250		
225-275		
275-350		
300-375		
350-450		
375-475		

**Review of "Box Method" for calculating percentages found on the next page.**

Example: Calculate a 20% reduction in an amperage range of 80-100 amps

To solve this problem start with the question what is 20% of 80 amps?

**Step #1** lay out your box with percentages on the left hand side and 100% placed in the lower left hand corner

Part of total Quantity	Percent of total
Total Quantity	100%

**Step #2** Fill in two of the remaining three boxes with the information that you are given in the problem. Remember keep all percentage information on the left hand side of the box.

Part of total Quantity	20%
80 amps	100%

**Step #3** To find out what is 20% of 80 multiply the two numbers that are diagonal to each other and then divide that number by the number you have not already used in the box (in this case 100).

$$20 \times 80 \div 100 = 16 \text{ amps}$$

Remember this result tell you that 20% of 80 amps is 16 amps.

**Step #4** Subtract your 16 amp answer from your 80 amps to find out what the setting would be with a 20% reduction.

$$80 \text{ amps} - 16 \text{ amps} = 64 \text{ amps}$$

Repeat this process (changing the numbers inside the box) to find 20% of 100 amps

Part of total Quantity	20%
100 amps	100%

$$20 \times 100 \div 100 = 20 \text{ amps}$$

$$100 \text{ amps} - 20 \text{ amps} = 80 \text{ amps}$$

**Answer:** A 20% reduction of a range of amperage from 80-100 amps is 64-80 amps.

## CHECKING AND ADJUSTING YOUR WIRE FEED SPEED

Welders need to know how to figure their wire feed speed (WFS), the speed at which the wire comes out of the gun in inches per minute (IPM). Why is this so important? There are several answers to this question, one of them, of course, having to do with figuring how much wire you use and therefore its cost on a given weld. We'll work on this later. Another importance of WFS is that it is often specified by the Welding Procedures, and you need to know if you are welding in the appropriate range of wire feed speed. Finally and probably most importantly, a welder needs to understand the interrelationship between wire feed speed, amperage, and voltage and their influence on achieving a balanced arc condition.

Well, as you know, this is the math section, so let's start with how to figure your wire feed speed. You may ask why you can't just set the WFS dial to a number in the range given in the Weld Procedures and go from there? You can start there, and for newer equipment, it will probably work just fine. But older welding equipment varies considerably, and some have a wire speed dial whose numbers have absolutely nothing to do with inches per minute (IPM). These are often expressed in numbers 1 - 10. Some machines have a WFS/IPM dial that makes more than one revolution, but nothing to count how many revolutions have occurred. Without actually measuring the wire, you may not be able to determine the wire feed speed, because you may not be able to know how many times the dial has done 360 degrees. Also, even newer welding equipment gets old and loses calibration, and you just cannot count on the WFS/IPM dial accurately reflecting the speed output. You need to be able to measure the speed you get and adjust your dial to a setting that actually gets your speed within range.

Let's go over that procedure:

1. First, cut the wire flush to the nozzle on your gun
2. If the dial has IPM settings, set the WFS dial to a number within the WFS range given in the procedures of one of your projects. If the dial has 0 - 10 or another non-IPM setting, adjust it mid-range, e.g. "5."  
  
*If you are using a newer machine, like the Lincoln Power Wave 455, which has an IPM wire feed speed dial, you should understand that even a newer machine might not always give out what you set them to, so it's a good idea to go through this procedure to check the WFS/IPM dial accuracy. Basically, you need to be able to do this.*
3. Squeeze the trigger for exactly 6 seconds.
4. Measure the amount of wire that came out of the nozzle, to the nearest 1/16".
5. Multiply this number by 10 to get the number of inches for a full minute (6 sec x 10). You may need to use the fraction (**a b/c**) key on your calculator as you will probably be dealing with a mixed number. Round to the nearest whole number, that is, to the nearest inch.
6. Check to see if this number lies between the numbers given in the Procedure range, and if it doesn't, adjust your setting accordingly.
7. Until you get good at this, you may need to measure and adjust a few times to get your speed right, especially if you're working on a machine which does not have an IPM dial. Ideally, you should be within the range given. There are certain circumstances in which you can be outside the range, but until you're an expert welder, you should focus on getting within the range parameters.

Okay, let's look at an example of this. Suppose your Welding Procedure gives you a range of 230 - 280 WFS/IPM. You can use this range for Dual Shield welding, in case your Welding Procedure gives only volts and amps and not the wire feed speed (WFS). For now, regardless of which machine you have been using, even if they are relatively new machines with probably close-to-accurate digital readouts (but not always) of WFS/IPM . . .you still need to follow the procedure and check.

So, set your WFS/IPM dial somewhere in the middle of the range, say 250 IPM, and follow the steps to figuring your **actual** WFS. How close is the actual to 250 IPM? Also be sure to take a look at the amperage readout and write that down: \_\_\_\_\_ amps.

Now, turn the dial to 280 WFS/IPM and note any change in amps. Write it here: \_\_\_\_\_

Now, turn the dial to 230 WFS/IPM and note the change in amps. Write it here: \_\_\_\_\_

Now, turn the dial to 350 WFS/IPM and note the change in amps. Write it here: \_\_\_\_\_

What happens to the amperage when you up the WFS?

What is your conclusion about the relationship between WFS and amperage?:

## **REVIEW- CHECKING AND ADJUSTING YOUR WIRE FEED SPEED WLD 142**

The last class in WLD 141 we spent a little time making sure we understood the interrelationship between wire feed speed and amperage; we also did a few calculations to determine our WFS's on different dial settings. Because of the importance of wire feed speed (WFS/IPM) in achieving a balanced arc condition, we are going to take a little time and space here to review the procedures you use in calculating and adjusting it.

You need to be able to measure the speed you get and adjust your dial to a setting that actually gets your speed within range.

Let's go over that procedure:

1. First, cut the wire flush to the nozzle on your gun
2. If the dial has IPM settings, set the WFS dial to a number in the WFS range given in the procedures of one of your projects. If the dial has 0 - 10 or another non-IPM setting, adjust it mid-range, e.g. "5."
3. Squeeze the trigger for exactly 6 seconds.
4. Measure the amount of wire that came out of the nozzle, to the nearest 1/16".
5. Multiply this number by 10 to get the number of inches for a full minute (6 sec x 10). You may need to use the fraction (**a b/c**) key on your calculator as you will probably be dealing with a mixed number. Round to the nearest whole number, that is, to the nearest inch.
6. Check to see if this number lies between the numbers given in the Procedure range, and if it doesn't, adjust your setting accordingly.

7. Until you get good at this, you may need to measure and adjust a few times to get your speed right, especially if you're working on a machine which does not have an IPM dial. Ideally, you should be within the range given. There are certain circumstances in which you can be outside the range, but until you're an expert welder, you should focus on getting within the range parameters.

Okay, let's look at an example of this. Suppose your Welding Procedure gives you a range of 160 - 260 WFS/IPM. You can use this range for Inner Shield welding, in case your Welding Procedure gives only volts and amps and not the wire feed speed (WFS). Say you set your old welding equipment dial to a mid-range, like "5," and squeeze the trigger. In 6 seconds, 13 13/16 " of wire comes out. When you multiply this by 10, using your fraction key, you get 138.125 IPM. We round that down to 138 IPM and check the range again. It's low. You will need to adjust up, measure and check again, and so on, until you get within the range set in the procedures.

If possible, try doing this on a couple different machines over the course of the term.

See how many different machines you can practice this on; write down a measurement for at least each of two settings:

Machine (Company/Number) \_\_\_\_\_ location in shop \_\_\_\_\_

**Circle one: Dual Shield/Inner Shield**  
**280/ 160-260**

**Circle one range: 230-**

Setting on dial \_\_\_\_\_

Actual WFS/IPM = \_\_\_\_\_

Setting on dial \_\_\_\_\_

Actual WFS/IPM = \_\_\_\_\_



Machine (Company/Number) \_\_\_\_\_ location in shop\_\_\_\_\_

**Circle one: Dual Shield/Inner Shield  
280/ 160-260**

**Circle one range: 230-**

*Setting on dial* \_\_\_\_\_ *Actual WFS/IPM =* \_\_\_\_\_

*Setting on dial* \_\_\_\_\_ *Actual WFS/IPM =* \_\_\_\_\_

Machine (Company/Number) \_\_\_\_\_ location in shop\_\_\_\_\_

**Circle one: Dual Shield/Inner Shield  
280/ 160-260**

**Circle one range: 230-**

*Setting on dial* \_\_\_\_\_ *Actual WFS/IPM =* \_\_\_\_\_

*Setting on dial* \_\_\_\_\_ *Actual WFS/IPM =* \_\_\_\_\_

Machine (Company/Number) \_\_\_\_\_ location in shop\_\_\_\_\_

**Circle one: Dual Shield/Inner Shield  
280/160-260**

**Circle one range: 230-**

*Setting on dial* \_\_\_\_\_ *Actual WFS/IPM* \_\_\_\_\_

*Setting on dial* \_\_\_\_\_ *Actual WFS/IPM* \_\_\_\_\_

Machine (Company/Number) \_\_\_\_\_ location in Shop\_\_\_\_\_

**Circle one: Dual Shield/Inner Shield  
280/ 160-260**

**Circle one range: 230-**

*Setting on dial* \_\_\_\_\_ *Actual WFS/IPM =* \_\_\_\_\_

*Setting on dial* \_\_\_\_\_ *Actual WFS/IPM =* \_\_\_\_\_

# SETTING THE DIALS TO OBTAIN THE CORRECT AMPERAGE SETTINGS

Amperage is the measure of current flow. The more amps you have the more current you will have. In order to obtain the best weld possible you must accurately set the amperage to the specified level. This can be challenging because the amperage settings on every machine are different. On most machines there is an amperage range setting and a fine adjustment. The newer machines are less confusing to use, but most shops, unless they specialize, will have older machines.

In this packet you will be welding aluminum using Alternating Current (AC). When choosing your range make sure that you are on the alternating current settings.

We will discuss the settings on three different machines:

- Miller Syncrowave 250
- Sureweld
- Lincoln Ideal Arc Welder TIG 300/300

## Miller Syncrowave

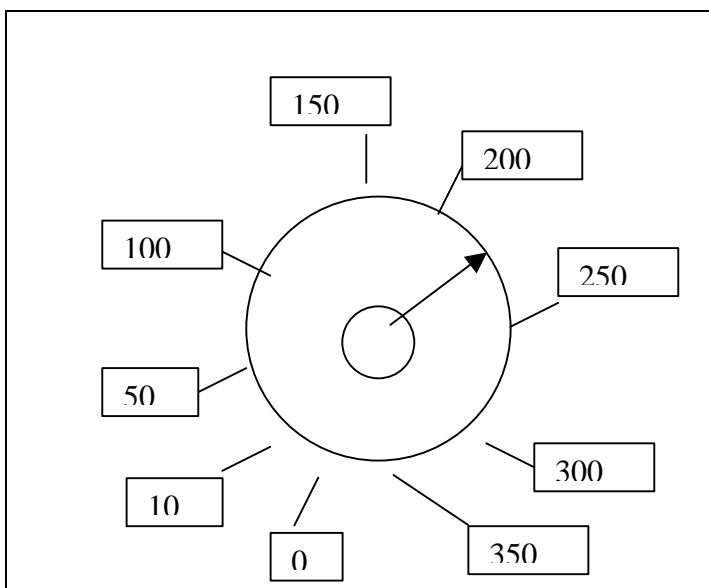
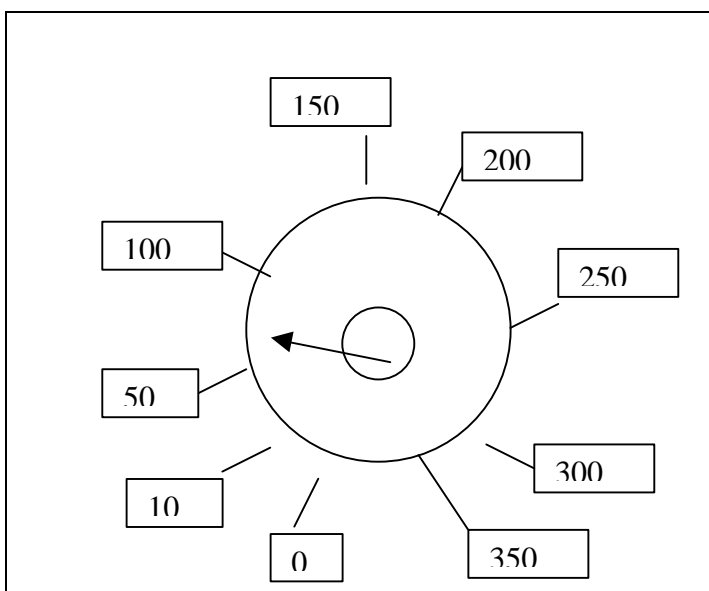
The easiest machine to set is the Miller Syncrowave. It is the newest machine and has just one dial to set.



Notice that the amperage adjustment goes from 0-310 amps.  
Starting with 50 amps and going to 300, the dial is set in 50 amp increments.  
i.e. 50, 100, 150...

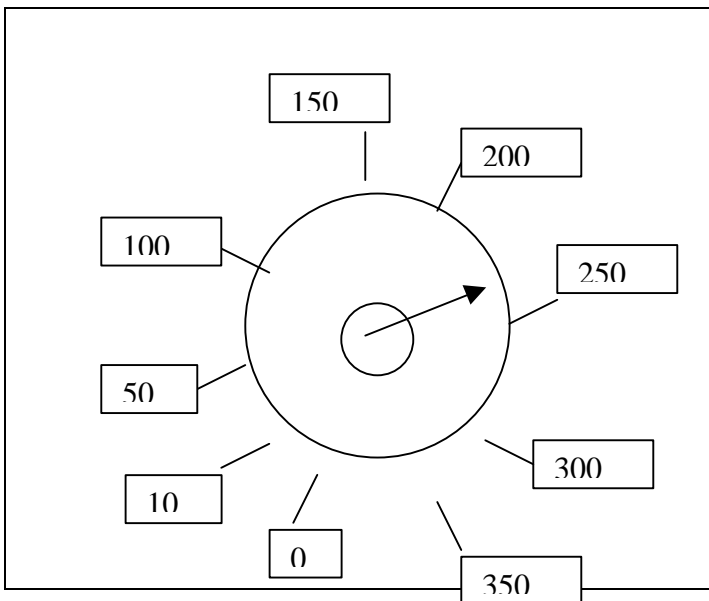
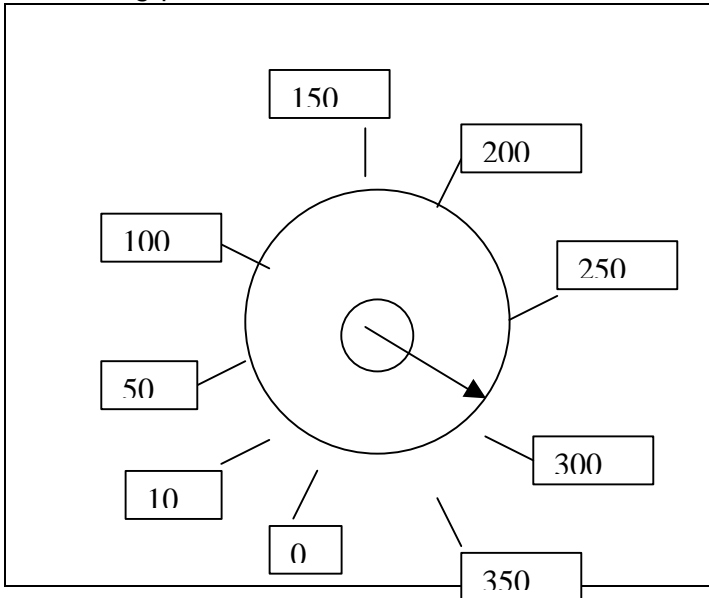
There are no graduations between the numbers so you can not set this dial to exact amperage. You can only come close.

Since you know that there is a 50 amp difference between the numbers you can estimate that half way between any two numbers is 25 more amps than the lesser of the two numbers. Halfway between 50 and 100 would be  $50 + 25$  or 75 amps. Halfway between 200 and 250 would be  $200 + 25$  or 225 amps.

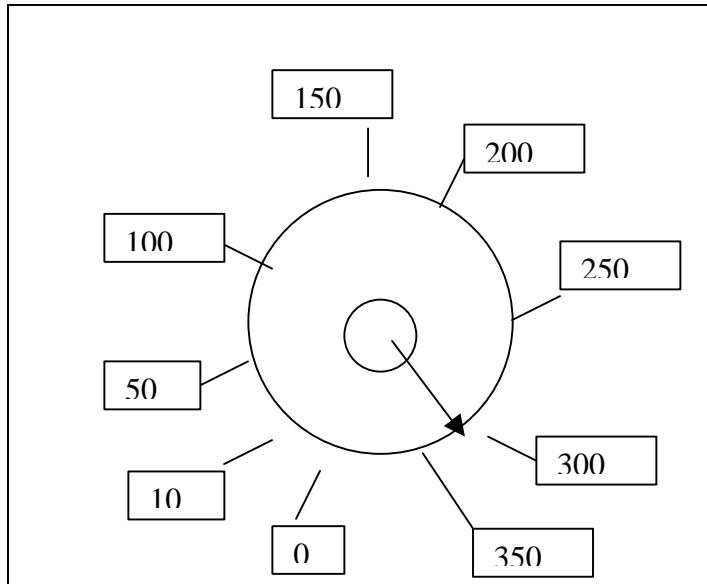


What if I need a setting of 110 amps?

Turn the machine to the 100 amp setting and then reason that an additional 10 amps is about 1/4 of the way to 150 amps, so I would set my dial as in the following picture.

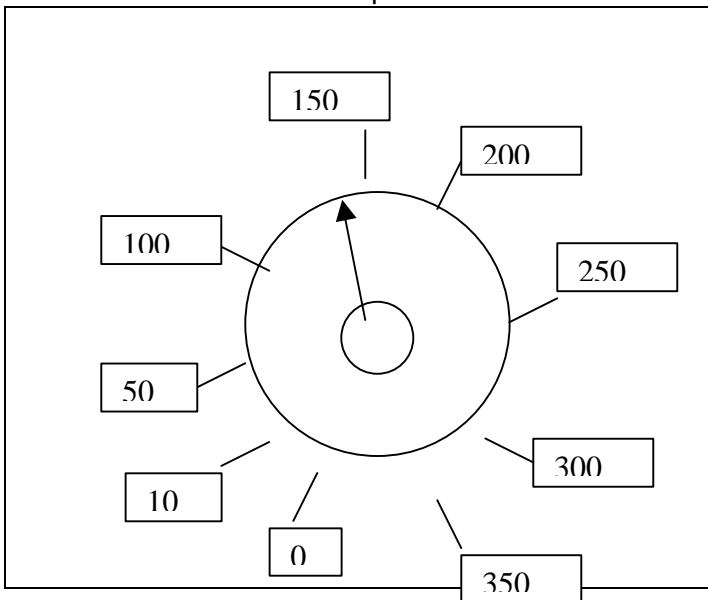


Look at the following two dials and determine what the amperage is set at. Explain your thinking process.



### Reading Very Low and Very High Settings

Look at the lowest settings and the highest settings on the amperage adjustment below. The lowest numbers are 0, 10 and 50. The highest settings are 300 and 310. If your amperage setting is below 50 or above 300 you will divide the space up differently. Between 0 and 10 amps there are only 10 amps. Half way between them is 5 amps; a quarter of the way between them is 2.5 amps etc.



## Sureweld

Next look at this picture of the Sureweld



The Sureweld has three AC amp range settings. They are:

- 5-48
- 20-230
- 190-435

Choose the lowest range which includes your intended amperage setting.

The Sureweld also has a fine adjustment dial that is labeled from 0-100. You can think of this dial as indicating a percent of the total amps in a given range. Remember the range is the difference between the greatest number and least number of amps given. Each graduation stands for 2% of the total amount of current available in that range. For instance if your lever is set in the middle range (20-230 amps) the 0 on the dial would indicate 20 amps and the 100 would represent 230m amps or 100% of the available amperage on the range.

Because this is a percentage problem, you can use the box method to solve it.

Another way to look at this is that we know that each graduation is worth 2% of the range. So we can use the box to determine how much each graduation is worth in a given range.

$$(210 \times 2) \div 100 = 420 \div 100 = 4.2 \text{amps}$$

Amps	%
?	2
210	100

For the middle range each graduation is worth 4.2 amps. Remember we start counting at 20 amps (the low end of the range) and then add 4.2 amps for each graduation) We could count 28 graduations in order to get to 140 or we can do it an easier way.

- We know that we want to set the dial for 140 amps.
- We know that each graduation in the middle range is worth 4.2 Amps
- We know that the dial starts at 20 amps

Take the dial setting you want, 140amps, and subtract 20 amps 140-20 = 120

Divide 120 by 4.2 to determine where you would set the dial.

$$120 \div 4.2 = 28.57$$

**To get 140 amps you would set the dial between 28 and 29**

**What if we wanted a dial setting of 75 amps?**

Take the dial setting you wish to get (75amps), and subtract 20 amps 75-20 = 55 amps

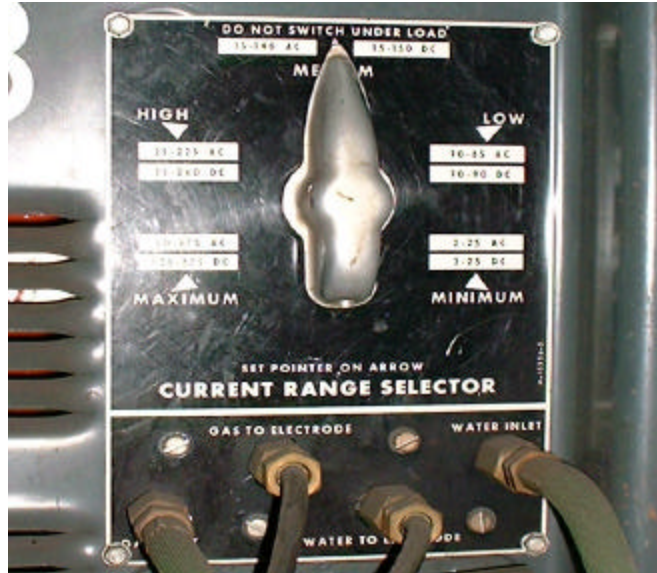
Divide 55 by 4.2 to determine where you would set the dial.

$$55 \div 4.2 = 13.09$$

**To get 75 amps you would set the dial on 13.**

## Lincoln Arc Welder

The third machine that you might use on your welding projects for this packet is the Lincoln Arc Welder- Ideal Arc TIG 300/300. Look at the first picture below. It shows the current range selector lever.



There are five possible AC ranges that you can choose from. They are:

- Minimum 2-25 amps
- Low 10-85 amps
- Medium 15-140 amps
- High 25-225 amps
- Maximum 60-375 amps

Set the current range selector to the lowest range that includes your intended amperage

The Lincoln Arc welder also has a fine current adjust setting as pictured below.





Notice the dial on the fine adjustment current control is labeled one to ten. There are no graduations between the numbers. You will only be able to get an approximate setting using this dial. It is impossible to be exact. In any case the number one represents the bottom number of your range and the number 10 represents the top number of your range.

To determine what each number in between one and ten means, you count the number of segments the dial is divided into. The answer is **nine segments.** There are 10 numbers but only nine spaces. You then determine the difference in the high and low of the range you are working in. Lets say we want to know what each number means in the low range (10-85 amps). When you see the word "difference" it means subtract.

$85 - 10 = 75$  amps. The difference between the high and the low in the low range is 75 amps.

You then take the difference in the range, 75 amps, and divide it by the number of segments on your dial. (9)

$75 \div 9 = 8.33$  amps. 8.33 is the number of amps between each dial setting in the low range.

**Each number on the dial represents an additional 8.33 amps when you are in the low range.** So the number 1 is 10 amps (the lowest number of amps on the low range). The number two represents 18.33 amps. (10 amps + 8.33 amps) The number three represents 26.66 amps. (18.33 amps + 8.33 amps) and so on.

**To determine where a specific amperage is on the low range, in this case 60 amps, follow these steps:**

1. Determine what each segment is worth in the particular range. In this case 8.33 amps
2. Subtract the low number of the range (10 amps) from the total amps that you want in your dial setting. (60)

$$60 \text{ amps} - 10 \text{ amps} = 50 \text{ amps}$$

3. Divide 50 amps by the amount each segment is worth  $50 \div 8.33 = 6.00$

4. Set the dial on six in order to get 60 amps.

What if I want to set my dial for a number of amps that is not represented by a number on the fine adjustment dial? You would then find the closest number and estimate where you would set the dial. For example if I needed 25 amps on the lowest range setting? I would set the dial slightly before the 26.66 amp setting that would be the number 3.

**Remember every time you change the range you change how many amps each number on the fine adjustment dial is worth.**

Let's set the machine for 125 amps.

**Step #1** Set the range selector to the number of AC amps that are required. In this case we would choose the medium range (15-140 amps) because it is the lowest usable range.

**Step #2** Determine what the numbers mean on the fine adjustment current control dial. Subtract 15 from 140, the low of the range from the high of the range.

$$140-15= 125 \text{ amps}$$

Divide 125 amps by the nine segments ( $125 \div 9$ ) and you determine that each number is worth 13.88 amps.

**Step #3** Set the dial by taking the intended setting (125 amps) and subtracting 15 amps, the bottom of the range.  $125- 15 = 110$  amps. Divide this number (110) by the amount each segment is worth.

$110 \div 13.88 = 7.92$  **Set the dial just before the number eight.** The number 8 represents 125 on the medium range.

**Now you practice.** Using the high scale (25-225 amps) how would you set the fine adjustment in order to get 145 amps? Please show your work.

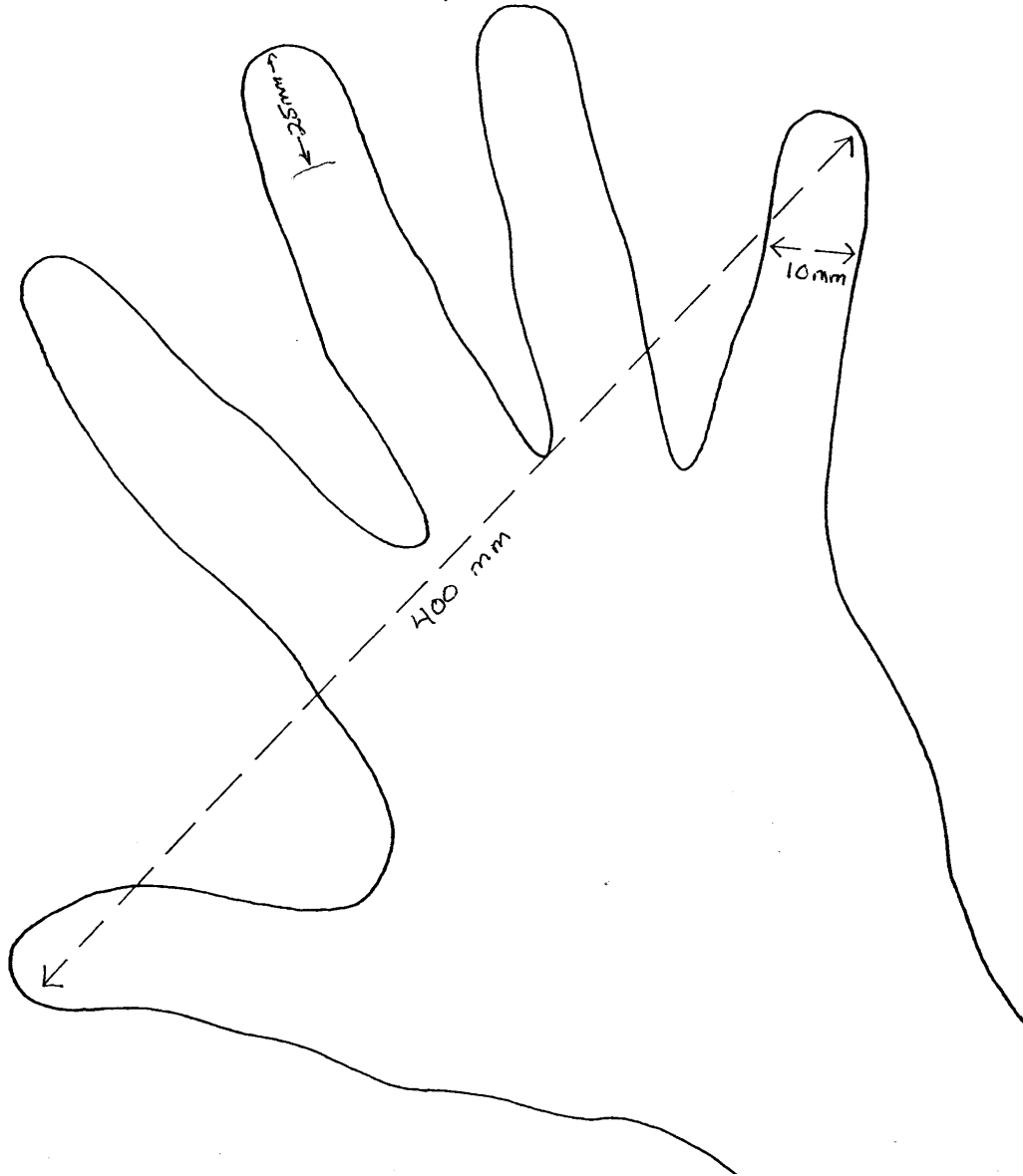
# INTRODUCTION TO METRIC UNITS

Applications:









- As a welder it is important that you can easily convert between metric units and Standard English units. These materials will assist you in learning the relative size of linear metric units and several different ways to do conversions.

## USING YOUR HAND AS A METRIC RULER

Memorize these few hand measurements. Remember they are just an approximation, but if you just remember these three measurements you will be able to estimate the size of most parts in millimeters.



# MORE ESTIMATIONS IN MILLIMETERS AND CENTIMETERS

	Size	Body References
	10mm 1cm	Width of tip of little finger, or the width of a fingernail.
	25 mm 2.5 cm	Tips of two fingers pressed together.
	50 mm 5 cm	Tips of four fingers pressed together.
	100 mm 10 cm	Width of hand from thumb to knuckle to side.
	200 mm 20 cm	Length of hand, from wrist to longest fingertip.
	500 mm 50 cm	From armpit to wrist, or from elbow to longest fingertip.
	1000 mm 100 cm	From left shoulder to tip of right hand.
	1500 mm 150 cm	From hand to hand (palm to palm).

**NOTE:** Establish your own body references. These are averages.

## ESTIMATING LENGTH IN MILLIMETERS

Estimate the following lengths:

The length of your forearm (from elbow to tip of middle finger)= \_\_\_\_mm

The length of your arm (from shoulder to tip of middle finger)= \_\_\_\_mm

The length from your right shoulder to the tip of your left middle finger  
= \_\_\_\_\_mm

The width of the palm of your hand = \_\_\_\_\_mm

The length of your pen or pencil = \_\_\_\_\_mm

The width of your pen or pencil = \_\_\_\_\_mm

The length of a credit card = \_\_\_\_\_mm

The width of your calculator = \_\_\_\_\_mm

The length of the table = \_\_\_\_\_mm

The distance from the floor to the seat of your chair = \_\_\_\_\_mm

The height of your chair (top to floor) = \_\_\_\_\_mm

The diameter of a dime = \_\_\_\_\_mm

The width of a quarter = \_\_\_\_\_mm

The length of your door key = \_\_\_\_\_mm

The width of your wristwatch band = \_\_\_\_\_mm

## CONVERTING TO METRIC EQUIVALENTS

The following chart is taken from your packet.

Note that the electrode diameters are given in both fractional and decimal inch measurements. In the chart below a third column has been added for electrode diameter given in millimeters. **Convert the given electrode diameter size to metric sizes.**

<b>Typical current ranges for tungsten electrodes, DCSP, Argon shielding gas</b>		
Current Range (amp.)	Electrode Diameter (in.)	Electrode Diameter (mm)
5-20	0.020	.508
15-80	0.040	
70-150	1/16	
150-250	3/32	
250-400	1/8	
350-500	5/32	
500-750	3/16	
750-1000	¼	

The easiest way to convert from inches to millimeters when you are out in the shop is to use the box method. See the math reference packet for a detailed review of this method of conversion.

**Remember that 1-inch is equivalent to 25.4 mm.**

Set up your box with an inch side and a millimeter side and with 1 inch directly across from 25.4 because they are equal lengths.

To use the box and determine the equivalent number of millimeters:  
Cross multiply (multiply the numbers that are at a diagonal to each other)  
and divide by the number you did not use.

$$0.020 \times 25.4 \div 1 = 0.508\text{mm}$$

Inches	Millimeters
0.020	?
1	25.4

**Using this box method, complete the rest of the chart by converting all inch measurements to millimeters.**

When you are finished check your answers on the conversion chart found on the next page and in your math reference packet.

**Need more help? See the following worksheets: Ratio and Proportion**



METRIC CONVERSION FACTORS FOR COMMON ENGINEERING TERMS

Property	To Convert From	To	Multiply By	Property	To Convert From	To	Multiply By
acceleration (angular)	revolution per minute squared	rad/s <sup>2</sup>	1.745 329 x 10 <sup>-3</sup>	power	horsepower	W	7 456 999 x 10 <sup>2</sup>
	acceleration (linear)	in./min	m/s <sup>2</sup> 7.055 556 x 10 <sup>-6</sup>		horsepower (electric)	W	7.460 000 x 10 <sup>2</sup>
angle, plane	ft/min	mm/s <sup>2</sup>	7.055 556 x 10 <sup>-3</sup>	pressure	Btu/min'	W	1.757 250 x 10
	in./min	mm/s <sup>2</sup>	8.466 667 x 10 <sup>-2</sup>		calorie per minute'	W	6.973 333 x 10 <sup>-2</sup>
	ft/min	rad	1.745 329 x 10 <sup>-2</sup>		foot pound-force per minute	W	2.259 697 x 10 <sup>-2</sup>
	ft/s <sup>2</sup>	rad	2 908 882 x 10 <sup>-4</sup>		round force per square inch	kPa	6.894 757
area	minute	rad	4.848 137 x 10 <sup>-6</sup>	temperature	bar	kPa	1.000 000 x 10 <sup>2</sup>
	second	m <sup>2</sup>	6.451 600 x 10 <sup>-4</sup>		atmosphere	kPa	1.013 250 x 10 <sup>2</sup>
	in <sup>2</sup>	m <sup>2</sup>	9.299 304 x 10 <sup>-2</sup>		kip/in.2	kPa	6.894 757 x 10 <sup>3</sup>
	ft <sup>2</sup>	m <sup>2</sup>	8.361 274 x 10 <sup>-1</sup>		degree Celsius, t <sub>c</sub>	K	t <sub>c</sub> + 273.15
density	yd <sup>2</sup>	mm <sup>2</sup>	6.451 600 x 10 <sup>2</sup>	torque	degree Fahrenheit, t <sub>f</sub>	K	(t <sub>f</sub> + 459.67) t <sub>c</sub>
	acre (U.S. Survey)	mm <sup>2</sup>	9 290 304 x 10 <sup>4</sup>		psi	MPa	1 = t <sub>f</sub> /1.8
	round mass per pound mass per	kg/m <sup>3</sup>	2.767 990 x 10 <sup>4</sup>		inch pound force	N-m	t <sub>c</sub> - (t <sub>f</sub> - 32)/1.8
	round mass per cubic foot	kg/m <sup>3</sup>	1 601 846 x 10		foot pound force	NKrt	t <sub>c</sub> - t <sub>f</sub> - 273.15
energ. work heat, and impact energy	found poundal	J	1.355 818	velocity (angular)	revolution per degree per minute	rad/s	1.047 198 x 10 <sup>-1</sup>
	Btu'	J	4.214 011 x 10 <sup>-2</sup>		revolution per	rad/s	2.908 882 x 10 <sup>-4</sup>
	calorie'	J	1.054 350 x 10 <sup>3</sup>		revolution per	deg/min	3.600 000 x 10 <sup>2</sup>
	watt hour	J	4.184 000		velocity (linear)	in./min	m/s
kiloaram-force	N	9.806 650	ft/min	m/s		5.080 000 x 10 <sup>-3</sup>	
pound-force (see energy)	N	4.448 222	in./min	mm/s		4.233 333 x 10 <sup>-1</sup>	
rod (U.S. Survey)	m	2.540 000 x 10 <sup>-2</sup>	ft/min	mm/s		5.080 000	
mass	rod (U.S. Survey)	m	5.029 210	volume	mile/hour	km/h	1.609 344
	mile (U.S. Survey)	km	1.609 347		in.3	m <sup>3</sup>	1.638 706 x 10 <sup>-5</sup>
	pound mass (avdp)	kg	4.535 924 x 10 <sup>-1</sup>		ft3	m <sup>3</sup>	2.831 685 x 10 <sup>-2</sup>
	metric ton	kg	1.000 000 x 10 <sup>3</sup>		yd3	m <sup>3</sup>	7.645 549 x 10 <sup>-1</sup>
	ton (short, 2000 lbm)	kg	9.071 847 x 10 <sup>2</sup>		in.3	mm <sup>3</sup>	1.638 706 x 10 <sup>4</sup>
	slug	kg	1.459 390 x 10		ft3	mm <sup>3</sup>	2.831 685 x 10 <sup>7</sup>
				in. <sup>3</sup>	L	1.638 706 x 10 <sup>-2</sup>	
				ft3	L	2.831 685 x 10	
				gallon	L	3.785 412	

From AWS Welding Handbook, 8th Edition, Volume 1, 1987

Property	To Convert From	To	Multiply By	Property	To Convert	To	Multiply By
Area dimensions (mm <sup>2</sup> )	in.2	mm <sup>2</sup>	6.45 600 102	power density (W/m <sup>2</sup> )	W/in.2	W/m <sup>2</sup>	1.55 003 103
current density (A/mm <sup>2</sup> )	A/in.2	A/mm <sup>2</sup>	1.55 003 10 <sup>-3</sup>	pressure (gas and liquid) (kPa)	psi	Pa	6.89 757 103
deposition rate" (kb/h)	lb/h	kg/h	0.45		lb/ft <sup>2</sup>	Pa	4.78 026 10
electrical (S2 - m)	S2 - cm	S2 - m	1.00 000 10 <sup>-2</sup>		N/mm <sup>2</sup>	Pa	1.00 000 106
electrode force (N)	round-force	N	4.44 222		kPa	psi	1.45 377 10-1
	kiloaram-force	N	9.80 650		kPa	lb/ft <sup>2</sup>	2.08 543 10
	lbf	N	2.24 089 10 <sup>-1</sup>		kPa	N/mm <sup>2</sup>	1.00 000 10 <sup>-2</sup>
Flow rate (l/min)	ft3/h	l/min	4.71 475 10 <sup>-1</sup>		torr	kPa	1.33 22 x 10-1
	gallon per hour	l/min	6.30 020 10 <sup>-2</sup>		(mm Hg at 0°C)	micron	1.33 22 x 10 <sup>-4</sup>
	gallon per	l/min	3.78 412		(cm Hg at 0°C)	kPa	7.50
	cm <sup>3</sup> /min	l/min	1.00 000 10 <sup>-3</sup>	tensile strength (MPa)	psi	kPa	6.89 757 103
	l/min	ft <sup>3</sup> /h	2.11 880 10 <sup>-3</sup>		lb/ft <sup>2</sup>	kPa	4.78 026 10-2
fracture (MN - m-3/2)	ksi - in1/2	MN • m-	1.09 855		N/mm <sup>2</sup>	MPa	1.00 000
	MN - m-3/2	ksi - inY2	0.91 038		MPa	psi	1.45 377 102
Heat input (J/m)	l/in	J/m	3.93 008 10	thermal conductivity (W/m - K)	cal/(cm - s - °C)	W/(m - K)	4.18 000 10 <sup>2</sup>
impact energy	foot pound	J	1.35 818				
linear measurement (mm)	in.	mm	2.54 000 10	travel speed wire	in./min	mm/s	4.23 333 10 <sup>-1</sup>
	mm	in.	3.93 008 10 <sup>-2</sup>	feed speed	mm/s	in./min	2.36 205
	mm	ft	13.280840x10 <sup>-1</sup>				

\* Preferred units are given in parentheses.

\* - Approximate conversion.

# METRIC TO METRIC CONVERSIONS

Converting to larger and smaller metric units

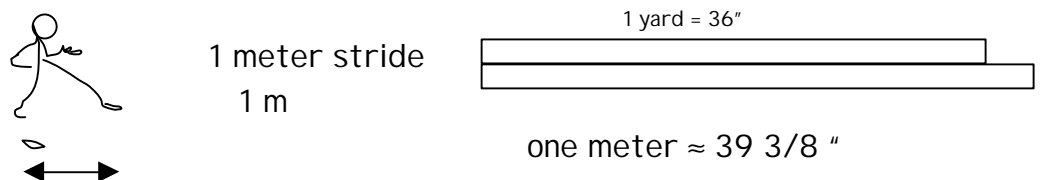
As many welding blueprints have measurements and tolerances printed in both English and metric, and since a few you come across may *only* have metric measurements, it is always a good idea to have some knowledge of the metric system.

The first thing to understand about conversions within the metric system is that this process is far easier than conversions from metric to standard (inch-foot-pound) units of measure. We just have to learn the language. Once you can know the names of the base units and can match the prefixes (milli-, centi-, kilo-, etc.) with their relative sizes, there is no easier system than the metric system. Once you learn how to convert one type of metric unit, say meters (along with centimeters, millimeters, etc), you can convert almost any type of metric unit.

Converting from *millimeters* to meters is exactly the same as converting from *milligrams* to grams!

In this lesson, we are going to stick to meters and the units which are directly built on meters, such as millimeters, centimeters, and so on. To get a handle on this mini-metric lesson, let's first talk about what sizes these meters, centimeters, and millimeters actually look like.

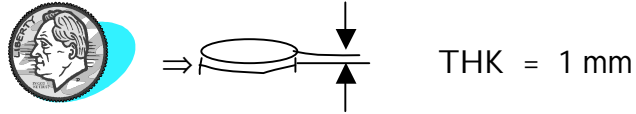
A meter (39 3/8") is a little over three inches longer than a football yard, about one full stride in walking. A meter is the *base unit* of length and so needs only one letter -- "**m**" as an abbreviation.



A centimeter is just a little longer than the width of the tip of your cutting torch. For some it might also be the width of their pinkie or of the nail of their pinkie. The abbreviation for centimeter is **cm**, **c** for centi- and **m** for meter.



A millimeter is the thickness of a dime. The abbreviation for millimeter is **mm**, **m** for milli- and **m** again for meter. Keep these visual sizes in your mind's eye while you go through this lesson on metrics.



It's also important to relate meters, centimeters and millimeters to each other in size. A **milli**-meter is **one-thousandth** of a meter (not one millionth!). A **centi**-meter is **one-hundredth** of a meter and is also the thickness of **ten** millimeters (*ten* thousandths =  $10/1000 = 1/100$  reduced).

*What unit would probably be the best one to measure the following objects/dimensions:*

*Use the linear units: **mm, cm, m, km**. Some may have two good answers. Remember that meters are similar to yards, while centimeters are similar to inches. Millimeters are used to measure fairly small dimensions, things you might just use sixteenths of an inch for.*

1. length of a barbecue grill \_\_\_\_\_
2. the distance from your home to school \_\_\_\_\_
3. your own height \_\_\_\_\_
4. the diameter of a boiler pipe \_\_\_\_\_
5. the diameter of most sheet metal screws \_\_\_\_\_
6. the length of a plate of steel \_\_\_\_\_
7. the length of a pipe \_\_\_\_\_
8. the length of the fab bay \_\_\_\_\_
9. the length of a pencil \_\_\_\_\_
10. the diameter of hard (GMAW) wire \_\_\_\_\_

## CONVERTING WITHIN THE METRIC SYSTEM USING THE METRIC STEP LADDER

The first thing you should do when you are deciding how to go about converting one metric unit to a larger or smaller unit is the following: determine whether you are going from a larger unit to a smaller unit OR from a smaller unit to a larger unit.

**Which of these is smallest? mm cm m**

**Largest?: mm cm m**

Then use a little common sense. If you were using inches to measure the length of a sheet of mild steel, you would measure a lot of inches probably. If you measured how many little sixteenths of an inch, you would have even more. But if you measured that same sheet of steel in yards or in feet, it would take much fewer of these to cover its length. The same is true of all measuring units. If you convert to a smaller unit, you will need more of them to cover the length or width, and if you convert to a larger unit, you will need fewer of these larger units than you did of the small ones. So . . . if you convert from meters to centimeters (from a larger to a smaller unit), you will find that the amount increases (100 times as many). You need more of those little centimeters. If you convert from millimeters to meters (from a smaller unit to a much larger unit), the amount of measuring units will decrease substantially (to one-thousandth as many). You need less of those big meters than of those little millimeters to cover the length of a sheet of steel. If you convert from millimeters to centimeters, it is still a conversion to a larger unit, and the amount of units will decrease, just not by so much. It will only decrease by a tenth. What do you think will happen when you convert from centimeters to millimeters? Will you have more or less?  
*More, because you are converting to a smaller unit. How many times more?  
Ten times more, because each centimeter is the same size as ten mm.*

Now let's learn how to use the number line on the next page and do some of these easy conversions. Keep in mind that this number line is constructed to make these conversions easy; smaller units are on the right to match the logic we covered in the last paragraph . . . focusing on how many we need of them, rather than on how big they are. Another way of looking at it is that centimeters are two spaces to the right of the base unit meter, just like cents (pennies) are two spaces to the right of our base unit of money -- the dollar.

The metric system is based on the number ten and the decimal system. Every lined notch on the line is worth a multiple of ten. For each line you move to the right on the line, you are going to multiply by ten. This is the same as moving your decimal point one place to the right. So if you need to move one line to the right, you move your decimal one space to the right. If you need to move one line to the left, move your decimal point one space to the left. This is the same as dividing by ten. What if you need to move three lines to the left? That's a multiple of one thousandth, as when you convert millimeters to meters. Then you move your decimal point three spaces to the left. Let's do some examples. Be sure you have the metric line in front of you as you go over these. Relax and know that it's easier to do these than to read about how to do them!

### **Example 1**

Let's convert 22.5 mm (**millimeters**) to cm (**centimeters**). Start with your finger on the millimeter line and then find the centimeter (cm) line with your eyes. Count over how many lines you have to travel and remember in which direction. You should have to travel one line to the left. Therefore, you need to move your decimal point one space to the left changing

$$22.5 \text{ mm} \quad \text{to} \quad 2.25 \text{ cm.}$$

↖

### **Example 2**

What about converting 1580 centimeters (cm) to meters? You might ask, "Where is the decimal point?!" If you cannot see a decimal point, it is ALWAYS at the end, the far right, of the number, just invisible. So, that would make 1580 = 1580. or 1580.0 Now let's convert 1580. cm to meters (m). Look on the chart and see that you need to move two lines to the left. This means you move your decimal point 2 places to the left, changing . . .

$$1580. \text{ cm} \quad \text{to} \quad 15.80 \quad \text{or} \quad 15.8 \text{ m (meters).}$$

↖

**Now try this problem:** How many mm are in 26 cm ?

$$26 = 26. \text{ cm}$$

"mm" is just one line to the right of "cm"

### **Move your decimal one space to the right**

Add a zero or zeros as you need them.

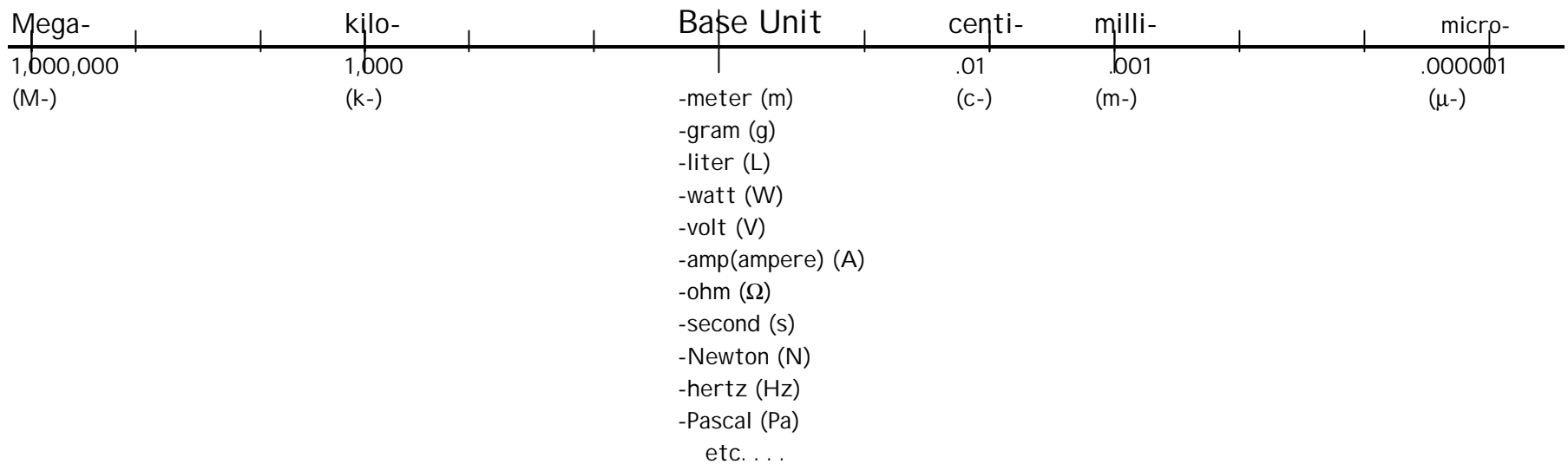
$$26. \text{ cm} = 260. \text{ mm} \quad = \quad \mathbf{260 \text{ mm}}$$

↖

**Use the 'Metric Step Ladder' on the following page to convert units within the metric system**

# CONVERSION WITHIN THE METRIC SYSTEM

## THE METRIC STEP LADDER



## CONVERTING METRIC TO METRIC

Use your metric "step-ladder" to convert these measurements to larger or smaller metric units as required:

1. 999.5 m = \_\_\_\_\_ mm      999.5 g = \_\_\_\_\_ m

2. 250 mm = \_\_\_\_\_ m      250 mg = \_\_\_\_\_ g

3. 1300 mm = \_\_\_\_\_ cm

4. 580 cm = \_\_\_\_\_ m

5. 7125 m = \_\_\_\_\_ km      7125 watts = \_\_\_\_\_ kilowatts

6. 87 mm = \_\_\_\_\_ cm

7. 4000 mm = \_\_\_\_\_ m

8. 500  $\mu$ m = \_\_\_\_\_ mm

9. 3.5 cm = \_\_\_\_\_ mm

10. 2125 mm = \_\_\_\_\_ m

*Note that when you change your base metric unit, like from meters to grams, here is no difference in how you do the actual math. No new skills to learn!*



## METRIC-TO-METRIC CONVERSION PRACTICE

Use your metric conversion line to convert these measurements to larger or smaller metric units as required: *Note: “?” represents liters, and “g” represents grams.*

1. 999.5 m = \_\_\_\_\_ mm      999.5 ? = \_\_\_\_\_ m?

2. 250 mm = \_\_\_\_\_ m      250 mg = \_\_\_\_\_ g

3. 1300 mm = \_\_\_\_\_ cm

4. 580 cm = \_\_\_\_\_ m

5. 7125 m = \_\_\_\_\_ km      7125 watts = \_\_\_\_\_ kilowatts

*Note that when you change your base metric unit, like from meters to grams, there is no difference in how you do the actual math. No new skills to learn!*

6. 87 mm = \_\_\_\_\_ cm

7. 4000 mm = \_\_\_\_\_ m

8. 10 m = \_\_\_\_\_ mm

9. 3.5 cm = \_\_\_\_\_ mm

10. 2125 mm = \_\_\_\_\_ m

# FORMULAS

Applications:

- Ohm's law
- Power formulas
- Finding heat input
- Calculating temperature conversions
- Layout and fabrication

# SOLVING FORMAULS

Solving the formulas that are typically used by welders is easy to do. There are several rules that you need to follow in order to successfully use a formula.

**Step #1 Read the formula and understand what it says**

- a. What do the letters (variables) stand for?
- b. What math operations does the formula tell you to perform?

**Step #2 Substitute the numbers for the letters**

**Step #3 Follow the rules for 'order of operation' to solve the problem**

**Step #1 Read the formula and understand what it says**

Example:  $V = IR$

This formula says: Voltage equals current times resistance

Each letter in a formula is called a **variable**. A letter stands for a word(s).

**Make sure you know what the letters in your formula stand for.**

In this example of Ohm's law

V =Voltage

I = Amperage (current flow)

R = resistance

**Be careful when reading formulas because in different formulas the same letters can stand for something different. In the following formula**

$$V = L \times W \times H$$

**V stands for volume (not voltage).** This formula says volume equals length times width times height.

**After you determine what the letters or variables stand for in the formula you must figure out what the formula says to do with them.** (Do you add them together, subtract, multiply or divide?)

Let's go back to our original example

$$V = IR$$

What this formula says is 'voltage equals current **times** resistance.'

This means you **multiply** current **times** resistance.

**Anytime you see variables next to each other with no separation between them you multiply them together.**

So  $IR$  is the same as  $I \times R$ .

In fact there are several ways to indicate multiplication in a formula. They are:

$$V = IR$$

$$V = I \times R$$

$$V = I * R$$

$$V = I \cdot R$$

Each different example above tells you to multiply current times resistance

There are also different ways to indicate division in a formula.

Example:  $R = V / I$

You would read this formula: Resistance equals voltage divided by current.

The slanted line (/) tells you to divide. It is the same as writing  $R = V \div I$

Other ways to indicate division are:

$$R = V/I$$

$$R = V \div I$$

$$R = \frac{V}{I}$$

A fraction is just another way of telling you to divide the top number by the bottom number.

**Step #2 Substitute numbers for variables.** Going back to our original formula:

$$V = IR$$

If: Current (I) equals 5 amps and  
Resistance equals 4 ohms ( ? )

We replace the letter I with 5 amps and we replace the letter R with 4 ohms

$$V = 5 \text{ amps} \times 4 \text{ ohms}$$

Always include the units when you substitute numbers for variables

We can now solve our equation:

$$5 \text{ amps} \times 4 \text{ ohms} = 20 \text{ volts}$$

### **Step #3 Follow the rules for order of operation**

How do we handle a formula that has more than one mathematical operation in it? You must follow the correct order of operation. (Do anything within parenthesis first, next do exponents, then multiplication and division and finally addition and subtraction.) For details please see the following page on order of operations.

Example: Let's say we wanted to know the Fahrenheit temperature when we know that it is 28°Celsius outside"

The formula to convert Celsius temperatures to Fahrenheit temperature is:

$$F = \frac{9}{5}C + 32$$

**Read the formula and understand what it says;**

Fahrenheit degrees equals 9 times Celsius degrees divided by 5 plus 32.

$$F = \frac{9}{5}28 + 32$$

**Substitute numbers for variables.** In this case 28

Degrees is substituted for C

$$F = 50.4 + 28$$

**Follow the correct order of operation:** first multiply  $\frac{9}{5} \times 28$ . Hint: use your fraction key to multiply the fraction and the whole number together.

$$F = 82.4^\circ$$

**Finally do the addition**

# INTRODUCTION TO THE ORDER OF OPERATIONS

Just like a game has rules so that everyone understands how it plays and who wins, math has rules. Sometimes these rules have no particular reason for being one way rather than another; they were merely created for the purpose that everyone will understand mathematical expressions in the exact same way. One of these sets of rules is the Order of Operations. This set of rules governs the correct order in which different parts of an expression will be operated on. Math is an exacting science, and any deviation from these rules is unquestionably wrong. If it were not so, you would frequently have different answers to the same mathematical expression with no way to arbitrate which answer was correct.

Should you ever wonder why we need a set of rules like the Order of Operations, all you need to do is input an expression like "32-5 x 3 + 3" into two types of calculators: one being any scientific calculator and the other being a simple 10-key plus operations non-scientific calculator. You will most definitely get two answers, and only one is correct. This is because the scientific calculator is programmed to operate according to the order of operations, while the simpler non-scientific calculator does not know these rules and will merely perform operations in the exact order they are inputted. The scientific calculator will accept all numbers and operations inputted and will not operate on them until you hit the equal sign, at which time it will perform the operations according to the order we will discuss here. *Try it. Which answer is right? 20 or 84?*

The following pages give the order of operations. The first rule within this set will probably be familiar. It says to always perform the operations inside the parentheses first. This means that you get the answer from within the parentheses before you move on to the rest of the expression. So, in  $16 - (5 \times 3)$ , you would first multiply 5 by 3 to get 15 and then subtract that answer, 15, from 16. This would get you the correct answer of "1."

$$\begin{aligned} 16 - (5 \times 3) &= & 16 - 15 \\ &= & 1 \end{aligned}$$

The Order of Operations says that any exponents – numbers raised to a power – should be evaluated next. Exponents are numerical expressions like  $5^3 (= 5 \times 5 \times 5)$ ,  $3^4$ ,  $x^2$ , and  $16^{1/2}$ . This means that if you have an expression with parentheses, exponents, and multiplication, you should do the operations in the parentheses first, then the exponents, and then the multiplication.

e.g. (A)  $26 - 4^2 + (14 - 5)$  would first become  $\dots 26 - 4^2 + 9$   
 which in turn would become  $26 - 16 + 9$ .  
*and*

(B)  $2 \times 3^2$  would become  $2 \times 9 = 63$  (not  $6^2 = 6 \times 6 = 36$ )

The next rule in this order says that after performing all operations in parentheses and all exponents, you should perform all multiplication and division, making the decision on which of these should be done first based on left-to-right order.

So,  $35 - 4 \times 3 \div 6$  would become  $35 - (4 \times 3) \div 6$  which in turn would become

→  $35 - 12 \div 6$  (*multiplication is done before division because*

$= 35 - (12 \div 6)$  *it is furthest LEFT)*

$= 35 - 2$

$= 33$

Finally, you should perform all addition and subtraction last (unless you find them inside the parentheses), and again, the decision on which of these should be done first, second and so on should be based on left-to-right order.

$56 - 24 + 30 = (56 - 24) + 30$  (*the subtraction is done here before addition*

→  $= 32 + 30$  *because it is furthest LEFT)*

$= 62$  (not  $56 - 54 = 2$ )

To summarize, the best way to think of doing problems according to the Order of Operations is to SCAN the entire math expression first for parentheses. Do anything inside parentheses you find. Then scan the entire expression for exponents and evaluate these numbers, raising to whatever power is expressed. Then scan for multiplication and division and perform these just as you read them, left to right. Then scan for addition and subtraction and perform these just as you read them, left to right. The next page will repeat this order and help you find a way to remember the order.

*Now, try solving these problems by applying the Order of Operations:*

1.  $34 - 17 \times 2 = ?$

2.  $56 + 45 \div 3^2 = ?$

3.  $12 \times [(8 + 1) \div 9] = ?$

4.  $170 - 5^2 \times 4 = ?$

*Hint: Work from inside out, ( ) first, then []*

5.  $58 - 24 + 10 = ?$

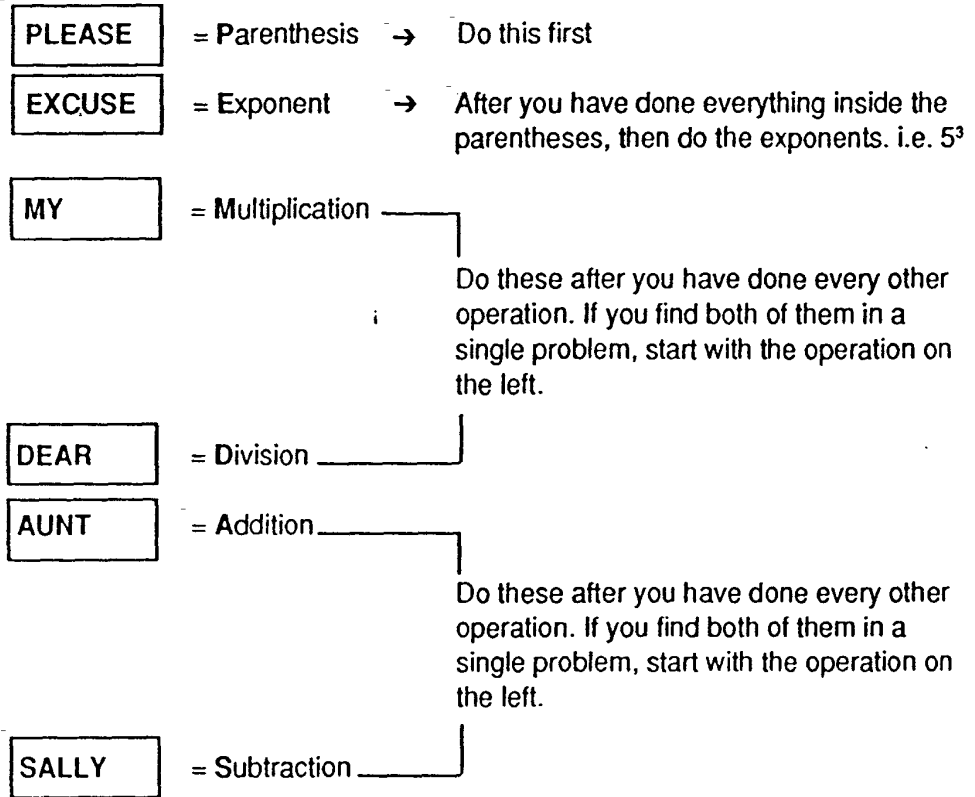
6.  $64 - 20 \div (2 + 3) = ?$

**Need more help? See the following worksheets: Solving formulas, scientific calculator**



# A Short Cut Way to Remember the Order of Operation Rules

Please Excuse My Dear Aunt Sally



EXAMPLE:  $12 \times (8 - 6) - 2^2 \times 0 + 1$

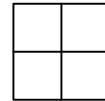
$$\begin{array}{r}
 12 \times (8 - 6) - 2^2 \times 0 + 1 \\
 \quad \quad \quad \downarrow \\
 12 \times 2 - 2^2 \times 0 + 1 \\
 \quad \quad \quad \downarrow \\
 12 \times 2 - 4 \times 0 + 1 \\
 \quad \quad \quad \downarrow \\
 24 - 4 \times 0 + 1 \\
 \quad \quad \quad \downarrow \\
 24 - 0 + 1 \\
 \quad \quad \quad \downarrow \\
 24 + 1 \\
 \quad \quad \quad \downarrow \\
 25
 \end{array}$$

**\*REMEMBER:** Your scientific calculator is preprogrammed for the correct order of operation. You can enter the problem from left to right. Remember to include the parenthesis keys.  $12 \times (8 - 6) - 2^2 \times 0 + 1 =$

## Squaring Numbers

In order to solve some of the formulas that you may encounter as a welder, or find the areas of various geometrical shapes, it's important for you to be able to understand what square numbers are, AND how to use your calculator to get them fast.

If you think about the word "square," what do you know about that kind of shape? All its sides are equal, right? It's like a (square) kitchen tile. The length of the tile is the same as the width. To find the area of a square, you multiply the length by the width. Since they are the same, you are multiplying a number by itself.



... a 2-by-2 has  $2 \times 2$  square units or **4** square units

In fact, we tend to measure most surface areas by square feet or square inches or square meters, etc., units that have the same length and width. This is where "squaring (a number)" got its name.

Examples:  $5^2 = 5 \times 5 = 25$  square units

A square with 5-inch sides will be 25 square inches in surface area

$12^2 = 12 \times 12 = 144$  square units

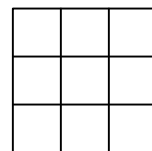
A square with 12 inch sides (**1 foot**) will have 144 square inches in area

$1^2 = 1 \times 1 = 1$  square unit

A square kitchen tile measuring 1 foot on each side will have 1 sq. ft. of area

**How many square feet are there in a square yard?**

Just count them up : \_\_\_\_\_  $ft^2$



So, to square a number, you simply multiply it by itself. You can do this in one of four ways. It's not hard to guess which way will be your method of choice by the end of this lesson . . . You can either multiply them (1) in your head; (2) using pencil and paper; (3) using a calculator to enter the number twice with a multiplication sign ("x") in-between and an "=" after (Example: "5 x 5 ="); or (4) you can get used to using the square key on your calculator, marked  $x^2$ . The way this key works is whatever number you give it goes into the "x" spot and gets squared.

**All you need to do to square your number is:**



Input your number



Press

-----

Try it with "4" to get "16."

How about squaring 15?

What did you get? 225?

Notice something else:

*The little "2" written above and to the right of your number to be squared is the symbol for squaring and tells you to multiply exactly two of those numbers together.*

**Give the squares of the following numbers: For each of the new numbers, state whether it is smaller or larger than the original number. Remember Comparing Decimals from WLD 142.**

1.  $14^2 =$  \_\_\_\_\_ 2.  $.98^2 =$  \_\_\_\_\_

3.  $25^2 =$  \_\_\_\_\_ 4.  $.25^2 =$  \_\_\_\_\_

5.  $2.5^2 =$  \_\_\_\_\_ 6.  $60^2 =$  \_\_\_\_\_

So, does squaring ALWAYS make the number larger? When does it and when does it not?

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## KEEPING YOUR UNITS STRAIGHT WHEN YOU WORK ON A FORMULA

### **Note on “ Dimensional Analysis”**

A good way to do a ‘sanity check’ on a formula is to look at the units for each variable and make sure that the units you end up with match the units you expect to see in your answer. In the heat input example your answer needs to come out in Joules/inch :

Our original formula was:

$$\text{Heat input} = \frac{V \times I \times 60}{S}$$

Substituting units for symbols this translates into:

$$\text{Joules/inch} = \frac{\text{Volts} \times \text{Amps} \times \text{seconds/minutes}}{\text{inch/minute}}$$

We already know that Volts x Amps = Watts and that Watts are Joules/second

Substituting Joules/seconds for Volts x Amps we get:

$$\text{Joules/inch} = \frac{\text{Joules/second} \times \text{second/minutes}}{\text{inch/minute}}$$

Note: inches/ minute in the denominator become minutes/inch in the numerator, so:

$$\text{Joules/inch} = \text{Joules/second} \times \text{second/minute} \times \text{minutes/inch}$$

The seconds and minutes cancel each other out and you are left with:

$$\text{Joules/inch} = \text{Joules/inch}$$

Because the units are the same on both sides we know our “sanity check” is successful.

# TEMPERATURE CONVERSION

Applications:

- Determine accurate temperatures using either Fahrenheit or Celsius scales
- Heat input problems



Convert the following Fahrenheit values to Celsius (metric) temperatures:

$$\begin{array}{ll} \text{Example: } F = 1000^{\circ}C = (1000 - 32) \cdot 1.8 & \text{OR } C = 5/9(1000-32) \\ C = 968 \cdot 1.8 & C = 5/9(968) \\ C = 537.78 \text{ degrees} & C = 537.78 \end{array}$$

*degrees*

7. F = 400° (max. interpass temp.)
8. F = 200° (preheat plates)
9. F = 1600° (kindling temp)

**Need more help? See the following worksheets: Solving formulas, order of operations**



# ELECTRIC POWER PROBLEMS

Applications:

- Determining power
- Determining resistance
- Determining current

## REVIEW OF ELECTRIC POWER PROBLEMS AND MANIPULATING EQUATIONS

$$\begin{array}{rcl} P & = & I^2R \\ I & = & \underline{\hspace{2cm}} \\ R & = & \underline{\hspace{2cm}} \end{array}$$

1. How many kilowatts (groups of 1000 watts) are in a system with 12 amps current and 140 ohms resistance?
2. How many kilowatts are in a system with 10 amps and 120 ohms resistance?
3. How much current do you have in a system with 120 ohms resistance and 8 kilowatts (8000 watts) power?
4. How much current do you have in a system with 130 ohms resistance and 11 kw power?
5. How much resistance is in a system with 9 kw (= 9000 watts) power and 10 amps current?

**Need more help? See the following worksheets: Solving formulas, order of operations, squaring numbers, square roots**

# GEOMETRY

## Applications:

- Finding area of different shaped objects
- Calculating missing dimension
- Layout- most efficient- least wasteful
- Calculating costs
- Bidding on jobs
- Squaring your sheet metal in order to get a good corner to work from
- Creating and/or checking for square corners
- Finding the center of a rectangle
- Fabrication- creating angles and lines needed for fabrication
- Construction with Angles and Bevels
- Forming pipes and tubes
- Squaring corners
- Finding the center of different shaped objects
- Purchasing materials
- Help you to find unknown measurements

## Table of Abbreviations

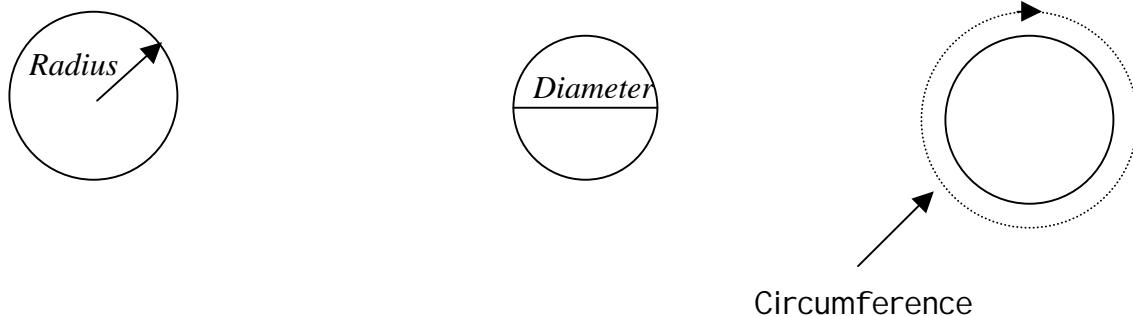
<b>Pi</b>	<b>p</b>	<b>3.14</b>
<b>Diameter</b>	<b>dia.</b>	<b>DIA</b>
<b>Radius</b>	<b>r</b>	
<b>Inside Diameter</b>	<b>ID</b>	
<b>Outside Diameter</b>	<b>OD</b>	
<b>Circumference</b>	<b>Cir</b>	

## UNDERSTANDING CIRCLES AND Pi ( $\pi$ )

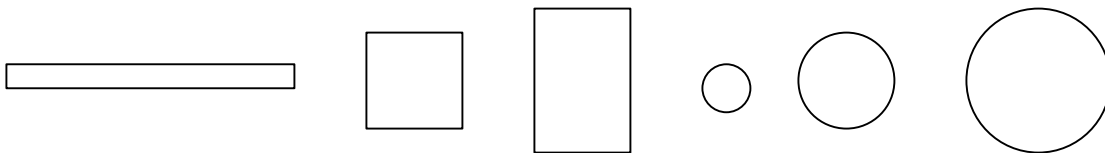
For welding fabrication, it is important to understand and be able to use some basic geometric principles about different kinds of shapes. In WLD 261 we mostly worked with square or rectangular shapes. For WLD 262, we need to include circular and cylindrical shapes, and with those comes the funny little Greek symbol that sounds like a dessert.

The first thing you should know about pi ( $\pi$ ) is how useful it is, and the second thing you should know is what it represents and why it is approximately 3.14.

We use pi ( $\pi$ ) to determine what the circumference or area of any circle is when we know its radius or diameter. We use pi ( $\pi$ ) to determine what the diameter or radius of a circle is when we know its circumference or area. That makes ( $\pi$ ) a very useful and powerful number.



To understand more about pi, we need to remember that a diameter of any circle goes through its center, as does the radius of any circle. Also, we should compare circles to rectangles, and notice that circles always have the **exact same shape**, whereas rectangles can be short and squat, perfectly square, or long and skinny . . . many different shapes. While rectangles and other shapes can look proportionally different, circles can only differ in size. Their shape and therefore their proportions never differ! This fact is very important and is why we have been able to discover and use pi.



*What is Pi (p) ? Why is it about 3.14? To understand that a little better, try this:* Measure the diameter of any circle. Then measure the circumference of the same circle. Divide the circumference by the diameter. What do you get? Now do it for another circle of a different size, and another and another. You will always get pi or approximately 3.14 . . . You can also look at it in the way that if you cut a string the length of the diameter, it will take a little more than 3 lengths of that string to get the circumference.

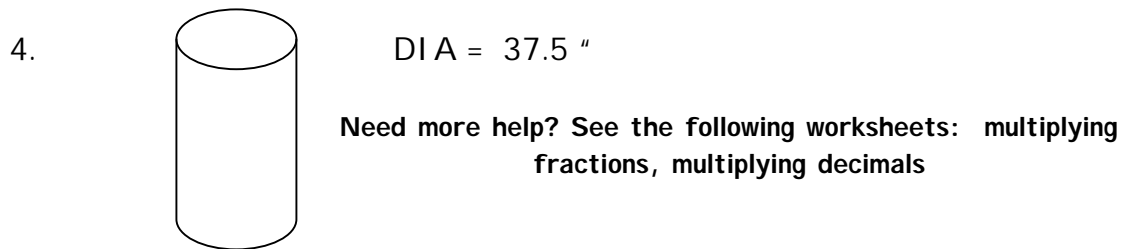
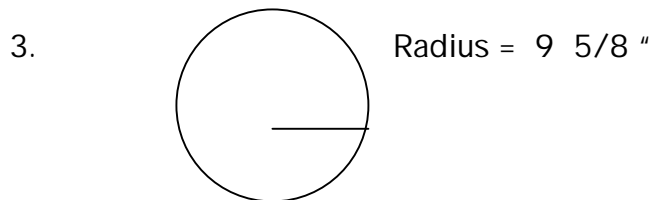
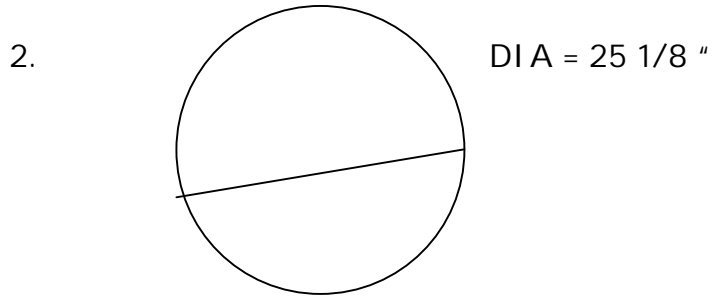
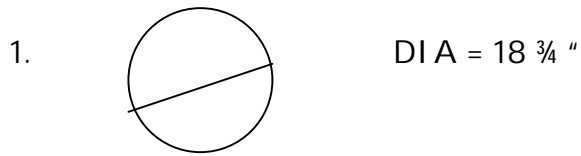
Pi ( $\pi$ ) or 3.14 . . . represents the ratio between the circumference and diameter of a circle.

Knowing this, we can use it to find the circumference from the diameter. The question we have to ask ourselves is: if we divided the circumference by pi to get the diameter, what do we have to do to the diameter to get the circumference???? What is the opposite of divide?

All we have to do is multiply the diameter by 3.14 (pi)!

The only tricky thing to remember is that if you have the radius, you must first double it to get the diameter and then multiply by  $\pi$ . Also, if you have the symbol  $\pi$  on your calculator, use it, because it is more accurate than the shortened 3.14. The only reason not to use the more accurate  $\pi$  on your calculator is when you are working with other people where it is understood that they are using an approximation like 3.14. Then you might want to just have your answers match with theirs to make discussion, i.e. sharing answers, easier.



Find the circumference of these circles/cylinders:



## SQUARING NUMBERS

In order to be able to do some of the tricks in this section on squaring corners or determining if an object is square, it's important for you to be able to understand what square numbers and square roots are AND how to use your calculator to get them fast.

If you think about the word "square," what do you know about that kind of shape? All its sides are equal, right? It's like a (square) kitchen tile. The length of the tile is the same as the width. To find the area of a square, what do you do? You multiply the length by the width. Since they are the same, you are multiplying a number by itself. In fact, we tend to measure most surface areas by square feet or square inches or square meters, etc., units that have the same length and width. This is where "squaring" got its name.

So, to square a number, you simply multiply it by itself. You can do this in one of four ways. Let me just guess which way will be your method of choice by the end of this lesson . . . You can either multiply them (1) in your head; (2) using pencil and paper; (3) using the calculator to enter the number twice with a multiplication sign ("x") in-between; or  (4) you can get used to using the square key on your calculator, marked . The way this key works is whatever number you give it goes into the "x" spot and gets squared.



**All you need to do to square your number is:**

Input your number

Press

Notice something else:

*The little "2" written above and to the right of your number to be squared is the symbol for Squaring and tells you to multiply exactly two of those numbers together.*

How about squaring 15?

What did you get? 225?

**Give the squares of the following numbers: For each of the new numbers, state whether it is smaller or larger than the original number. Remember Comparing Decimals from WLD 142.**

1.  $14^2 =$  \_\_\_\_\_ 2.  $.98^2 =$  \_\_\_\_\_

3.  $25^2 =$  \_\_\_\_\_ 4.  $.25^2 =$  \_\_\_\_\_

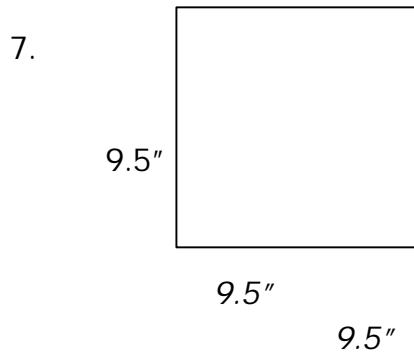
5.  $2.5^2 =$  \_\_\_\_\_ 6.  $60^2 =$  \_\_\_\_\_

So, does squaring ALWAYS make the number larger? When does it and when does it not?

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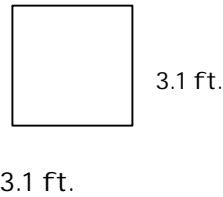
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Find the area of the following figures or faces of figures (follow the arrow if there is one):

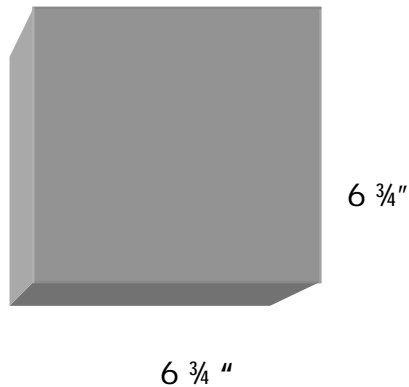


Area = \_\_\_\_\_ square inches  
(also written as **sq.in.** or **in<sup>2</sup>**)

8. Area = \_\_\_\_\_ ft<sup>2</sup>



9.



What is the area of the surface facing you?

( Did I mention you can use the square key with the fraction key?!!!)

Need more help? See the following worksheets: using your calculator, multiplying fractions and decimals



Use our calculator to find the square root of the following:

1.  $\sqrt{89} =$  \_\_\_\_\_

2.  $\sqrt{8} =$  \_\_\_\_\_

3.  $\sqrt{107} =$  \_\_\_\_\_

4.  $\sqrt{.25} =$  \_\_\_\_\_

5.  $\sqrt{.04} =$  \_\_\_\_\_

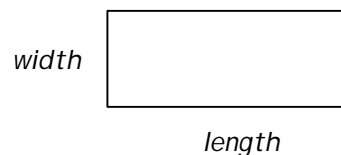
6.  $\sqrt{.01} =$  \_\_\_\_\_

If you want to check these answers, just square your answers to see if you got the original num

## Calculating Surface Area of Weld Pieces

Some of the math projects for this class will be calculating the total cost of the project piece you are welding, including the final exam project. To do this, you will need to calculate the surface area in square feet (or in square inches and convert to square feet) and then use this number and price per square foot of a particular metal to calculate the cost. This section of our Math on Metal is to get you ready to calculate surface areas of different shapes.

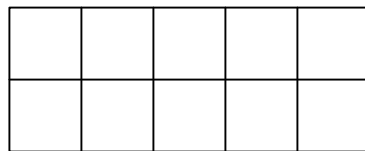
First, we have the basic rectangular shape:



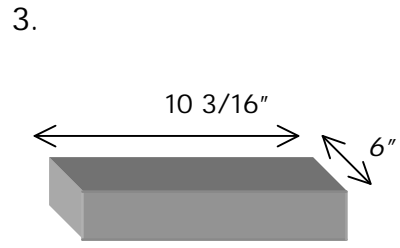
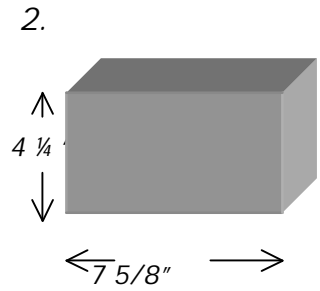
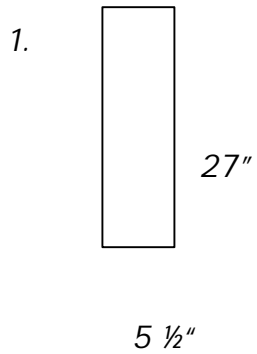
To get the area of any rectangle (or square), all we have to do is multiply the length by the width, making sure that both numbers represent the same measuring unit, not a mixture of feet and inches, for example. Imagine that one floor tile was exactly one foot by one foot, exactly one square foot. If we count the rows of these tiles and then multiply by how many tiles are in each row, we will get the total number of tiles or square feet.

*2 rows of 5 make 10*

*$2 \times 5 = 10$  square tiles or 10 square feet*



Calculate the area of the surfaces indicated below:



Area = \_\_\_\_\_ in<sup>2</sup>  
 = \_\_\_\_\_ ft<sup>2</sup>

Area = \_\_\_\_\_ in<sup>2</sup>  
 = \_\_\_\_\_ ft<sup>2</sup>

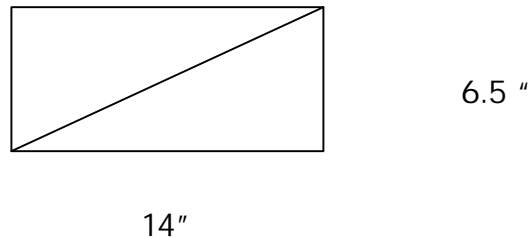
Area = \_\_\_\_\_ in<sup>2</sup>  
 = \_\_\_\_\_ ft<sup>2</sup>

Look back at the first page of "Squaring Numbers" and find how many square inches are in a square foot (12 x 12). Use this number to divide your three answers to get new answers in **square feet**. **Need more help? See the following worksheets: Squaring number, multiplying fractions, and decimals**

## CALCULATING TRIANGULAR AREA

So far we've only calculated rectangular surface areas. What about triangular metal pieces? How do we figure the amount of metal used in these shapes?

The formula for triangular area comes from a slight variation in the rectangular area formula. It is easiest to see this with right triangles, that is, triangles with a 90-degree or right angle. Look at the picture below:

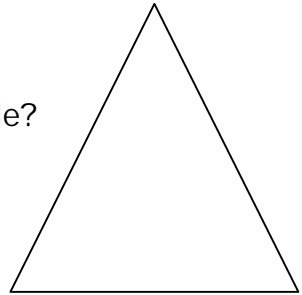


Now, in this figure, it is easy to see that the triangle with altitude or height 6.5 inches and base of 14 inches is  $\frac{1}{2}$  the size of the whole rectangle. What is the area of the rectangle? You should remember from our previous lessons that the rectangle area is length x width, which here is  $14 \times 6.5$  or 91 square inches. Half of this area, the area of the triangle is  $\frac{1}{2}$  of 91 or **45.5 square inches**.

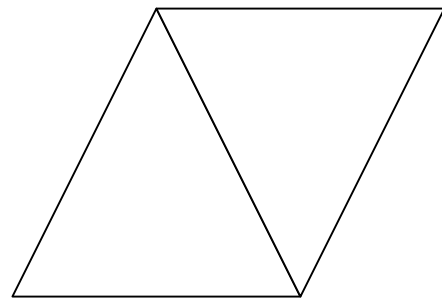
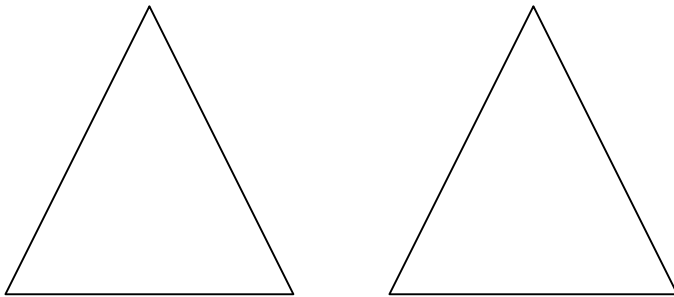
**So here's our formula: Area =  $\frac{1}{2}$  (base x height)** *Remember to follow the Order of Operations!*

Well, that's easy enough, but is it always that easy, even when triangles do not have 90-degree angles? Let's look at triangles of different shapes and angles. It's important that you see that the formula for triangles which uses half of the base x height works for all triangles.

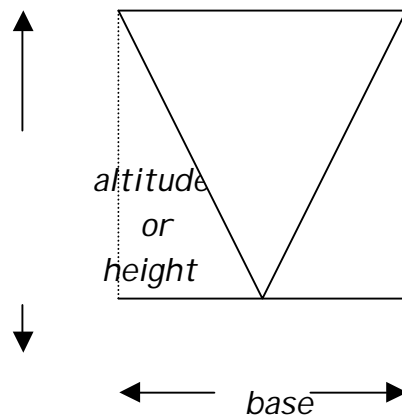
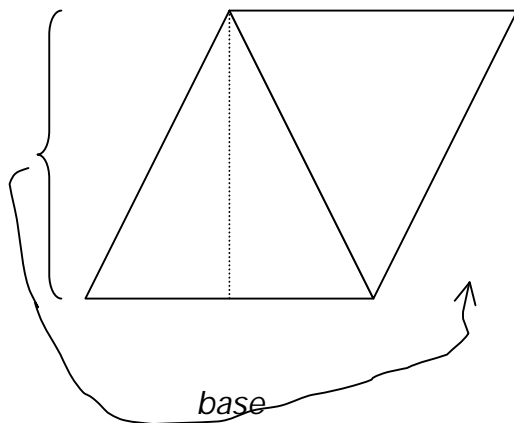
What about this one, for example?



Suppose you have two of them . . .

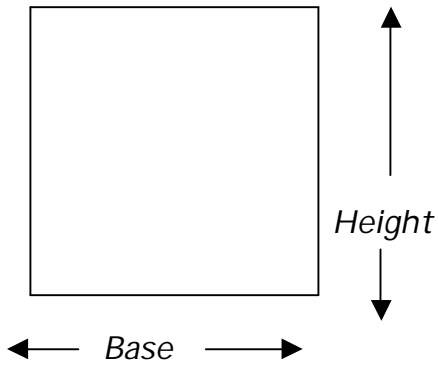


Rotate the second triangle and butt it up against the first one. Remember that you now have twice as much area as one triangle. top left corner straight down to the base.



Move the triangular slice you cut off to the right side of the picture, and you have a . . .





RECTANGLE, where the base has not changed in overall length, and the height is the same as ever.

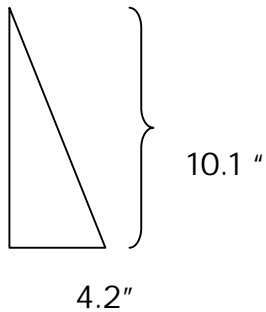
Remember that this area is twice the size of your original triangle, so all you have to do is find the area of the rectangle and divide it in half.

So, for all triangles, the formula for their area is

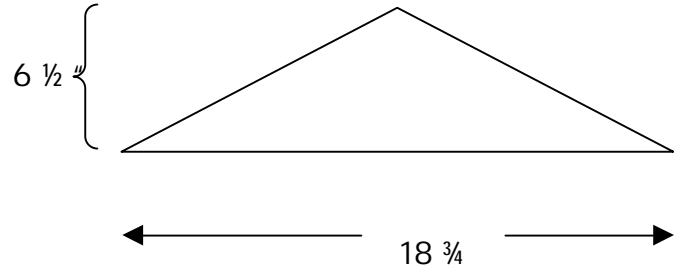
$$\text{AREA} = \frac{1}{2} (\text{base} \times \text{height})$$

Calculate the area of each of the following triangles:

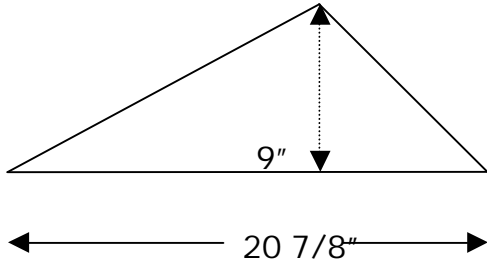
1.



2.

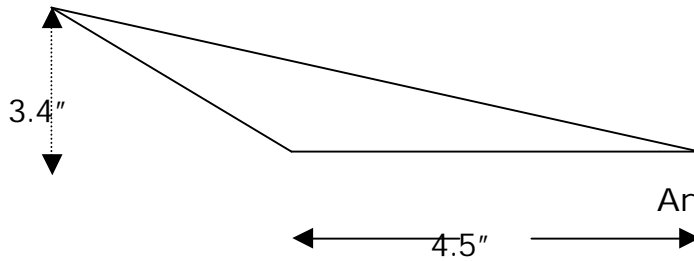


3.



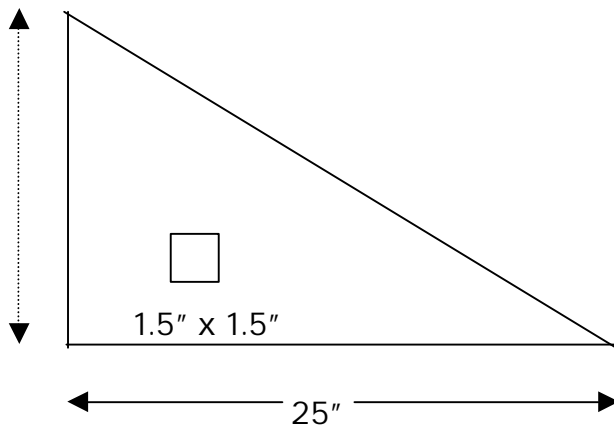
Area = \_\_\_\_\_

4.



Area = \_\_\_\_\_

5.



Find the actual surface area of 17" metal on this side of the piece - excluding the square hole:


Area = \_\_\_\_\_ inches<sup>2</sup>

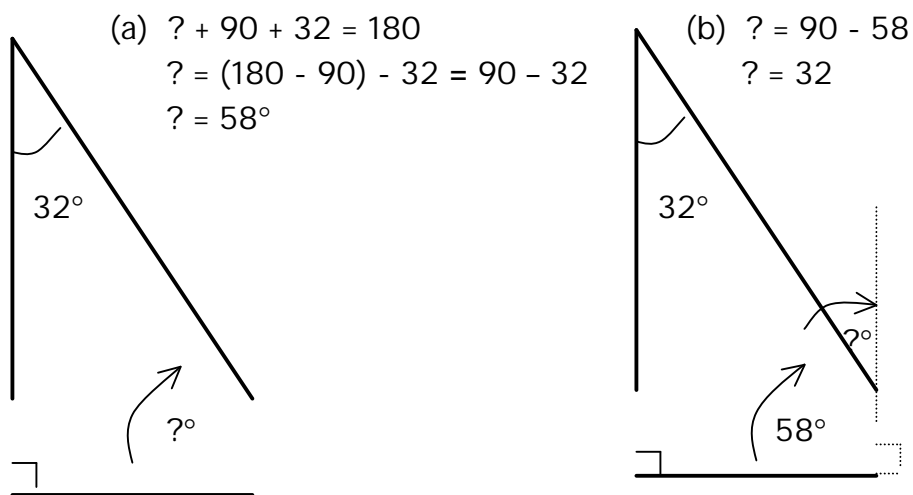
**Need more help? See the following worksheets: Solving formulas, order of operations, multiplying fractions, multiplying decimals, calculating surface area**

## CONSTRUCTION WITH ANGLES/BEVELS

Welding involves a good deal of cutting on an angle in order to either create a beveled edge for a weld or to create edges for joining two pieces at an angle. It is useful to know a little about angles before working with them.

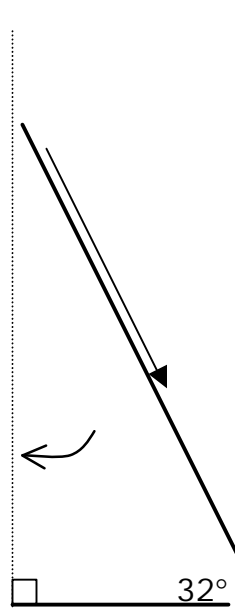
The following are some very useful facts to keep in mind when measuring angles:

1. To go around in a complete circle is to go 360 degrees 
2. In any triangle the three angles **ALWAYS** add up to 180 degrees. *see figure (a)*



3. Two angles which together make a right angle must add up to  $90^\circ$ . *see figure (b)*
4. Notice Figure b's similarities with the following figure (c). Note that the two dotted lines are parallel to each other, and that the bold line intersects with them both. Then note the position of the two angles which are equal to each other. This will always be true with one line or surface intersecting two parallel lines or surfaces.

Figure (c)



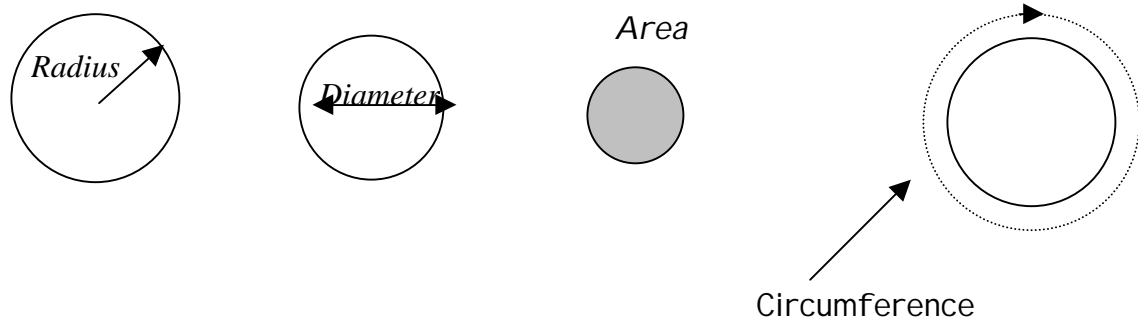
Angle  
finder  
tool

Next time you use your angle finder tool *torch* to set your torch angle at the track *direction* burner, notice the arrow indicates how  $32^\circ$  you position your torch, with it pointing toward the angle of adjustment from vertical. And this angle is equal to the opposite and internal angle of your angle finder tool.

*Remember that you often measure  $\frac{1}{2}$  the bevel, which is why you use a  $22 \frac{1}{2}^\circ$  angle finder for a  $45^\circ$  bevel. track burner surface.*

## Calculating Circle Area

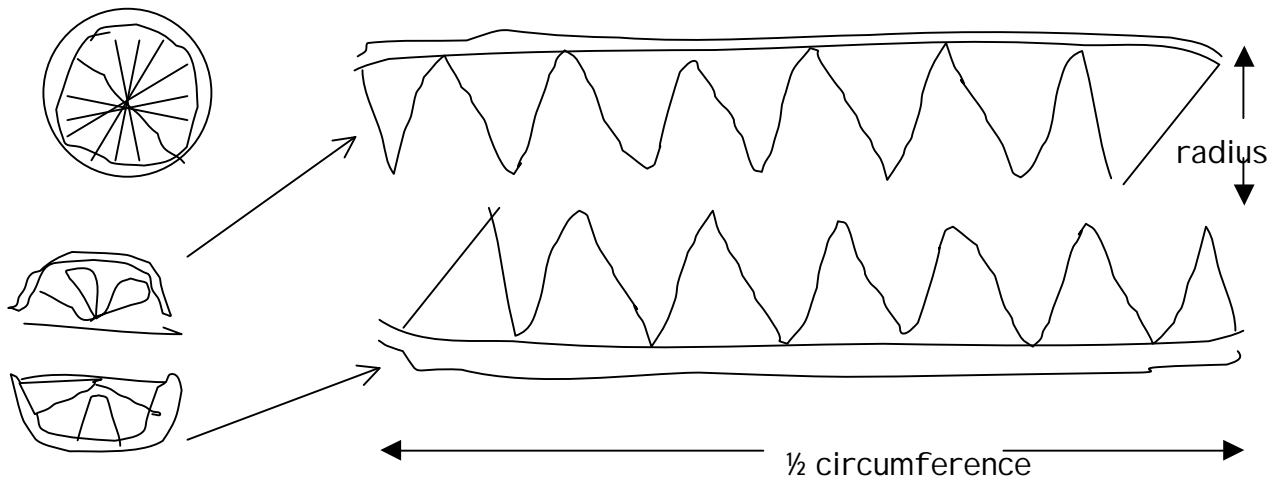
It's good to know a little terminology about the circle before we begin on their areas.



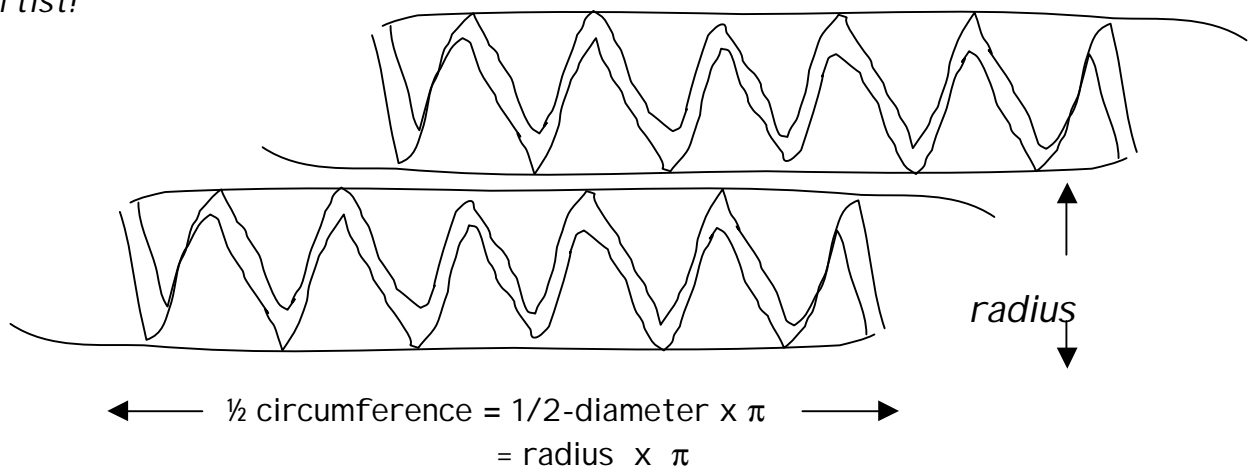
*Now next comes the part that you might want to skip if you just want to know how to do it and not why it works. If you just want to know how to do the problems, skip to the part with the title "How to use the formula."*

The "magic number" that comes from the fact that every circle circumference length is **directly proportional** to the circle's diameter (and vice versa) is pronounced "pie," written as  $\pi$  or 'pi.' Pi ( $\pi$ ) or 3.14 . . . represents the ratio between the circumference and diameter of any circle. If you multiply the diameter times  $\pi$ , you get the circumference.

The formula for circle area involves the radius and pi. Although the explanation for the formula is beyond the scope of this math packet, you need to imagine a circle like a slice of an orange. Suppose I were to cut the slice into two half hemispheres and spread each of the two halves out so that their peel formed a straight line.



*If you were to fit these two stretched-out pieces of orange slice together, you'd get something like this . . . well, you get the idea . . . I never said I was an artist!*



So . . . now the area of a circle looks more like a what? A rectangle . . . where the width of the rectangle is the length of the radius of the circle, and the length is  $\frac{1}{2}$  the circumference, or  $\frac{1}{2}$  (diameter  $\times$  pi). That means that the length of our "rectangle" is radius  $\times$  pi. Put these little tidbits together in the formula for rectangular area, and you get radius  $\times$  (radius  $\times$  pi) or radius<sup>2</sup>  $\times$  pi OR  $r^2p$

## How to use the formula

$$\text{Area of a circle} = \pi \times \text{radius}^2 \quad \text{OR} \quad \boxed{\text{Area} = pr^2}$$

It is very important to follow the Order of Operations when using this formula, which means to square the radius BEFORE multiplying by  $\pi$ . It is also important to make sure you are squaring the radius and not the diameter. It will not work to square the diameter and then  $\frac{1}{2}$  it!!!

The first thing to do is get the radius of the circle.

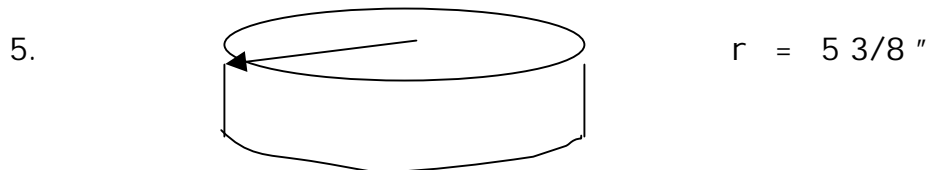
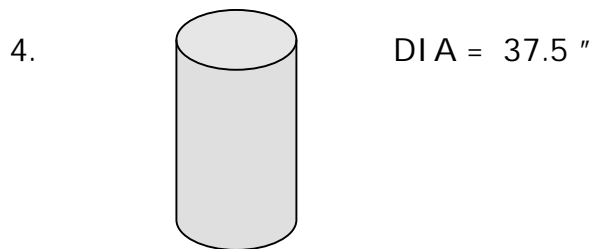
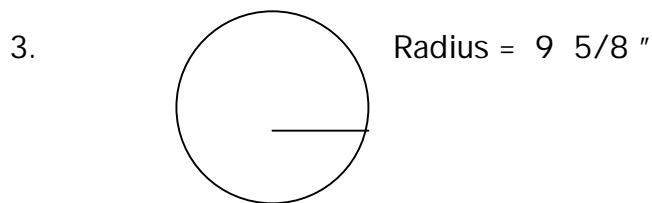
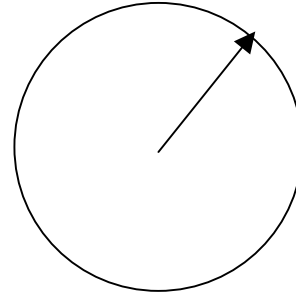
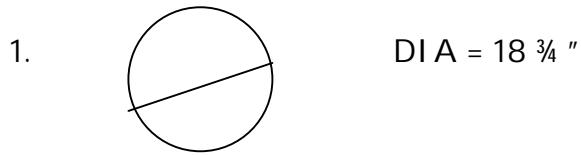
↳ Square that number; use the  $\times^2$  button

↳ Multiply by either 3.14 or the  $\pi$  button on your calculator.

↳

**Press "="**

Find the indicated surface area of these circular shaped metal pieces  
(Remember: you can use the fraction key):





6. Find the area of the hole drilled out of this piece:



**Need more help? See the following worksheets:**

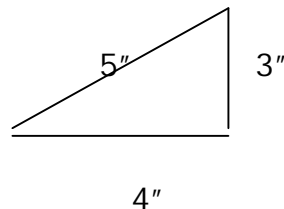
Solving formulas, order of operations, squaring numbers, understanding circles and Pi  $r = 2.75$  "

## 3 - 4 - 5 TRIANGLES

### SQUARING YOUR CORNERS

It is a good idea to square your sheet of steel in order to get a good corner to work from. This way you will be able to make a straight cut and get a good working edge.

A time-honored, tried-and-true method of squaring your corners is the 3-4-5 ratio method, known as the "golden triangle." It's the golden triangle, because you have nice simple numbers for the lengths of the sides:



If you square the two smaller numbers, the legs, you get 16 and 9. Add them and you get 25, which is the square of 5, the length of the longest side. This triangle has a perfectly square or 90-degree corner. (*It follows the Pythagorean Theorem*)

The beauty of this is that you can use these simple numbers to say that if you measure 3 inches in one direction and 4" in a different direction, if you connect you're the end points of these two measurements and get 5" in diagonal length, you have a square corner. If you have less or more than a 5" diagonal, it is not a square corner.

Here's the way to do it on your sheet of metal: (for smaller sheets, use inches)

Starting from the corner you want to be square, measure 3 feet down one side of your piece and mark it. Measure 4 ft. from the same corner down the other side and mark it. Then put your tape from one of your marks on the edge to the other mark. If you get 5', it's a square corner. If not

square (not = 5 ft), shift the corner left or right and measure until you get the magic 5 feet.

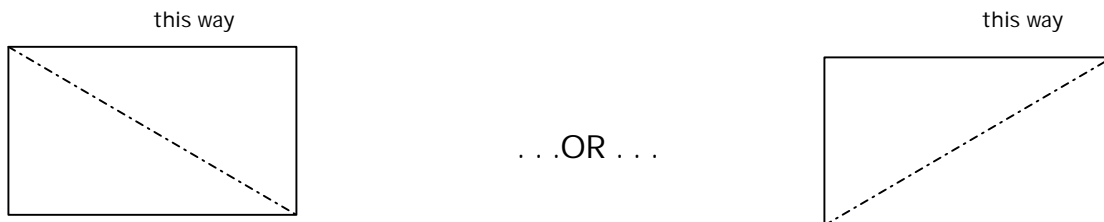
*Make sure you try this method at least once. It is especially useful on a large piece of metal or for laying out a square corner deck or room.*

**Need more help? See the following worksheets: Squaring numbers, square roots**

## SQUARING OFF

In fabricating your pieces for welding, a large portion of your pieces that you need to cut will be rectangular with square (90 degree) corners. There are several tricks of the trade to (1) create a square corner; (2) check an already cut or measured corner to see if it is square; and (3) find the center of a rectangular, using the fact that its corners are square.

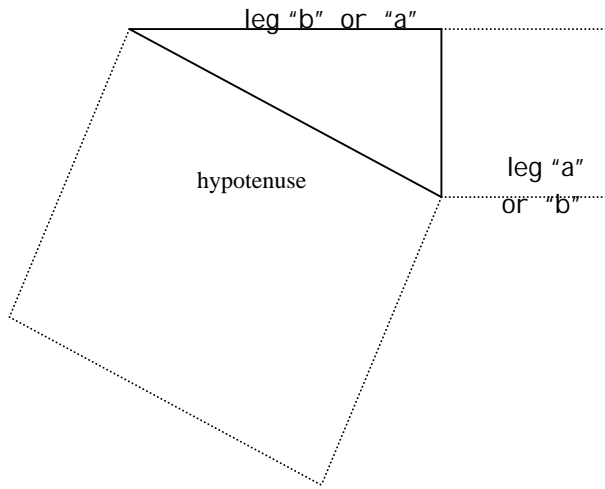
When you are trying to make sure that your corner is exactly square, it is useful to use that little rule called *Pythagorean's Theorem*. This rule talks about triangles rather than rectangles, so first imagine your piece as two triangles put together:



Now, think of the triangles, all of them, as having one longest side (through the middle of the rectangles) and two shorter sides, which are the sides of the rectangle. *Pythagorean's Theorem* says that for any triangle having or wanting a 90-degree angle, or square corner, the following must be true: if you square each of the two shorter sides and add these squares together, you will get the square of the longest side, called the equally long name of "hypotenuse." The shorter sides are the simpler "legs."



*Add the square areas off the two smaller sides (legs) and you get the area off the longer side.*



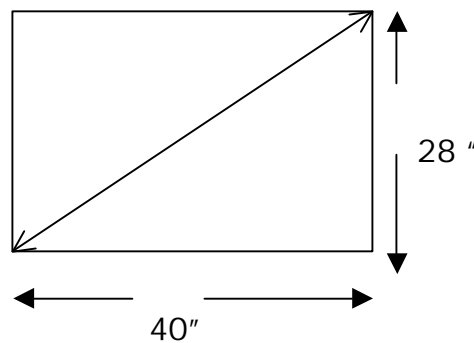
You often see this written as the formula:

$$c^2 = a^2 + b^2 \quad (\text{"c" being the length of the long side})$$

If you manipulate this formula so that it's written to more easily calculate the length of  $c$ , you get:

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

Suppose you have a piece of metal that looks roughly like this:



and you measure the diagonal to get  $49 \frac{1}{4}$ ". **Is this piece of metal squared up at the corners?** Only if I can square each leg (40" and 28"), add these two numbers, and then take the square root of that number.

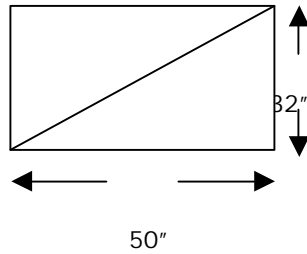
Using your TI 30Xa, or some similar calculator, you would do the following:

Enter 40  
Press the  $x^2$  button  
Press the + button  
Enter 28  
Press the  $x^2$  button  
Press the = button  
Press the  $\sqrt{\quad}$  button

This will get you an answer of about 48.826 . . . definitely less than  $49 \frac{1}{4}$ ".  
This piece of metal is not square at the corners.

Do the calculations on the following pieces of metal and decide if they have squared off corners or not:

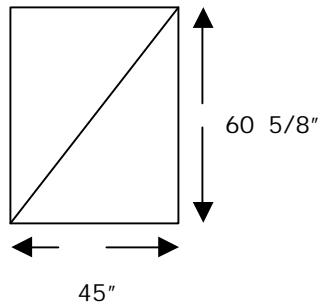
1.



*the diagonal measures  $58 \frac{1}{2}$ "*

Is this piece square? \_\_\_\_\_

2.

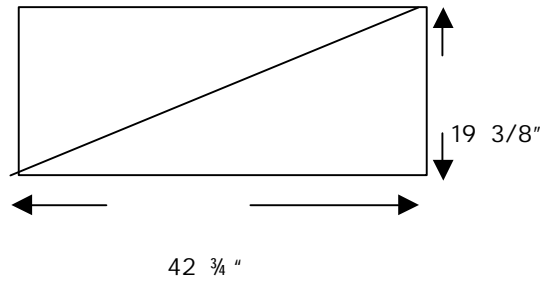


*The diagonal measures  $75 \frac{1}{2}$ "*

What should the diagonal be? \_\_\_\_\_

Is this piece square? \_\_\_\_\_

3.

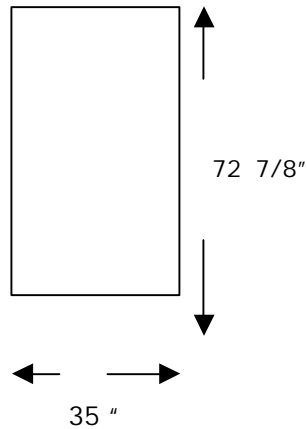


The diagonal measures 46  $\frac{15}{16}$  "

What should the diagonal be? \_\_\_\_\_

Is this piece square? \_\_\_\_\_

4.

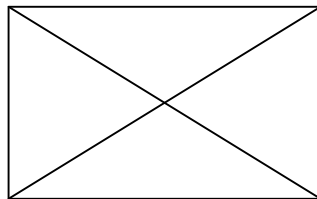


The diagonal measures 79  $\frac{3}{4}$  "

What should the diagonal be? \_\_\_\_\_

Is this piece square at the corners? \_\_\_\_\_

And of course, another way to check is to measure both diagonals: if they measure exactly the same, then you have a square-cornered piece of metal.



**Need more help? See the following worksheets: squaring numbers, square roots**

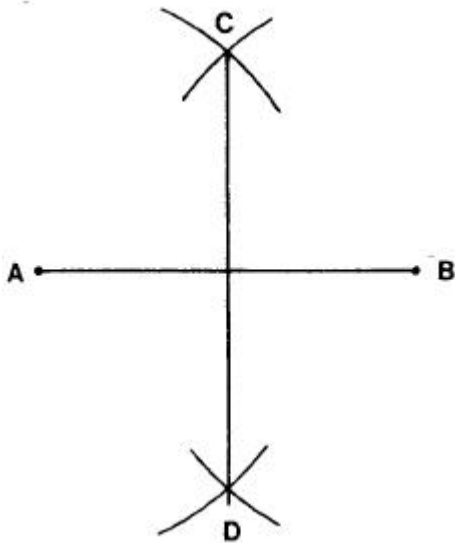


# GEOMETRIC CONSTRUCTION FOR FABRICATION ON METAL

The following exercises are not only fun but also very useful ones for creating the angles and lines that are commonly needed in fabricating the pieces you need for a welding project. During this section of Math on Metal, you are going to learn how to use simple tools (pencil and compass) to create 90-degree (perpendicular) angles, perpendicular bisectors (lines that cut other lines in half, . . . and a few other tricks. The ones presented here are just a small sample of what you can do.

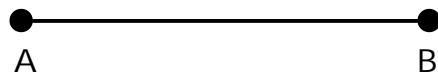
The point of these exercises is to allow you to see the possibilities of what you could do . . . what kinds of shapes and lines you can do with very simple tools.

Figure 1



The first construction we will do is a very useful one; it is to make a **perpendicular (90-degree) bisector through a line**. A bisector is a line that cuts another line exactly in half.

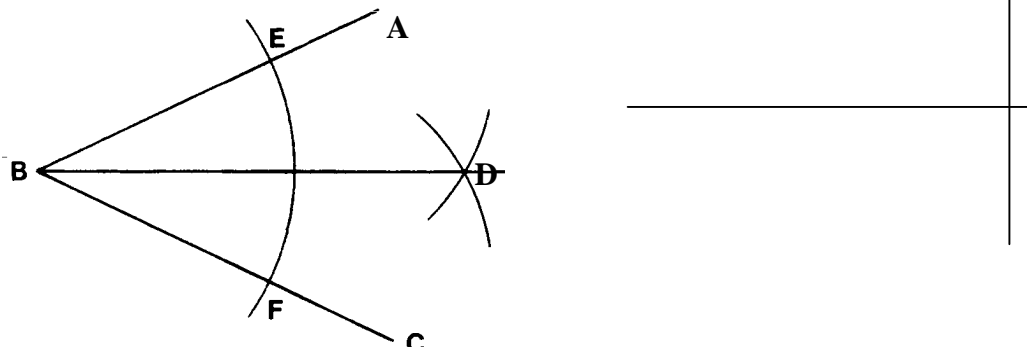
Look at the drawing below:



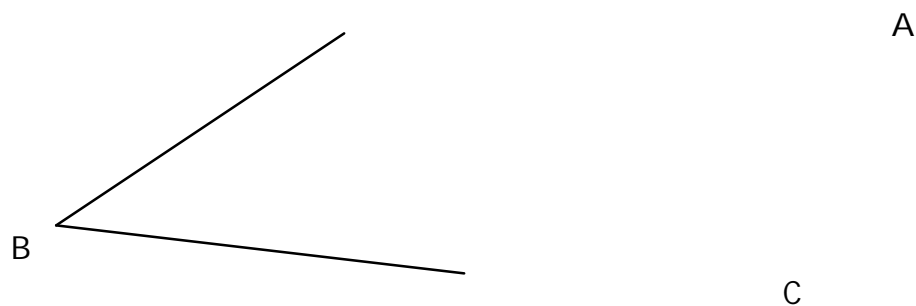
We are going to reconstruct this drawing. You would first draw the line AB; in this case, we have done that for you so that it would fit on our page. Take a compass out and put the sharp point right into A as the center. Set your compass so that your pencil is more than halfway the distance to B. Swing your pencil so that you make arcs both above and below your line AB. Then move your compass point (BUT DO NOT CHANGE THE COMPASS SETTING/RADIUS) so that it centers at B. Again, swing your pencil so that you make arcs both above and below your line AB, and so that your arcs cross with those from before. **see Figure 1** at points C and D. Connect arc intersection points C and D with your pencil. This new line is your perpendicular bisector of line AB. You should do it a couple times in order to get the hang of it.

**Bisect the following lines; draw the perpendicular bisector:**  
*Even better, draw larger lines on a separate sheet of paper.*

Figure 2

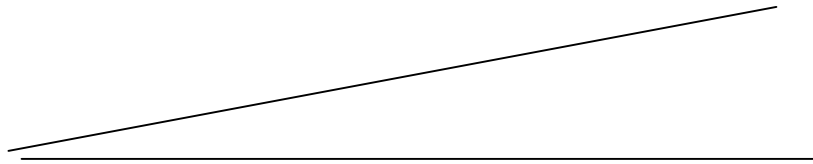


You might also want to **bisect an angle**. Look at Figure 2 below and try to copy the procedure on the angle drawn to the right. The instructions are below.



With B as your center, and a radius that fits on your angle, swing an arc through both sides of the angle (**see points E and F in Figure 2**). In the drawing the intersections of these arcs with the angle are E and F.

Now use one of these intersection points (E) as your center, and a radius more than  $\frac{1}{2}$  the distance between your two intersection points, and swing an arc out to the far right. Do the same with your other intersection point (F) as a center, and swing an arc intersecting with the first so that it looks like the intersecting arcs at D in the drawing. Draw a line from D to B; this line is the line bisecting your angle. Again, you should do it a couple times in order to get the hang of it.



Here are the steps in passing an arc of a given radius through two given points:

Create points A and B.

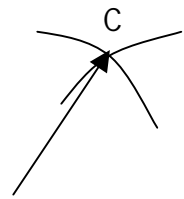
Use the given radius R and points A and B as centers to pass arcs that intersect at point C

With point C as the center and the given radius R, now swing arc AB. see **Figure 3.**

Figure 3



Now use the two points



below and a radius of  
Draw the arc through the  
two points. Show center.



Try this on a separate piece of paper with more room. Just make 2 points and decide a reasonable radius for the arc that flows through both of them.

Here are the steps in dividing a circle into 6 equal parts:

Draw circle with diameter AB.

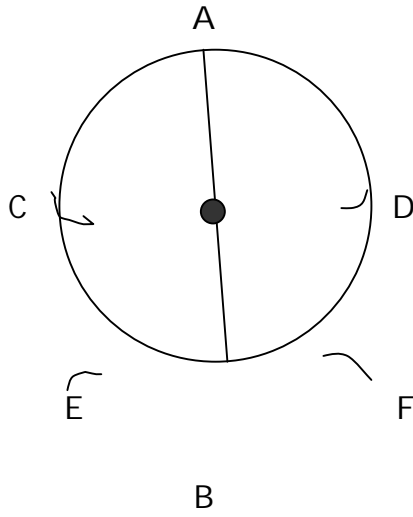
Find the center of the diameter by methods mentioned above . . . call it "O"

With A as a center and AO as the radius, create points C and D

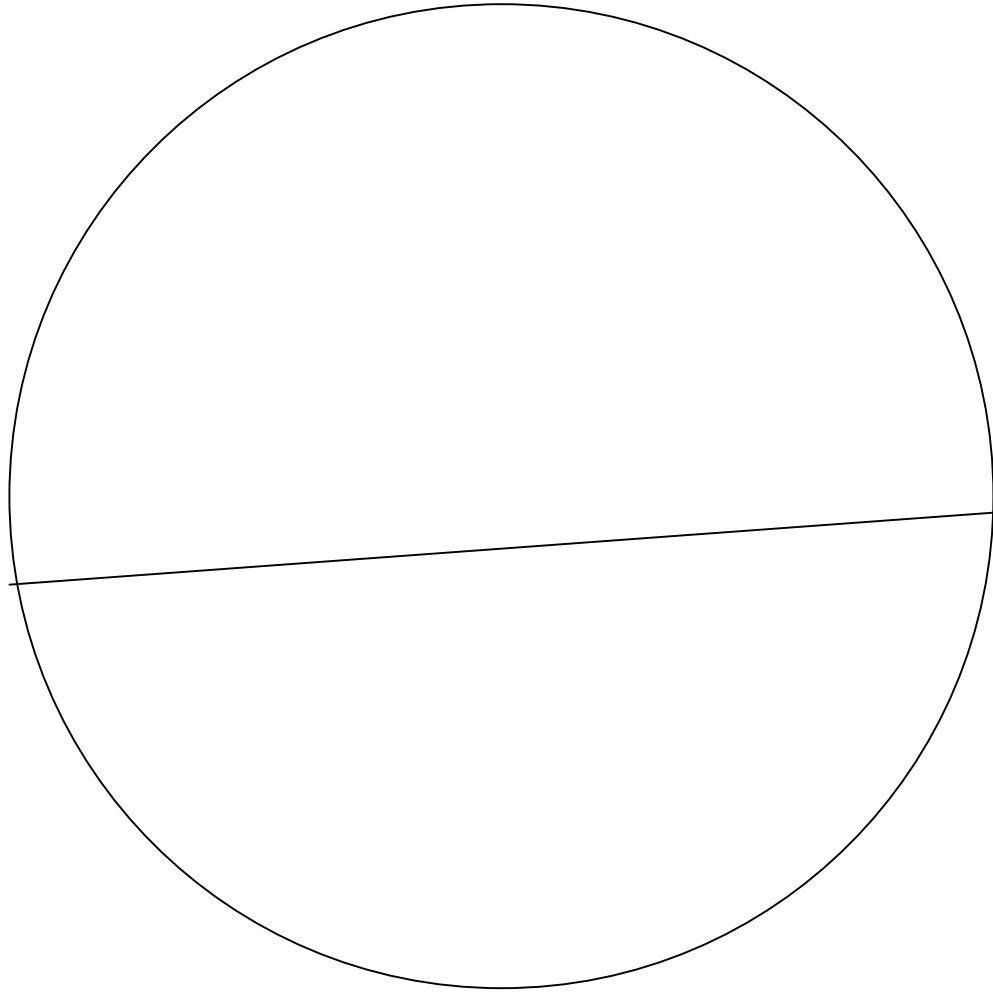
With B as the center and AO as the radius, create points E and F.

This divides the circle into 6 equal parts.

**Figure 4**



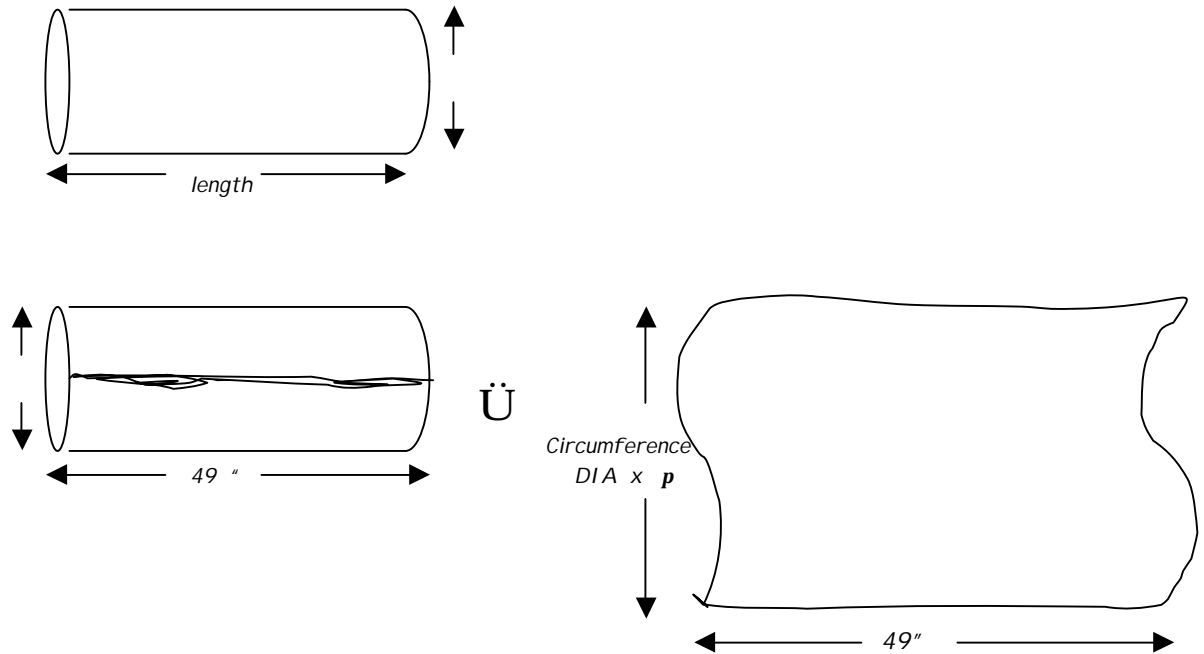
Divide this circle into 6 equal parts. *Remember to first locate the center of the circle.*



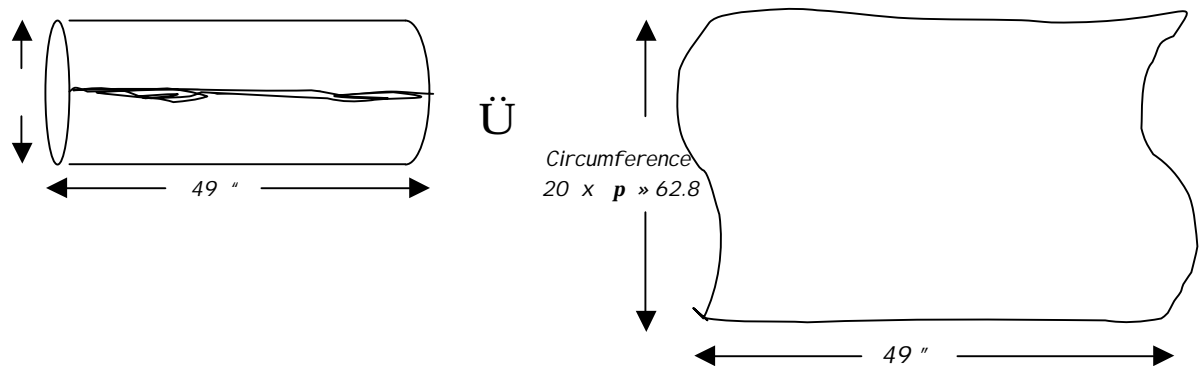
**Need more help? See the following worksheets: understand circles and Pi, multiplying fractions, multiplying decimals**

## FORMING PIPES AND TUBES

To form pipes and tubes, we usually start out with a sheet of flat metal. If we know the desired diameter of the pipe and its length, we can figure out the width and length of the piece of sheet metal to cut. Here's how it works:



Multiply the diameter (not the radius!) of the pipe by  $\pi$  (or about 3.14). This will get you the circumference of the pipe, which we can see by our pictures gives us the width of our sheet metal to cut . . . approximately equal to  $3.14 \times 20 = 62.8$  inches. The length of the pipe and the sheet metal are the same.

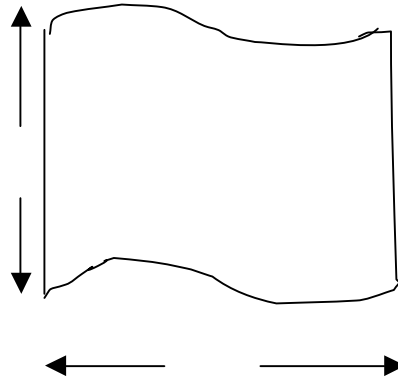
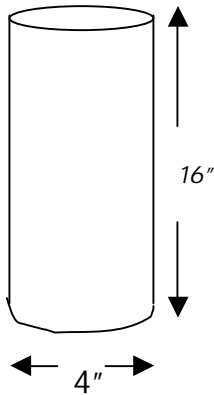


Here are some example problems to work. For each tubular drawing, give the length and width of the sheet metal piece to be cut. At this point, don't include any calculations on gain or loss of metal due to weld.

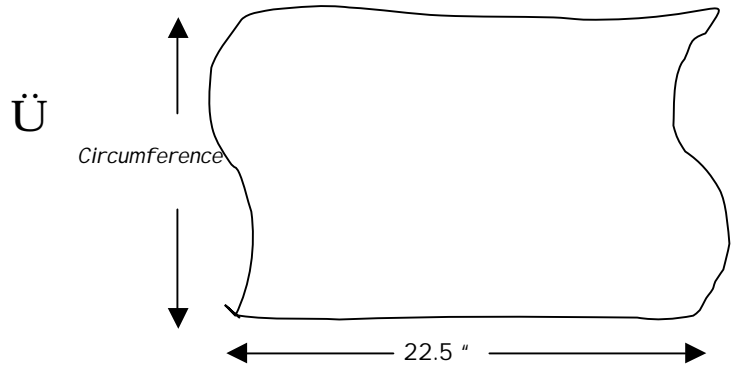
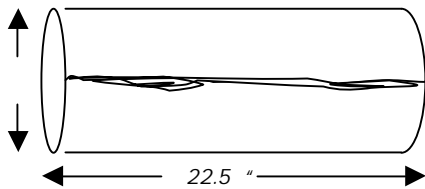
To Get this result:

Cut a piece like this:

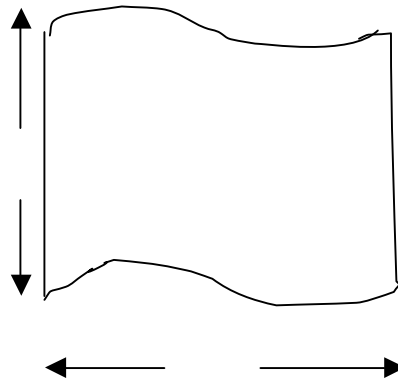
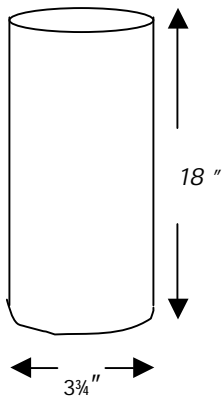
1.



2.



3.



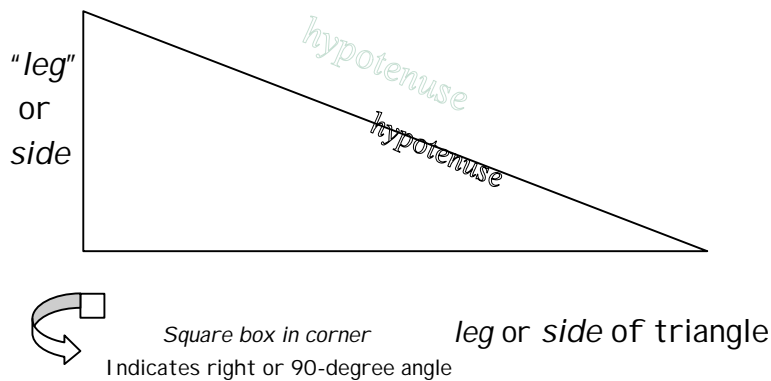
**Need more help? See the following worksheets: understand circles and Pi, multiplying fractions, multiplying decimals**



## MAKING TRIGONOMETRY WORK FOR YOU

When working on the fabrication of a particularly tricky piece of work, there may be times when simple geometry is not quite enough to find the measuring information you need. Basic right angle trigonometry can be a very useful tool to have when trying to use facts you *know* about the angles and side lengths of a triangle to get the rest of the facts about that triangle that you don't know.

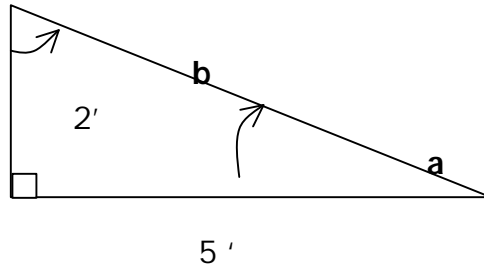
This comes up sometimes when you are fabricating a brace or support for a right angle corner; or it may come up when you are working on travel or run lengths or the cut angles for pipe offsets. And it may come up when you are planning the angle of a metal staircase. But before we get to do some of these applications, there are a few bits of theory and lingo we need under our belts.



In a right triangle you have 3 angles and 3 sides. There is always one  $90^\circ$  angle marked by a square in that corner. There is always one longest side; it is called the hypotenuse. The two other (shorter) sides are called "legs" and are also named by their position with respect to the particular (non- $90^\circ$ ) angle you are discussing.

Looking at the figure below, if you are discussing angle "a," the side next to it is 5 feet long and is called the "*adjacent*" side with respect to angle a. The adjacent side can never be the hypotenuse. The side across from it or opposite it is 2 feet long and is called the "*opposite*" side with respect to angle a. The opposite side can also never be the hypotenuse.

FIG. 1



Because there are 2 non-right angles in a right triangle, each of the two sides are opposite to one of the angles, and each of the two sides take their turn at being adjacent to one of

the angles. Each is opposite to one angle and adjacent to the other non-right angle. Therefore, if you look at that last triangle again, you can see that the side *adjacent* to angle **b** is 2' long, and that angle **b's opposite** is 5' long. The hypotenuse, you will be relieved to know, is always just itself.

In the triangle to the right,

**b**

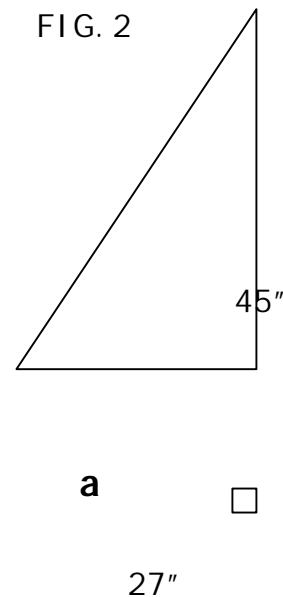
How long is the hypotenuse? \_\_\_\_\_

If we are looking at angle **b**,  
how long is its opposite? \_\_\_\_\_

36"

How long is its adjacent? \_\_\_\_\_

FIG. 2



**a**

27"

Let's take this one step further. It will become very useful to understand the ratio between two sides of a triangle. A ratio is the relationship between two sides; it can be written as a fraction. Order matters. Put them in the order you hear them. So the *ratio of b's adjacent side to b's hypotenuse* would be 36 to 45 or 36/45, which reduces to 4/5. The *ratio of b's opposite to b's hypotenuse* would be 27 to 45 or 27/45, which is 3/5 reduced. What would the ratio of b's opposite to adjacent be? *Stop here and test yourself. Answers at bottom of page.*

*Then, test yourself with the following questions: {Order is important AND be sure to reduce your fractions to lowest terms! Answers at bottom of page.}*

Looking at FIG. 2,

What is the ratio between angle **a**'s opposite and hypotenuse?:

What is the ratio between angle **a**'s adjacent and hypotenuse?:

What is the ratio between angle **a**'s opposite and adjacent?:

*Answers to example questions about Fig.2( for angle b):*

*Hypotenuse = 45"*

*Opposite = 27"*

*Adjacent = 36"*

*FIG. 2 Ratio for b's opposite-to-adjacent @ 27 to 36 or 27/36, which reduces to  $\frac{3}{4}$  or .75*

**Angle a's opp. to hyp:  $\frac{36}{45} = \frac{4}{5}$  or .80**

Angle a's adj to hyp:  $\frac{27}{45} = \frac{3}{5}$  or .60

Angle a's opp to adj:  $\frac{36}{27} = \frac{4}{3}$  or 1.333333 . . .

Now, the really neat thing is that knowing these side or leg lengths and ratios, you can figure all of the angles out . . . but that's for the next section. Let's practice what we know so far. *And for these exercises, convert your answer to a decimal; just divide your fraction: top divided by bottom, and round to the nearest hundredth.*

**Exercises:**

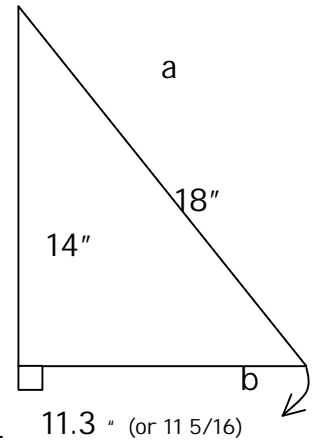
1. For the triangle to the right, answer the questions below:

What is the length of the hypotenuse? \_\_\_\_\_

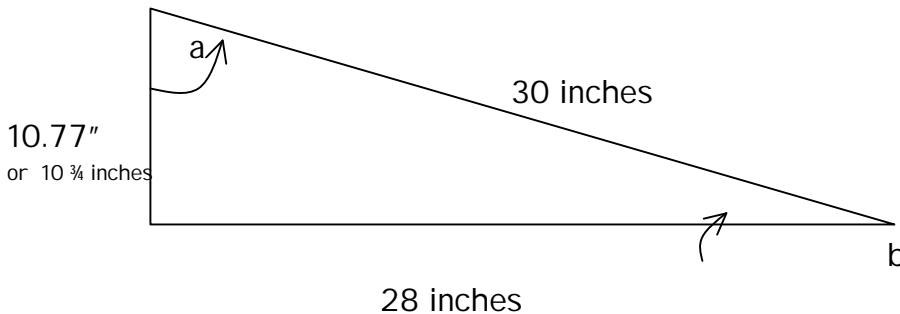
What is the length of the side opposite to angle **a**? \_\_\_\_\_

What is the ratio of the a's adjacent to hypotenuse? \_\_\_\_\_

What is the ratio of the a's opposite to adjace \_\_\_\_\_



2. For the triangle below, answer these questions:



What is the length of the hypotenuse? \_\_\_\_\_

What is the length of the side adjacent to angle **b**? \_\_\_\_\_

What is the length of the side opposite to angle **b**? \_\_\_\_\_

What is the ratio (in decimal form) of angle **a**'s adjacent to hypotenuse?

\_\_\_\_\_

What is the ratio (in decimal form) of angle b's opposite to adjacent?  
\_\_\_\_\_

Now that we've got that straight, let's go a little further towards making this all useful. . .

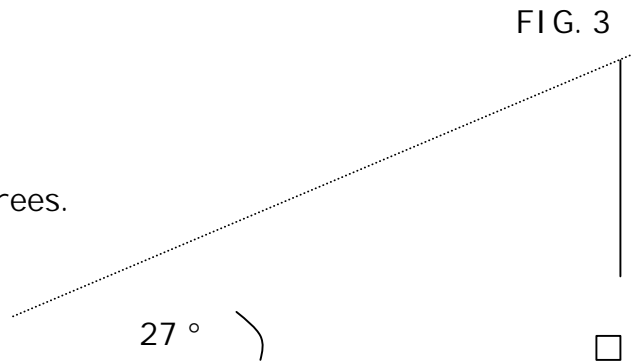
Some facts: for all triangles, the three angles add up to 180 degrees. So . . . if you know two angles of any triangle, you know the third one as well. This also means that in a right triangle, with 90 degrees already set in stone, the other two angles have to add up to 90 degrees as well. You could say that given two specific size angles of any triangle, there is a unique angle that will close off the triangle. **See below.**

?

The ? angle has to be 63 degrees.

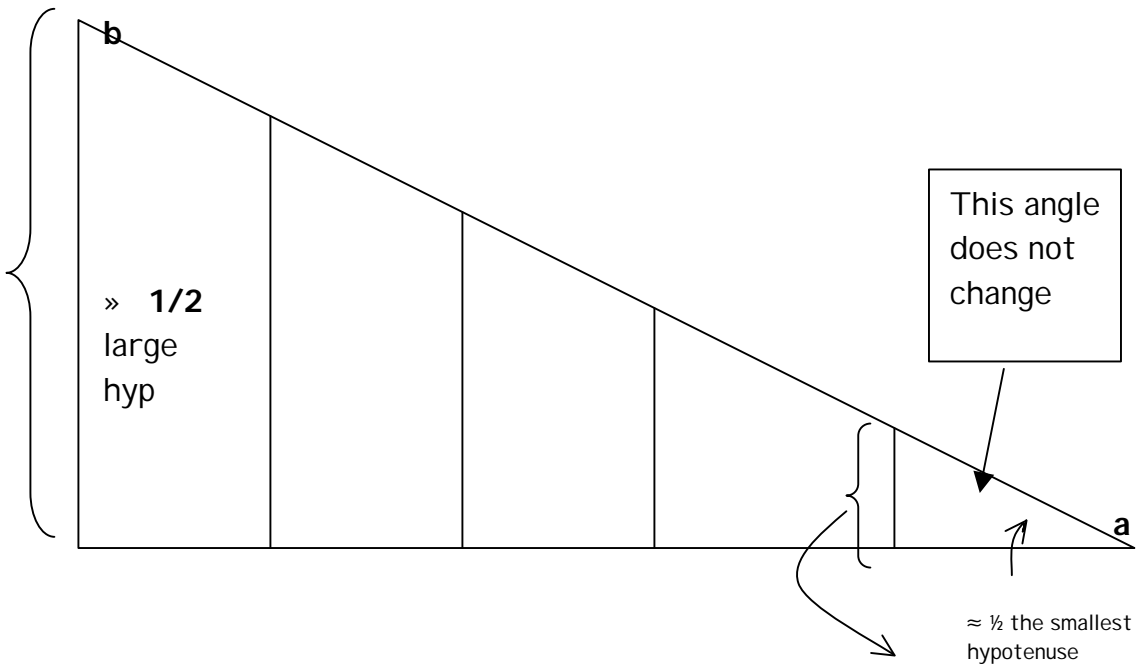
$(90 - 27)$  or

$[180 - (90 + 27)]$



Remember, in a right triangle, when you know one of the angles besides the right angle, you know the sizes of all of them. This will also lead us to say that for that right triangle with a known angle besides the 90° one, the ratio between any 2 sides is set in stone. Why? Can you see from the imbedded triangles below that no matter the size of the triangle, the ratio between any two given sides remains constant as long as the angles remain constant. In fact, for this triangle, you could probably estimate that the side opposite the angle **a** is roughly ½ the size of the hypotenuse. This is true for the largest triangle and its sides. And if you chop off the slices left to right, as shown, you will see that the same is true for the smaller triangles which remain. Finally, if you were to change angle **a** (which would also change angle **b**), the ratio between its opposite and hypotenuse would change equally for all the triangles.

FIG. 4



We've done a lot of the leg work (no pun intended); now let's learn a little more vocabulary. Let's put names to the special relationships or ratios between all the sides of the triangle.

The ratio between the opposite and the hypotenuse is called the **sine**, which shows on your calculator as the abbreviated "sin." If you press the number "30," representing the degrees of a 30-degree angle, followed by the "sin" key on your calculator, this will give you the ratio, in decimal form, between the opposite and hypotenuse of a 30-degree angle. (Some calculators require you to push the "sin" key first and an "=" later). You should get .5 as an answer. That's because the ratio between the opposite and the hypotenuse of a 30-degree angle is  $\frac{1}{2}$ . The opposite side of a 30-degree angle is  $\frac{1}{2}$  the length of its hypotenuse.

You can find the sine of any other angle exactly the same way.

$$\sin = \frac{\text{opp}}{\text{hyp}} \qquad 30 \quad \boxed{\text{sin}} \qquad \sin 30^\circ = .5$$

The other two ratios talked about in this section work the same way. The ratio between the adjacent and the hypotenuse is called the **cosine**, which shows on your calculator as the abbreviated "cos." Pressing the number of

angle degrees followed by the "cos" key on your calculator will get you the cosine of that size angle.

$$\cos = \frac{adj}{hyp}$$

$$60 \boxed{\cos}$$

$$\cos 60^\circ = .5$$

The ratio between the opposite and the adjacent is called the "tangent," which shows on your calculator as the abbreviated "tan." Pressing the number of angle degrees followed by the "tan" key on your calculator will get you the tangent of that size angle.

$$\tan = \frac{opp}{adj}$$

$$45 \boxed{\tan}$$

$$\tan 45^\circ = 1.0$$

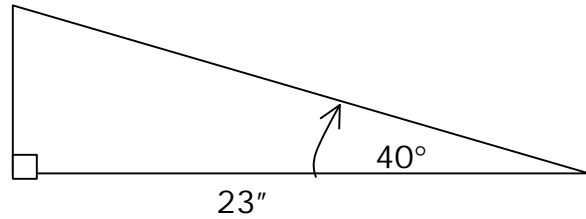
*The ratio between opposite and adjacent is 1:1, which makes sense for an angle of 45°.*

There are two really great uses for this information. One is that if you know the two sides, you can find the ratio between the two sides, and from this, find the angle which has that particular sine, cosine or tangent ratio.

Also, if you know the angle, you know the ratio of two of the sides, and if you know one of the sides you can find the other. Okay, now let's practice finding different parts of the triangle for a while, and then we'll put this stuff to some more practical use.

Example A: Finding the opposite side when you know the adjacent ?

FIG. 5



You know the size of the angle -- 40 degrees.

You know the size of its adjacent;

And you want to know the size of its opposite.

Which ratio (sin, cos, or tan) involves these two sides: adjacent and opposite?

*You've got it! The tangent.*

So . . . here's what you do.

Set up your equation: you now that  $\text{tangent} = \text{opp}/\text{adj}$  & that the  $\text{adj} = 23$

$$\tan 40^\circ = \frac{\text{opp}}{\text{adj}} \quad \text{Put 23 (inches) in for the adjacent . . .}$$

.....

$$\tan 40^\circ = \frac{\text{opp}}{23}$$

Find the tangent of 40°.

$$40 \boxed{\tan} \text{ gets } .839 \quad \text{Replace } \tan 40 \text{ with } .839 .$$

.....

$$.839 = \frac{\text{opp}}{23} \Rightarrow \quad \text{Note: } \text{opp} \div 23 = .839, \text{ so thinking}$$

*backwards, undo the division with multiplication:*

$$\text{opp} = .839 \times 23 = 19.297''$$

$\approx 19 \frac{5}{16}''$  is the length of the opposite side



Example B: Finding the adjacent side when you know the hypotenuse

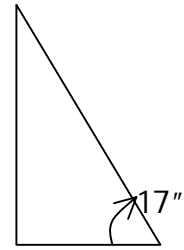
You know the size of the angle:  $50^\circ$

You know the size of its hypotenuse: 17"

You want to know the length of its adjacent side.

$50^\circ?$

FIG. 6



**a =**

Which ratio (sin, cos, or tan) involves these two sides: adjacent and hypotenuse?

*Did you answer the cosine?*

What to do: First set up your equation and substitute the information you know:

$$\cos 50^\circ = \frac{adj}{hyp} = \frac{adj}{17}$$

Then find the cosine of 50° and substitute it

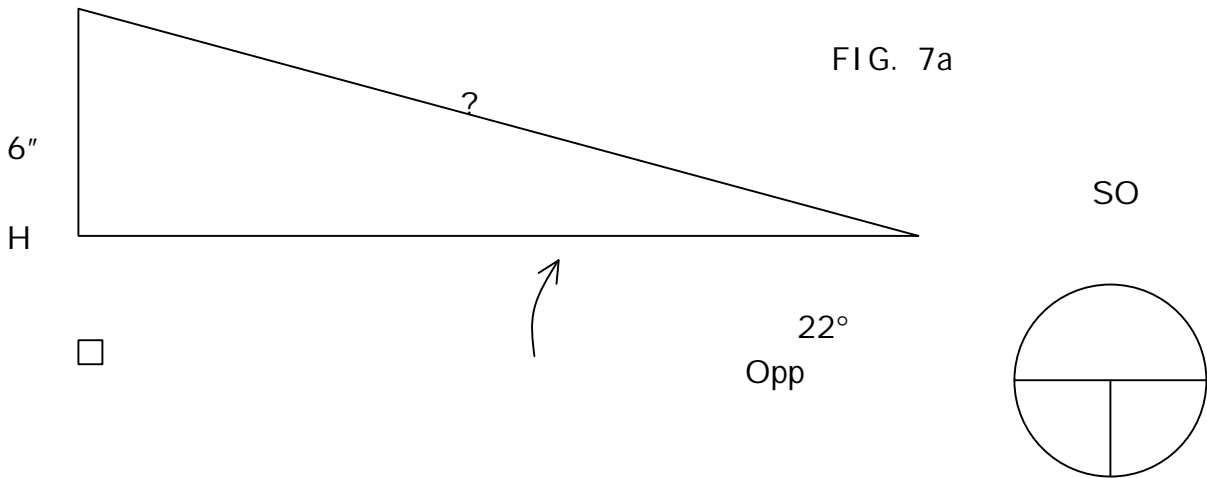
for the cosine.

$$50 \quad \boxed{\cos} \quad \boxed{\phantom{00}} = \text{ gets } .643 \text{ to the nearest thousandth}$$

$$.643 = \frac{adj}{17} \Rightarrow adj = .643 \times 17 = 10.931''$$

$$\approx 10 \frac{15}{16} \text{ inches}$$

Example C: Finding the hypotenuse when you know one of the other sides:



You know the size of the angle: 22 degrees

Sin Hyp

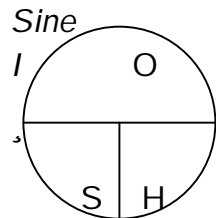
You know the size of the opposite: 6 inches

You want to know the length of the hypotenuse.

Which ratio involves these two sides: opposite and hypotenuse?

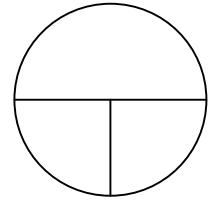
Set up your equation:  $\sin 22^\circ = \frac{opp}{hyp} = \frac{6}{hyp}$

Find the sine of 22 degrees = .375



Substitute .375 for the sine of 22 degrees:

$$.375 = \frac{6}{hyp}$$



This means that  $6 \div hyp = .375$ ; which, if we undo division with multiplication means that  $.375 \times hyp = 6$ ,  $.375 H$   
Which in turn means that  $6 \text{ divided by } .375 = \text{hypotenuse}$ .

$$\text{Hypotenuse} = 16 \text{ inches} \quad (6 \div .375)$$



**Tangent = Opp/Adj**

... which means that  
 ... **and** means that

Opposite = tangent x adjacent  
 Opposite , adjacent = tangent see Fig. 7b

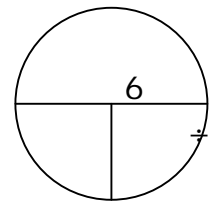
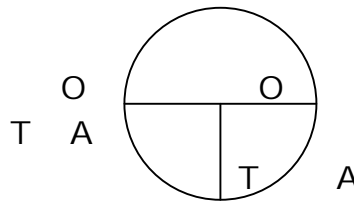
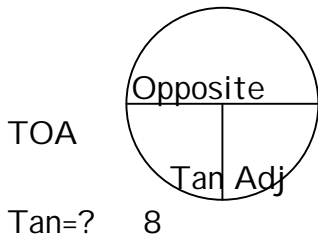
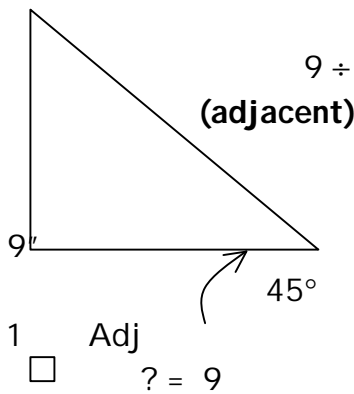
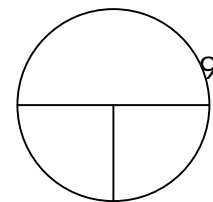
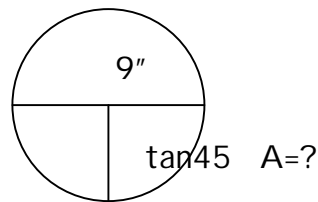


Fig. 7d



$9 \div \tan 45 = \text{adj}$  →  $9 \div 1 = 9 \text{ inches}$

(adjacent)

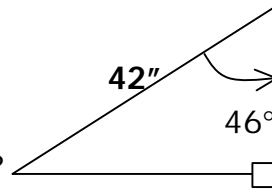


**Need more help? See the following worksheets: understand circles and Pi, multiplying fractions, multiplying decimals, constructing with angles and bevels**

Now, let's try some exercises, including a practical application:

**Exercises:**

1. What is the length of the "?" side of this triangle?



?

*Guided questions:*

*What side do you know?* \_\_\_\_\_

*What side do you want to know?* \_\_\_\_\_

*What ratio (sin, cos or tan) deals with those 2 sides?*

\_\_\_\_\_

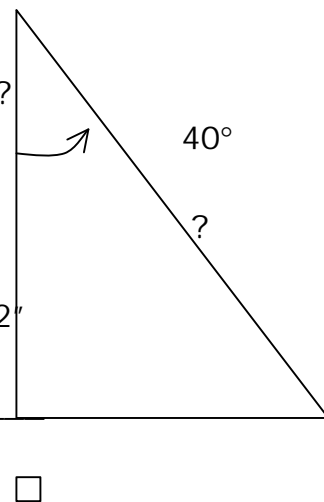
*Set up your equation:*

*Substitute the information you know:*

*Perform the mathematical calculation:*

*Convert the decimal number of inches to fractional inches (to the nearest 16<sup>th</sup>):* \_\_\_\_\_

2. What is the length of the side "?" of this triangle?



*Guided questions:*

*What side do you know?* \_\_\_\_\_

*What side do you want to know?* \_\_\_\_\_

What ratio (*sin*, *cos* or *tan*) deals with those 2 sides?

\_\_\_\_\_

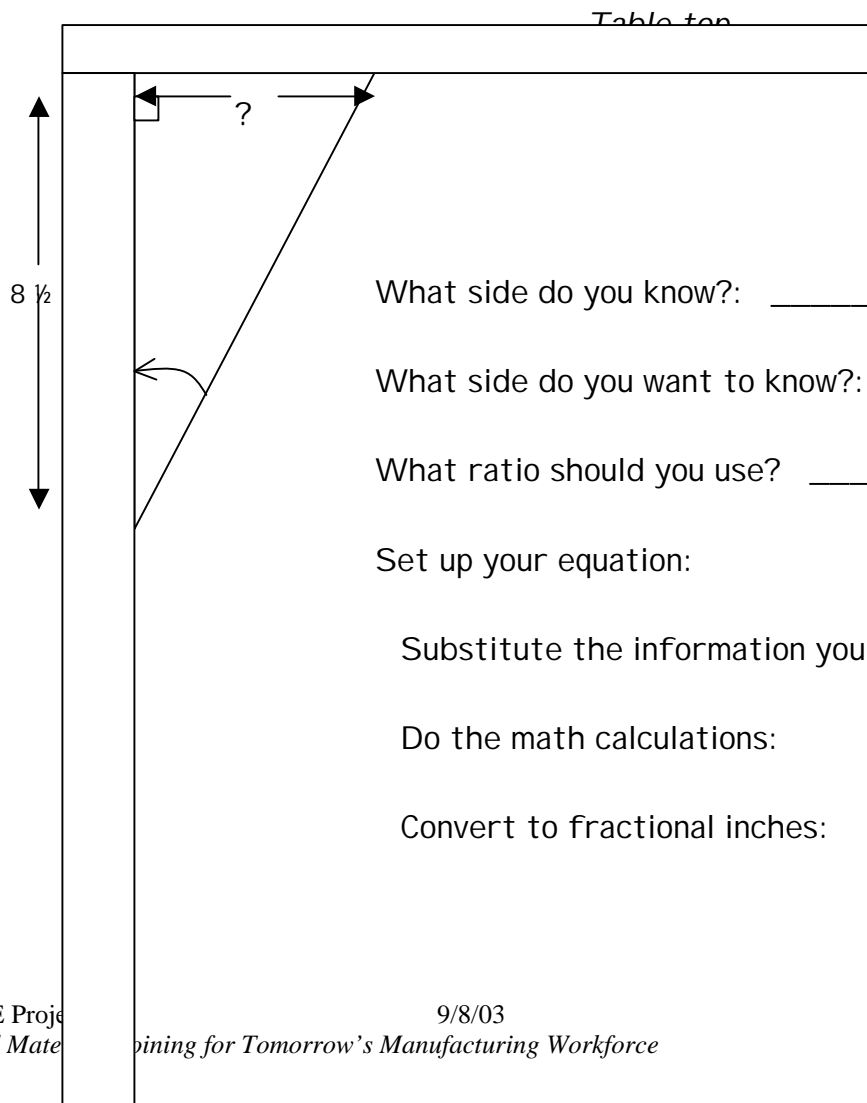
Set up your equation:

Substitute the information you know:

Perform the mathematical calculation:

Convert the decimal number of inches to fractional inches (to the nearest 16<sup>th</sup>):\_\_\_\_\_

3. Look at the drawing below. For stability to a table/table leg, you want to create a brace in the form of a 30-60-90 degree triangle. Find the length of the side on the top of the brace.



What side do you know?: \_\_\_\_\_

What side do you want to know?: \_\_\_\_\_

What ratio should you use? \_\_\_\_\_

Set up your equation:

Substitute the information you know:

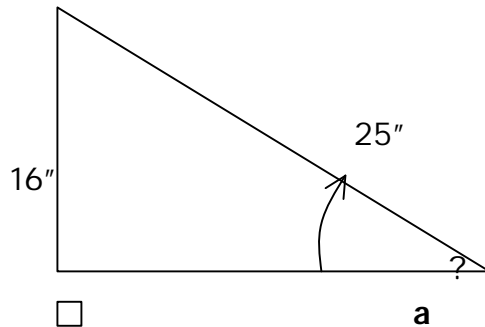
Do the math calculations:

Convert to fractional inches:

Okay, so far, in the triangles we have seen, we have known one angle besides the right angle and the length of one side. What if we do not have any known angles, but we do know the length of two out of three sides?

If we know two sides of a right triangle, we can relate them to whichever angle we wish to know.

FIG. 8



In Fig. 8 above, we have the lengths of two sides. Relating these sides to angle **a**, the side of length 16" is opposite angle **a**, and the side of length 25" is angle **a**'s hypotenuse. So, in order to find the angle **a**'s size, we decide which ratio (sin, cos or tan) involves both opposite and hypotenuse: this is the sine ratio. But because we know both numbers in the ratio and not the angle, we have to go about things a little differently.

First, we use the two sides to find the decimal value of the ratio, in this case, sine **a** (we say "sine of **a**").

$$\text{Sine } \mathbf{a} = \frac{\text{opp}}{\text{hyp}} = \frac{16}{25} = 16 \div 25 = 0.64; \quad \mathbf{\sin a = .64}$$

In order to find which one unique angle has a sine ratio (opp/hyp) of .64, we have to work a little backwards. We find the ratio value and then use the inverse sine function to find the angle. The inverse sine function is worked by first pressing the "2<sup>nd</sup>" function key and then the sine key. If we already have 0.64 in the calculator screen and then press this sequence, we should get the angle size. Some calculators may work in the reverse direction, first using the inverse sine function and then the ratio value.



The TI -30Xa works like this:

$$16 \div 25 = 0.64$$

2<sup>nd</sup>

sin

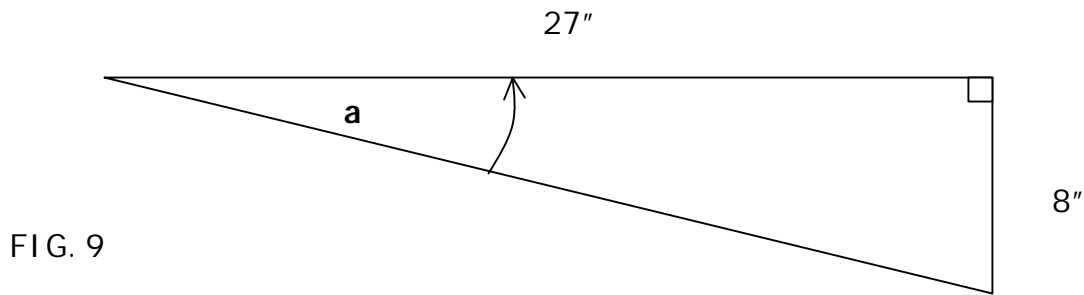
after pressing the "sin" key, you will get an answer that rounded to the nearest hundredth, is **39.79** degrees.

*If you want to check this, take the sine of this angle,*

*and see if it*

*doesn't equal approximately .64.*

Let's do one more example like this, and then you'll get to practice.



In the right triangle in Fig. 9, all we know is the lengths of two sides. In relation to angle **a**, the 8" side is its \_\_\_\_\_ (opp, adj, or hyp?), and the 27" side is its \_\_\_\_\_ (opp, adj, or hyp?). Fill in those two blanks, and the next question to ask yourself is which ratio (sin, cos, or tan) involves those particular two sides?

*Hopefully, you picked the 8" side as **a**'s opposite and the 27" side as **a**'s adjacent. These two sides are involved in **a**'s tangent.*

$$\tan a = \frac{\text{opp}}{\text{adj}} = \frac{8}{27} = 0.296296 \dots \quad \text{Follow this with } \dots$$

$$\boxed{2^{\text{nd}}}\ \boxed{\tan} \quad (\text{"tan}^{-1}\text{" called the "inverse tangent"}) = 16.50436 \dots$$

$$\approx 16.5^\circ$$

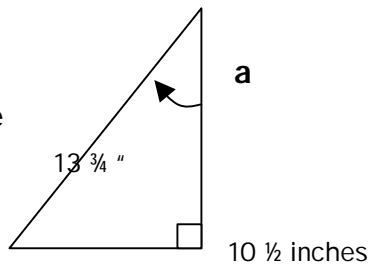
**Again, you can check this by taking the  $\tan 16.5$  » ("approximately equal to") .296**

Find the angle measure of **a** in each of these triangles:

1.

$\frac{3}{4}$  " side

the



With respect to angle **a**, the 13

is the \_\_\_\_\_, and

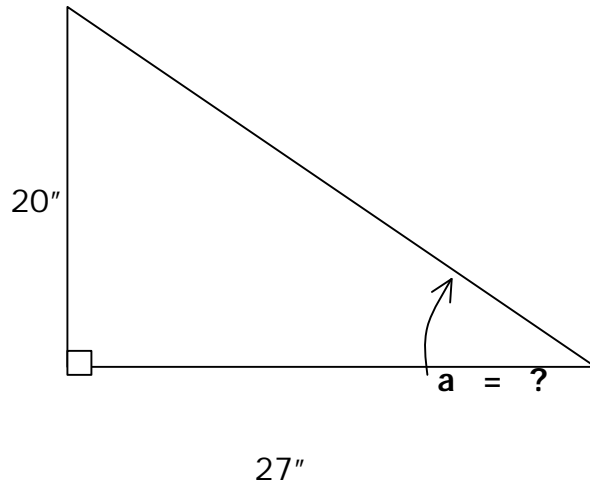
10 1/2 " side is the \_\_\_\_\_.

These two sides are involved in

The \_\_\_\_\_ (*sin*, *cos* or *tan*) ratio.

Angle **a**  $\approx$  \_\_\_\_\_ $^{\circ}$

2.



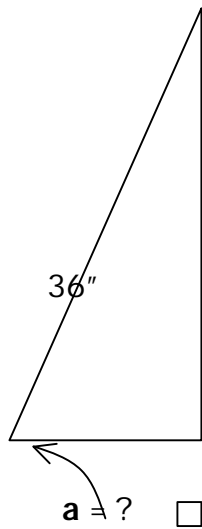
The 20" side is the \_\_\_\_\_ side with respect to angle **a**.

The 27" side is the \_\_\_\_\_ side with respect to angle **a**.

These two sides make up the ratio \_\_\_\_\_ with respect to angle **a**.

Angle **a** = \_\_\_\_\_ °

3.



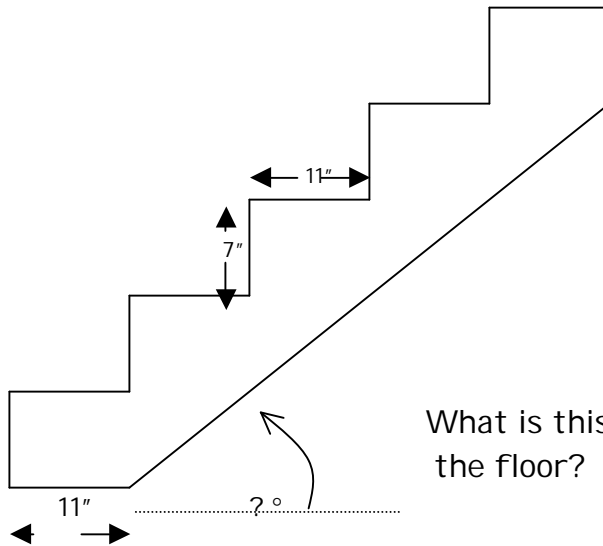
13 1/8"

Angle **a** = \_\_\_\_\_°

4. Suppose that you are doing the layout for a steel staircase like the one below.

You know the risers are 7" and each step is 11" deep. What angle will get

you the ratio involving these two legs of a right triangle?



What is this angle between the staircase and the floor? \_\_\_\_\_ $^\circ$

## A LITTLE MORE INFORMATION ABOUT ANGLES

### Lines called transversals crossing through two parallel lines:

Look at the drawing (Fig. 10) below and assume that what looks true is true. What might you say about the size of angles **a** and **c**? They look equal, right? And as long as the two horizontal lines are parallel, these angles which are "opposite" each other are equal.

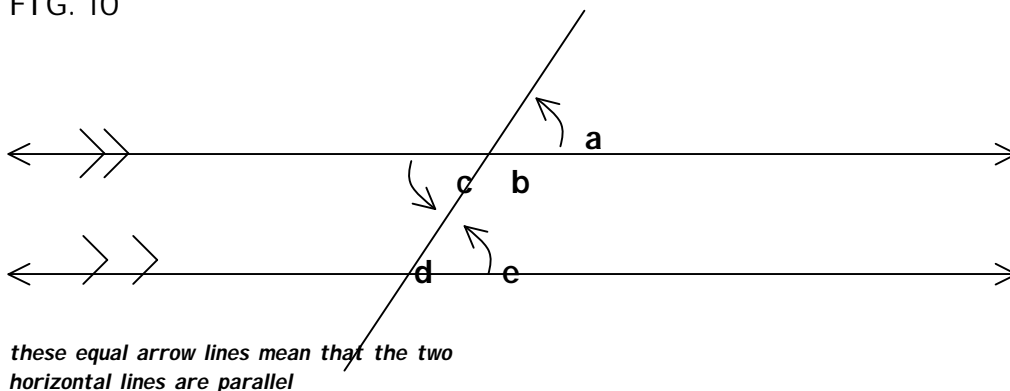
How about angles **a** and **e**? Also equal under these circumstances, just like they look.

How about **b** and **d**? These angles are also equal under these circumstances, just like they look. Angles **c** and **e** are also equal, just like they look.

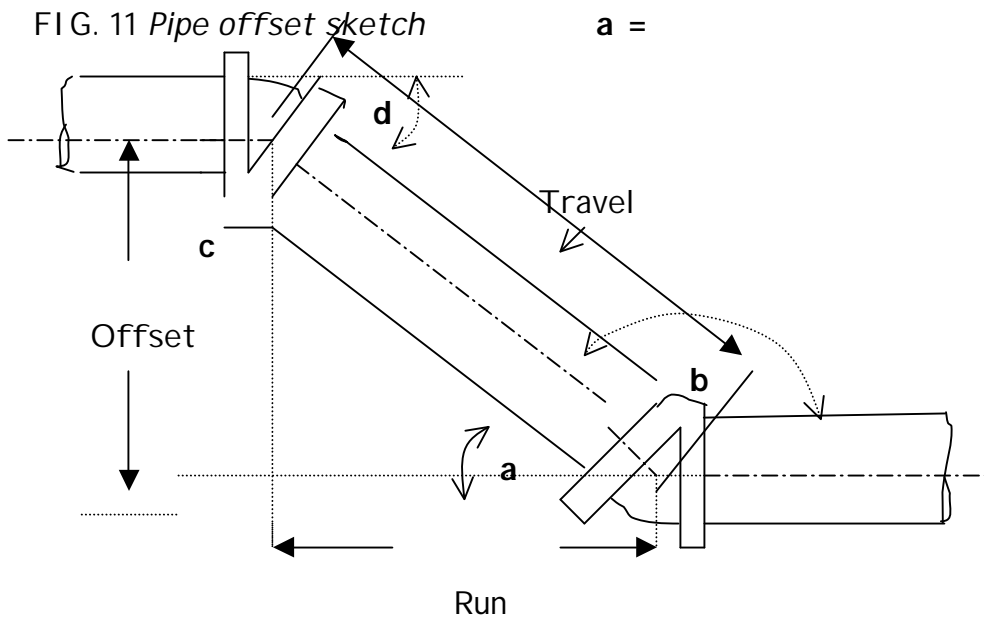
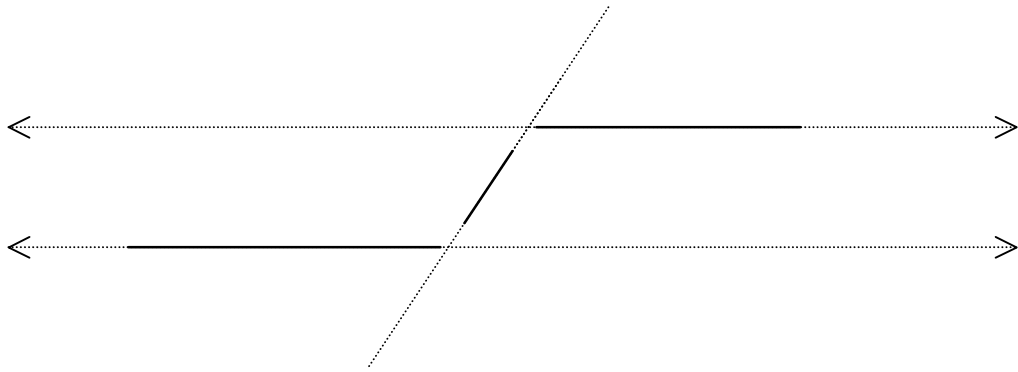
Now, what about the relationship between angles **c** and **b**, between **a** and **b**, and between angles **d** and **e**?

Each of these pairs always adds up to 180 degrees. For the record, they are called supplementary angles, but all we care about now is that they add up to 180°.

FIG. 10



Now look at the more practical picture below and see if you can find a connection between what we learned above about angles formed by transversals crossing parallel lines. Fill in the blanks at the right, using the above information and just what looks to be true.

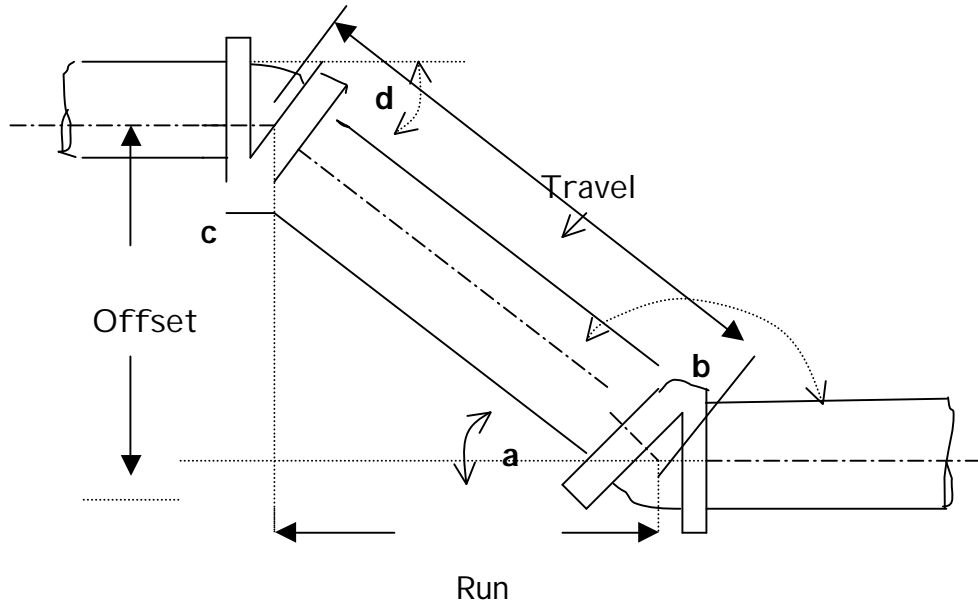


Answers: a = 52; d = 128; e = 52; f = 52



We are going to continue to look at pipe offsets as triangles with parallel lines involved.

FIG. 12



The offset connects two parallel sections of pipe. It acts like the line or transversal that crossed our parallel lines on the previous two diagrams. In relation to the angle marked **a** in the triangle formed, the offset is our opposite side, and the run is our adjacent side. The travel length is the hypotenuse of our imaginary triangle. All the rules and relationships we've learned so far still apply.

The sin of angle **a** in this picture is the  $\frac{\text{offset}}{\text{travel}}$ , and by figuring this ratio and applying the inverse sine function on our calculators, we can calculate the angle. Also, if we know the length of the offset and the angle, we can use the sine key of the calculator and the simple calculations we've worked with so far to figure the travel length. The same goes for the run length, if we use the inverse cosine and cosine functions.

In addition, we can use what we learn about angle **a** to calculate all the remaining angles in the offset.

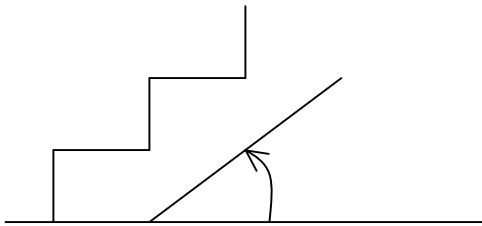
**Practice:** Let's put what we know to a test by assigning the angle **a** to be  $22\frac{1}{2}^\circ$  and the offset to be 14 inches. **What will the travel length be?** Label the other angles on the drawing above.

Your last project in this math section of trigonometry is the following:

Draw and calculate the missing dimensions in a steel staircase that totals 250 inches in length. This total 250 inches includes two landings of 4 feet length each, one about halfway up and one at the top. The treads are the standard 7" rise and 11" deep.

Draw a side view of the staircase to scale, noting the number of steps before and after the middle landing.

Determine the angles formed by the stairs to the ground for both sections, before and after the middle landing.



**Need more help? See the following worksheets: construction with angles/bevels, dividing fractions, multiplying decimals, dividing decimals, using a protractor**

# WELDING COSTS

Applications:

- Determining costs of a job
- Bidding on a job
- Ordering supplies and materials
- Maximizing efficiency
- Reducing waste

# BASIC COSTING PROCEDURES LAB

When estimating the basic cost of welding you must include the following factors:

1. Direct labor costs
2. Overhead costs (Which include amortization of plant and equipment)
3. Welding consumables cost (electrode, flux, wire, shielding gas etc.)
4. Power costs <sup>1</sup>

In this lab we will learn to estimate each cost separately and then combine them to get total cost.

## Definitions

### Direct labor costs

The cost per hour of labor including salary and benefits.

Often a company will preset the direct labor costs that they charge clients

### Overhead Costs

The cost of running a business that are not directly chargeable to the specific job i.e. facilities rental or lease, telephone, heat and lights, administrative jobs, sales, etc. The overhead costs are usually set by the company and don't need to be calculated for each job.

### Operating Factor

The total hours that you work on any given job is always greater than the actual amount of time you spend welding because of preparation time and follow-up time, so you need to in effect 'average out' the different types of work performed on any given job. This is called your operating factor. The operating factor is the ratio of the hours spent actually welding to the total hours worked on the job doing something other than actually welding.

---

<sup>1</sup> The Procedure Handbook of Arc Welding, Thirteenth Edition, The Lincoln Electric Company, Cleveland, Ohio, 1994 p. 12.1-4

## CALCULATING ARC TIME VERSUS PREPARATION TIME

Arc time and preparation time are often calculated at two different rates. Use this chart to help you determine how much time you are spending in doing different welding related activities.

For this lab you will need to keep track of all time you spend in performing your required weld projects.

After you have completed your projects and recorded all your time you will then compare the amount of time it takes you to prepare the project and finish the project to the actual arc time. Arc time is usually billed out at a higher rate so it is important to know where you are spending your time.

Activity	Time Spent
Plate preparation	
Cutting	
Fitting the plate together	
Tack welding	
Welding	
Grinding	
Fitting up the pipe	
Tack welding	
Welding	
Grinding	
Post Weld cleanup	

**Using the above record, determine the total amount of time you spent in:**

Preparing the parts for the weld: \_\_\_\_\_ minutes

Arc time: \_\_\_\_\_ minutes

Post weld clean up: \_\_\_\_\_ minutes

For the welding projects in this packet calculate the percentage of your time you spent in:

Preparation for welding: \_\_\_\_\_%

Arc time \_\_\_\_\_%

Post Weld Clean-up \_\_\_\_\_%

**Need more help? See the following worksheets: percentages**

## CALCULATING DIRECT LABOR COSTS

**Direct labor costs** are the hourly salary and benefits paid to an employee(s) multiplied by the number of hours it takes to complete a job usually including preparation for and follow-up to the job.

Direct labor costs = (Salary + benefits per hour) x number of hours to complete the job

Example: An employee must work for 3 hours to complete a welding job. He is paid \$11.00 per hour plus benefits calculated at 30% of his hourly salary. What are the direct labor costs for this job?

1. **Determine dollar amount of benefits per hour** by calculating 30% of the hourly rate.

Using the box method:

?	30
11.00	100

$$11 \times 30 \div 100 = \$3.33$$

Total benefits per hour are \$3.33

2. **Determine total salary and benefits per hour**

$$\text{Salary + Benefits per hour} = \$11.00 + \$3.33$$

$$\text{Salary + Benefits per hour} = \$13.33$$

3. **Determine total direct labor cost for this job**

Direct labor costs = (Salary + benefits per hour) x number of hours to complete the job

$$\text{Direct labor costs} = \$13.33 \times 3 \text{ hrs.}$$

$$\text{Direct labor costs} = \$39.99$$



## Practice Problems

Determine the total direct labor costs in the following situations:

1. Salary \$12.00 per hour, benefits 25% of hourly salary, 5 hour job
  
2. Salary \$12.50 per hour, benefits 35% of hourly salary, 8 hour job

## Other Ways of Looking at Labor Costs

When you weld you in fact do many tasks. These tasks can include:

Welding joint preparation

Assembly

Tack-up

Positioning

Welding

Changing electrodes, moving location, changing settings (downtime)

Post weld clean-up

Removal of assembly

Sometimes these tasks are performed by different people and sometimes they are performed by one person depending on the size of the business or job. Often different parts of the job are cost out at different rates. For example:

- Welder's helper \$8-\$10 per hour
- Welder \$10-\$14 per hour
- Welder fabricator \$14- \$20 per hour

## Practice Problem

Let's say that:

All time used in preparation for the weld is charged at \$10.00 per hour

All time spent actually welding will be charged at \$18 per hour

All time spent in post weld clean up and removal is charged at \$8.00 per hour.

Benefits are calculated at 30% for preparation and welding and 15% for cleanup

For this example let's say that in an eight-hour day:

4 hours are spent in preparation by the welder

3 hours are spent welding by the welder fabricator

1 hour is spent in post weld clean up by the welder's helper

**What are the total labor costs for this 8-hour day?** Remember you must include both salary and benefits when calculating total labor costs. Solve the following problem in order to figure out the total labor costs for the day.

4 hrs. x ( \$10.00 + 30%) + 3 hrs. x ( \$18 + 30%) + 1 x ( \$8 + 15% ) = total labor cost for 8 hour day.

Remember to follow the order of operation. Do the percentage problem and the addition inside the parenthesis first, the multiplication next and finally the addition outside the parenthesis.

## LABOR COST LAB

*Keep track of the hours you spend on fabricating in this packet*

Record the hours in the space provided:

ACTIVITY	RATE	HOURS SPENT
Welding joint preparation	\$9	
Assembly	\$9	
Tack-up	\$12	
Positioning	\$12	
Welding	\$15	
Changing electrodes, settings, etc. (downtime)	\$12	
Post weld clean up	\$9	
Removal of assembly	\$9	

The benefit rate is 25% of the hourly rate.

Calculate the total labor cost for completing all welding assignments in this packet.

**Need more help? See the following worksheets: calculating percentages, solving formulas, order of operations**

## Calculating Operating Factor

The total hours that you work on any given job is always greater than the actual amount of time you spend welding because of preparation time and follow-up time. Because of this you may need to in effect, 'average out' the different types of work performed on any given job. This is called your operating factor (OF). **The operating factor is the ratio of the hours spent actually welding to the total hours worked on the job including welding. The operating factor is often used in Welding Cost formulas.**

$$\text{OF} = \frac{\text{Arc Time}}{\text{Total Time}} \quad \text{or} \quad \frac{T_u}{T_u + T_d} \qquad \begin{array}{l} T_u = \text{Arc time} \\ T_d = \text{other time} \end{array}$$

This number is always less than one. The more time you spend in actual 'joining' the higher your number, or operating factor, will be.

### Example #1:

What is the operating factor when the arc time is 16 minutes and the total time spent is 1 hour?

Operating factor (OF) =  $\frac{16 \text{ min}}{60 \text{ min}}$ . **Note:** Hours were changed to minutes so that the units are the same

$$\text{OF} = 16 \div 60$$

$$\text{OF} = .267 \qquad .267 \text{ is the Operating Factor for this job}$$

**Note:** Often the Operating Factor is expressed as a percentage. In the above example .275 would be multiplied by 100 giving you an Operating Factor of 27.5%.

### Example #2:

Your Arc time for a specific job is 15 minutes. Your down time on the same job is 16 minutes. What is your operating factor expressed in percentage terms?

$$\frac{T_u}{T_u + T_d} \times 100 = \text{OF}$$

$$\frac{15}{15 + 16} \times 100 = \text{OF}$$

$$\frac{15}{31} \times 100 = \text{OF}$$

$$.484 \times 100 = \text{OF}$$

48.4% is the Operating Factor

**Practice Problem:** Your arc time is 25 minutes and down other time is 10 minutes. What is your operating factor expressed as a percentage?

**Need more help? See the following worksheets: solving formulas, order of operation, percentages**

## CALCULATING OVERHEAD COSTS

Usually a company will pre-determine their overhead costs. Often the overhead is given in a percentage of the total job. For example, overhead could be calculated at 40% of the total direct costs of a job. At other times the company will have calculated an hourly overhead charge.

If your overhead is 40% of your direct costs and your direct costs come to \$12 per hour what is your overhead per hour?

$$\frac{\text{?}}{\$12} = \frac{40\%}{100\%} \quad 12 \times 40 \div 100 = \$4.80 \text{ per hour}$$

Practice problems:

If your overhead is 30% and your direct costs are \$12.50 per hour, how much is your overhead per hour?

If your direct costs are \$16 per hour and your overhead is 15% of direct costs what is the amount of overhead per hour?

**Need more help? See the following worksheets: calculating percentages**

# DETERMINING THE COST OF STEEL

Steel plate is sold by weight per square foot.

In order to find the cost of the steel plate you might use on any given project, you need to know the following four things:

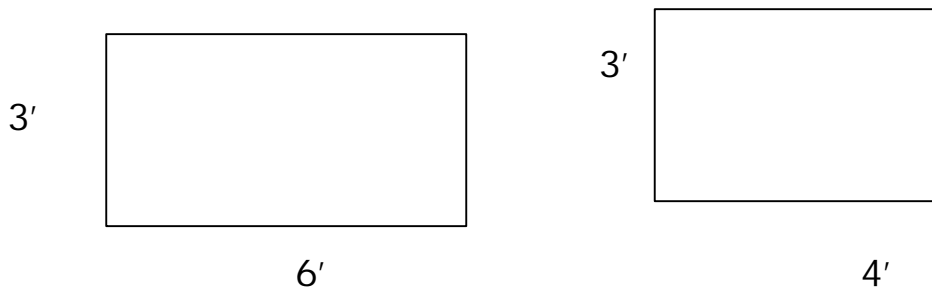
- The type of stock you are using ( plates, steel sheets, steel flats, etc.)
- The size of your plate (thickness, gauge, etc.)
- The number of square feet of plate used (determined by finding the area)
- The weight in pounds (lbs.) per square foot
- The cost per pound

Example:

How much will the steel plate cost for this upcoming project?

For this project you are required to use two pieces of rectangular plate. The first measures 4'x6' and the second 4'x3'. Both pieces are ¼" thick.

**Step 1:** Find the total area of the steel plate that you will use.



$$3' \times 6' = 18 \text{ ft}^2$$

$$3' \times 4' = 12 \text{ ft}^2$$

$$18 + 12 = 30 \text{ ft}^2$$

Total area of the two plates is 30 square feet

**Step 2:** Determine the weight per square foot.

In order to determine the weight of a specific type of steel you need to look in a handbook of specifications, sizes and weights for the steel industry. These handbooks are published by distributors of steel products.

You can find such a chart on page 12 of a handbook entitled The Steel Yard, published in Portland, Oregon.

The plate specified in our example was ¼"

Looking at the section of chart that says "PLATES" we see that ¼" plates weigh 10.21 pounds per square foot.

**Step 3:** Determine the total weight of steel needed for this project.

Multiply the total number of square feet used in this project by the weight per square foot.

$$30 \text{ ft}^2 \times 10.21 \text{ lbs/sq. ft.} = 306.3 \text{ lbs.}$$

**Step 4:** Determine the total cost

For this example the cost ¼' plate is \$.25 per pound.

Multiply the cost per pound times the total number of pounds.

$$.25 \times 306.3 \text{ lbs} = \$76.58$$

The total cost of then steel plate for this project is \$76.58

**Practice:**

Using the above chart that gives sizes and weights for various types of steel plates determine:

How many pounds per square foot is a  $3/8$ " floor plate?

\_\_\_\_\_

What is the weight per square foot of a plate that is  $1-3/4$ " ?

\_\_\_\_\_

What is the weight per linear foot of a UM plate that is  $5/8$  x  $16$ "? \_\_\_\_\_

If  $1-3/4$ ' plate costs \$.25 per pound and you need 23.25 pounds; what is the total cost of the plate? \_\_\_\_\_

**Need more help? See the following worksheets: Squaring numbers, order of operation, ratio and proportion, dimensional analysis**



## COST OF STEEL LAB

Determine the total cost of the steel used in the five projects in packet #114.

You will be using 3/8" mild steel which costs \$.25 per pound. In order to use the weight chart you will need to convert square inches to square feet.

See the math reference packet if you have forgotten how.

<b>Project</b>	<b># of Square Feet</b>	<b>Weight/Square Foot</b>	<b>Total Weight</b>	<b>Plate Cost/Project</b>
Project #1				
Project #2				
Project #3				
Project #4				
Project #5				
<b>Project Total</b>				

2. Now take a look at the drawing for the final project in packet WLD 114.

Determine the total number of square feet of mild steel that you will use for this project. Then determine the cost of the steel.

Note : In finding the surface area you will have basically 2 squares and a triangle. Remember to subtract out the area of the hole when computing the total area.

**Need more help? See the following worksheets: Squaring numbers, order of operation, ratio and proportion, dimensional analysis**

## CALCULATING WELDING CONSUMABLE COSTS FOR GAS TUNGSTEN ARC WELDING

Welding consumables are materials that are used up or consumed in the process of welding. They include electrodes, filler rod, flux, wire and shielding gases, etc. Consumable costs will be different for each different type of welding and for each individual job. The consumable costs, when added to labor, overhead and power costs will give you the total cost of a job.

In calculating consumable costs you need to look at the cost of:

- Electrodes
- Filler rods
- Shielding gas

### Electrodes and Filler Rods

There are two types of electrodes. Those that are consumable (i.e. stick electrodes) and those that you use with filler rods (i.e E70S-6). Non consumable electrodes still get used up because they eventually are damaged in the welding process. The less experience a welder has the more electrodes they will use.

Electrode consumption per foot of weld is preferably taken from floor experience. Remember only about 65% to 75% of the consumable electrode is actually deposited in the weld. (***This is called deposition efficiency.***) The rest is lost to coating, spatter and stub loss. Stub loss ranges from 2 inches up to 4 inches per length of filler metal in TIG welding. A typical stub loss length considered reasonable for stick electrode welding is 2 inches and 4 inches for TIG welding. When you are figuring out how many sticks you need you must remember that about 1/3 of the filler metal will not be used.

This holds true for filler rod. 25%-35% of a typical rod is lost to coating, spatter and stub loss.

The following rods are among the most common ones used in the PCC's welding shop.

The following specifications are for 1/8" diameter rod.

7018 13 pieces per pound. Deposit rate of 1.7 pounds per hour with an efficiency rate of 66.3%

7024 9 pieces per pound. Deposit rate of 4.2 pounds per hour with an efficiency rate of 71.8%

6010 17.3 pieces per pound. Deposit rate of 2.1 pounds per hour with an efficiency rate of 76.3%

6011 17.3 pieces per pound. Deposit rate of 1.3 pounds per hour with an efficiency rate of 70.7%

6013 17.1 pieces per pound. Deposit rate of 2.1 pounds per hour with an efficiency rate of 73%

**Determining the Amount of Consumable Electrode or Filler Rod You Will Use**

To figure out how many rods you would actually use in an hour, given the rate of deposition (the amount of material laid down in the weld) and the efficiency rate (the percentage of the rod that is laid down in the weld), we will again use the box method.

Look at the first example of 1/8" filler rod E7018. It states that the deposit rate is 1.7 lbs per hour and the efficiency rate is 66.3%.

Another way to say this is that we know that 1.7 lbs per hour is 66.3% of the filler rod that was used in an hour. You need to determine how many lbs of rod were actually used, or what equals 100%. (the amount laid down + the amount wasted)

	<b>#of lbs per hr.</b>	<b>%</b>
= (1.7 x 100) ÷ 66.3	1.7	66.3
= 2.56 lbs per hour	?	100

Let's try one more.

E6011 filler rod has a deposit rate of 1.3 lbs per hour and an efficiency rate of 70.7%.

What is the total amount of filler rod used in one hour?

= (1.3 x 100) ÷ 70.7  
= 1.84 lbs per hour

#of lbs per hr.	%
1.3	70.7
?	100

If the weld job required more than one hour, you would multiply the number of hours by the total amount used per hour.

Try one more on your own.

#7024 rod has a deposition rate of 4.2 lbs per hour and an efficiency rate of 71.8%. What is the total amount of filler rod used?

#of lbs per hr.	%
	100

\_\_\_\_\_ lbs per hour

**In order to calculate the cost of non-consumable electrodes you must know the following.**

- Type of electrode
- Electrode diameter
- Cost per stick
- How many sticks you will use for a given job

How many sticks you use in a given job of course depends on the size of the weld but also on the experience of the welder. A new student could easily go through a stick a day because of contamination and the need to re-sharpening the stick every time it sticks to the metal, whereas an experienced welder might make the same stick last for 40 hours.

**In order to calculate the cost of a consumable electrode you must know:**

- Type of consumable electrode or stick
- Number of sticks per lb
- Deposit rate in lbs per hour
- Efficiency rate
- Cost per lb

**In order to calculate the cost of filler rod you must know:**

- Type of filler rod
- Number of rods per lb
- Deposit rate in lbs per hour
- Efficiency rate
- Cost per lb

**In order to calculate the cost of shielding gas you need to know:**

- Type of gas
- Required flow rate in cubic feet per hour (cfh)
- Amount of time you will be spend welding on a given job
- Number of cubic feet per bottle
- Cost per bottle

### **Sample Calculation**

Let's figure out what the consumables will cost for a typical job that requires 24 hours of welding.

- Non-consumable electrode

- Electrode diameter ---3/32"
- Cost per stick-----\$2.
- How many electrodes you will use for a given job-----3 sticks (inexperienced welder)
- Type of filler rod you will use
- Filler rod diameter
- How many lbs of filler rod you will consume given deposition efficiency
- Cost per lb of filler rod
- Type of gas----- Argon
- Flow rate in cubic feet per hour (cfh) 30 cfh
- Number of cubic feet per bottle-----270cf per bottle
- Cost per bottle-----\$29

**Cost of electrode** = estimated number of electrodes you will use x cost of each electrode.

$$= 3 \text{ electrode} \times \$2.00 = \$6.00$$

**Cost of filler Rod** = estimated number of lbs of rod you will consume per hour x number of hours x cost per lb.

Say we use 1/8" rod E70S-6 with an average deposit rate of 1.7 lbs per hour and an efficiency rate of 66.3%.

The job requires 24 hours of welding

The filler rods cost \$2.50 per lb.

$$= (1.7 \times 100) \div 66.3$$

$$= 2.56 \text{ lbs per hour}$$

#of lbs per hr.	%
1.7	66.3
?	100

$$2.56 \times 24 \times \$2.50 = \text{cost of filler rod for this job}$$

$$= \$ 153.60$$

**Number of bottles of gas needed** = numbers of hours of welding **x** flow rate  $\div$  cubic feet per bottle.

$$= (24\text{hrs. } \times 30 \text{ cfh}) \div 270\text{cf}$$

$$= (720) \div 270$$

= 2.66 bottles (Note: you must round this number up to the next whole bottle because you cannot purchase partial bottles.)

$$= 3 \text{ bottles}$$

**Cost of shielding gas** = 3 bottles **x** \$29 per bottle

$$= \$87$$

**Total Cost of welding consumables for this job:**

Cost of electrode + cost of filler rods + cost of shielding gas = total cost

$$\$6.00 + \$153.60 + 87 = \$246.60$$



## CALCULATING THE COST OF ELECTRODES, FILLER RODS AND SHIELDING GAS IN WLD 225

This packet specifies that you will use:

- 1/8" 2% Thoriated Tungsten Electrodes -- \$4.73 per stick
- Argon shielding gas set at 20-25 cubic feet per hour (cfh)--\$29 per 270 cubic feet bottle
- Filler rods (filler metals) ER70S-6 and E7018

For the purposes of this lab we will calculate the cost of materials after you have completed the welding.

### Record the following:

Amount of time you spent actually welding: \_\_\_\_\_ hrs.

Number of electrodes you consumed in the welding process: \_\_\_\_\_ sticks

Number of filler rods you consumed in the welding process \_\_\_\_\_ rods

When you have completed the welding calculate the cost of the electrodes, filler rod and shielding gas that you have used.

Cost of electrodes \_\_\_\_\_

Cost of filler rods \_\_\_\_\_

Cost of shielding gas \_\_\_\_\_

**Need more help? See the following worksheets: solving formulas, order of operations**

# **LAB**

## **CALCULATING THE COST OF ELECTRODES AND STEEL USED IN WLD 115**

This packet specifies that you will use:

1/8" E6011 Electrodes at \$1.41 per lb.

E6011 electrodes have a flux coating so no shielding gas is used in the welding process.

3/8" Mild Steel

**For the purposes of this lab we will calculate the cost of materials after you have completed the welding.**

### **Instructions:**

After you have completed each individual project fill in the information in the charts provided. Be sure to keep track of the number of electrodes you consume and the steel that you used and any steel that became waste.

For additional instructions on calculating the cost of steel, see packet #114.

**Use the included chart to determine the weight of the steel plate.**

**The cost per lb of steel is \$.25**

**The cost per lb of electrode is \$1.41**

## COST OF MILD STEEL

Project	# of Square Feet in project	# of square feet of waste	Weight/Square Foot	Total Weight	Plate Cost/Project
Project #1					
Project #2					
Project #3					
Project #4					
Project #5					

## COST OF ELECTRODES FOR EACH PROJECT

Project	Type of electrode	Number of electrodes consumed	Cost per electrode*	Total cost of electrodes
Project #1				
Project #2				
Project #3				
Project #4				
Project #5				

\*get information on number of electrodes per lb from the tool room

### TOTAL COST OF CONSUMABLES

<b>Project</b>	<b>Cost of mild steel</b>	<b>Cost of electrodes</b>	<b>Other costs/waste</b>	<b>Total cost of project</b>
Project #1				
Project #2				
Project #3				
Project #4				
Project #5				

Note: determine weight of steel from steel plate chart located in supplier reference manual

# HEAT INPUT

Applications:

- Reduce damage to welded parts

## HEAT INPUT PROBLEMS

It is important to know your heat input into a plate when you are welding, as well as heat limitations for different metals. Some metals are more heat-sensitive than others, and damage caused by too much heat input might not be detectable for days.

The heat input (H) equation is

watts  
⏟

$$\text{HEAT INPUT} = \frac{\text{voltage (V)} \times \text{current (I)}}{\text{welding travel speed}}$$

or

$$\text{Heat Input} = \frac{V \times I}{S}$$

{Remember that a fraction is just a  
division problem: top  
divided by bottom}

where voltage is measured in volts (V), current in amperes or amps (I), and travel speed (S) in inches per second. It is often necessary to convert travel speed information given in inch/minute format to inches per second before using in the heat input equation. The heat input answer is usually given as a rate in joules/inch or kilojoules/inch. A joule is a metric unit of energy equivalent to one **watt** of power radiated for one second (think of 60 joules as the power involved in a 60-Watt light bulb on for one second - you can see why we might want to talk about kilojoules or how many **thousand** joules instead of just joules).

**Example:** Given a travel speed of 8 in/min, a voltage of **120 volts** and a current of **100 amps**, what is your heat input?

First, convert your speed from inches per minute to inches per second to conform to the equation: Remember, seconds are smaller units of time, so you can travel fewer inches in a second than in a minute. You will need to **divide** your inches per minute by 60:

$$8 \text{ in/min} = \frac{8 \text{ inches}}{1 \text{ min}} = \frac{8 \text{ inches}}{60 \text{ sec}} = \frac{8}{60} = 8 \div 60$$

or . . .

**.13333... in/sec . . . use this or 8/60 as your speed -- "S" in the heat input equation:**

$$\begin{aligned}
 H &= \frac{V \times I}{S} = \frac{120 \times 100}{\frac{8}{60}} && \text{or} && \frac{120 \times 100}{.1333333} \\
 & && \swarrow && \nwarrow \\
 &= \mathbf{90,000 \text{ J/in}} && = && \mathbf{90 \text{ kJ/in}} \\
 &\text{"ninety-thousand joules . . ."} && && \text{"ninety-thousand joules . . ."}
 \end{aligned}$$

*Note: the easiest way to do the above calculation is to:*

*multiply 120 by 100  
then divide by 8/60 (entered using the fraction key)  
and then push "="*

Usually, you measure your amperes, voltage and travel speed, and then you figure your heat input to tell you whether you are overheating the metal.

**Try these problems:**

1. What is the heat input in kJ/in for a travel speed of 6 inches per minute, a voltage of 35, and a current measuring 280 amps?  
**Remember to convert your answer in joules to kilojoules by dividing by 1000.**

**First, find your inches traveled per second: (Divide by 60)**

          
/60

$$\frac{\text{        volts} \times \text{        amps}}{\text{        inches per second}}$$

2. Calculate your heat input in kJ/in for a voltage of 120 V, a current of 100 amps, and a travel speed of 4 in/minute.
3. Calculate your heat input in kJ/in for a current of 300 A, a voltage of 30, and a travel speed of 3 in/min.
4. If your voltage is 30 V and your current is 250 A, what kind of travel speed would get you a heat input of 2.3 kJ/in?
5. What should your heat input be for a voltage of 40 V, a current of 310 amps, and a travel speed of 3.2 in/min? Remember to give it in kJ/in.



**Need more help? See the following worksheets: solving formulas, order of operations, dimensional analysis, multiplying and dividing fractions, using your calculator, ratio and proportion**

## HEAT INPUT LAB - WLD 132

In this exercise you will perform two welds in order to measure the heat input as expressed in Joules per inch.

Remember heat input is a fancy way of stating the amount of heat you're putting into a metal while welding. Knowing the heat input is important because heat may affect the manufacturing properties of the metal.

In this lab you will compare the heat input in Joules/ inch in the:

1. Pulse process
2. Spray process

In order to calculate heat input we need to know three different variables.

Current measured in Amps (I)

Voltage measured in volts (V)

Travel speed expressed in inches per minute (S)

In this lab you will be assigned different current and voltage settings, you will measure the travel speed and then calculate the heat input for the various processes.

The formula for heat input is:

$$\text{Heat Input} = \frac{V \times I \times 60}{S}$$

Note: the 60 in the formula allows you to express the speed in inches per minute rather than inches per second.

How to solve a heat input problem:

For detailed instructions on solving heat input problems see welding packet #253 or the math reference packet; for a refresher see the example below.

Example: I have two welds that are the same size. I need to know which settings generate the least heat input.

The first weld was made with settings of 175 Amps, 25 volts. The travel speed was 3 inches per minute.

The second weld was performed at 310 amps, 35 volts and 8 inches per minute

Which weld required less heat input?

Solution: 
$$\frac{175 \text{ amps} \times 25 \text{ volts} \times 60 \text{ seconds/minute}}{3 \text{ inches/minute}} = 87,000 \text{ joules/in.}$$

$$\frac{310 \text{ amps} \times 35 \text{ volts} \times 60 \text{ seconds/minute}}{8 \text{ inches/minute}} = 81,395 \text{ joules/in.}$$

The second weld process generated less heat as measured in joules/inch.

Please complete the following lab in order to compare heat input in two different welding processes. Note: your weld lengths must be the same.

Record your settings and times in the table below, then calculate the heat input.

### **Spray Process**

Spray process for a \_\_\_\_\_ inch weld.

My current setting is \_\_\_\_\_ Amps (I)

My voltage setting is \_\_\_\_\_ Volts (V)

It took me \_\_\_\_\_ minutes to complete my weld.

The heat input for this weld is \_\_\_\_\_ Joules/inch\_

### **Pulse Process**

Pulse process for a \_\_\_\_\_ inch weld.

My current setting is \_\_\_\_\_ Amps (I)

My voltage setting is \_\_\_\_\_ Volts (V)

It took me \_\_\_\_\_ minutes to complete my weld.

The heat input for this weld is \_\_\_\_\_ Joules/inch

Which process generated less heat?

**Need more help? See the following worksheets: solving formulas, order of operations, dimensional analysis, multiplying and dividing fractions, using your calculator, ratio and proportion**