WLD 204
Non Destructive Testing I
Math Review

NSF-ATE Project
Advanced Materials Joining for Tomorrow's Manufacturing Workforce

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READING NUMBERS

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.

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 one and seventy-eight hundredths.
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

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

The numbers being added are Addends.

The result is the Sum.

43.89 Addend
17.98 Addend
61.87 Sum

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

SUBTRACTION

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.

890 Minuend
- 78 Subtrahend

812 Difference
or Remainder

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

CREDIT OR NEGATIVE BALANCE

When subtracting a larger number from a smaller number, invert and subtract. The result is called a Credit or Negative Balance.

$1.25	$2.50	
- 2.50	- 1.25	
	$1.25	Credit Balance

MULTIPLICATION

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 interchangeable, the product is always the same.

1245 Multiplicand
x 19 Multiplier
23655 Product

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

MULTIPLICATION WITH DECIMALS

When multiplying with decimals, the product is pointed off from right to left as many decimal places as there are in the multiplicand and multiplier.

78.896 Multiplicand has 3 decimal places
x1.3 Multiplier has 1 decimal place
102.5648 Product has 4 decimal places

To multiply a decimal by any multiple of ten, move the decimal point as many places to the right as there are zeros in the multiplier.

.65 x 10 = 6.5
.789 x 100 = 78.9
.45 x 1000 = 450

DIVISION

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.

Quotient------ 13 3/4--- Remainder
Divisor---- 4/55--Dividend

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

55/4 $\frac{55}{4}$ 4 /55

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	13	Quotient
	x4	Divisor
	52	
	+ 3	Remainder
	55	Dividend figure

DIVISION OF DECIMALS

To divide a decimal by a whole number, place the decimal point in the quotient directly above the decimal point in the dividend and proceed as with whole numbers.

8 / 14.24 = 1.78

To divide a decimal by a decimal, move the decimal point in the divisor to the right until it becomes a whole number. Then move the decimal point in the dividend the same number of places to the right. (Add zeros if necessary.) Then place the decimal point in the quotient directly above the decimal point in the dividend.

5.6 / 19.488 = 3.48

To divide a smaller dividend by a larger divisor or to extend a quotient to a given number of decimal places, add enough zeros to the right of the dividend until the dividend contains the desired number of decimal places.

8 /2.0 = .25

12 / 145.000 = 12.083
Answer rounded to nearest hundredth (12.08)

As a rule, carry out the division problem one more decimal place than is needed, before rounding off. If the last figure is 5 or more, drop it and add 1 to the figure in the pre-ceding place. If the last figure is less than 5, just drop it entirely, (as above).

To divide a decimal or a whole number by 10 or by a multiple of 10, move the decimal point as many places to the left as there are zeros in the divisor.

89 / 10 = 8.9

165 / 100 = 1.65

67 / 1000 = .067

FRACTIONS

A fraction is a number that is less than a whole number (1/2).

The number below the line is the Denominator and indicates the complete number of equal parts into which the whole quantity has now been subdivided.

The number above the line is the Numerator and indicates how many of these equal parts are being considered.

$$\frac{\text{Numerator}}{\text{Denominator}}$$

The line dividing the two numbers means "divided by."

Common fractions may appear in various forms such as proper or improper, simple or complex.

Proper fractions, like 1/2, 1/4, 2/3 are called Proper fractions because their value is less than one.

Improper fractions, like 3/2, 8/3, 17/3 consist of a numerator larger than the denominator and are generally reduced to mixed numbers, e.g. 3/2 = 1 1/2

Simple fractions, like those above consist of whole numbers in the numerator and denominator.

Complex fractions have mixed numbers in the numerator and/or denominator, e.g.,

$$\frac{3\ 5/8}{1\ 3/4} \qquad \frac{13}{13/16}$$

DECIMALS

Decimals are another way of expressing Parts of a whole. Any proper fraction can be converted to its Decimal Equivalent by dividing the numerator by the denominator and then writing the quotient in decimal form.

.6667 Decimal Equivalent of 2/3
2/3 = 3 /2.0000

READING DECIMALS

First decimal place	Tenths	.7	7/10
Second decimal place	Hundredths	.07	7/100
Third decimal place	Thousandths	.007	7/1000
Fourth decimal place	Ten Thousandths	.0007	7/10000
Fifth decimal place	Hundred Thousandths	.00007	7/100000

Read the number to the right of the decimal Point as a whole number and give it the name of the last decimal place.

.489 is read as four hundred eighty-nine thousandths.

PERCENTAGE

Percentage and percents are used to show the relationship between two numbers in terms which provide more meaningful information. Percentage is a quantity and refers to a part of a whole quantity expressed in relation to 100. (The whole quantity is considered 100%.)

Percent or % is a rate and refers to a fractional or decimal part of one hundred. For example, 50 % means 50 parts of 100 or 50/100 or .50. (Notice that 50/100 can be reduced to 1/2.)

In working with a problem the % is changed to a decimal. To change a Percent to a decimal, remove the Percent sign and move the decimal point two places to the left.

80% = .80
1.1% = .011
35% = .35

To change a decimal to a percent, move the decimal point two places to the right and add a percent sign.

.75 = 75 %
1.1 = 110%
.685 = 68.5%

RECIPROCALS

The Reciprocal of a number is the quotient obtained by dividing 1 by that number. The reciprocal of 3 is1/3 or .3333. The reciprocal of 25 is 1/25 or .04.

Reciprocals are used to simplify some arithmetic problems by substituting multiplication for division. For example, 64 /4 = 16. Using the reciprocal method this problem becomes 64 x 1/4 or .25 (Reciprocal of Divisor) = 16.

Reciprocal Method: Dividend x Reciprocal of Divisor = Quotient

COMPLEMENTS

The Complement of a number is the difference between that number and the next higher power of 10. For example, the complement of 8 is 2 (10 - 8). The complement of 35 is 65 (100 -35). The complement of 400 is 600 (1000 - 400).

Complements are used to simplify some arithmetic problems by eliminating one or more steps.

A Complementary Percentage is the difference between a percent and 100 %. For example, the complementary percentage of 25% is 75%.

PERCENTAGE

BASE - The number on which the percent is to be calculated.

RATE - The number of hundredths taken (Rate is always a %).

PERCENTAGE - The number obtained by multiplying the Base by the Rate.

THREE TYPES OF PERCENTAGE PROBLEMS

(1) To find a certain percent of a number, multiply the number by the percent expressed decimally.

Example: Find 15% of 250. Percentage = Rate X Base .15 X 250 = 37.5

PRACTICE PROBLEMS

1. What is 25%of 5.00?

2. What is 40% of $4.50?

3. What is 20% of 9.00?

4. What is 38% of 117.75?

5. Whatis2% of 1.95?

(2) To find what percent one number is of another, the amount to which the comparison is made is used as the divisor.... (the number preceded by the word "of" is always the divisor).

Example: 375 is what % of 1500? Rate = $\frac{\text{Percentage}}{\text{Base}}$

375 / 1500 = .25 or 25%

PRACTIC E PROBLEMS

1. 50 is what % of 800?

2. 8.00 is what % of 25.00?

3. 96.49 is what % of 748.56?

4. 255.00 is what % of 1085.00?

5. 35 is what % of 9.25?

Math for Welding

A) Arithmetic

1) Manipulate fractions:

Simplify, add, subtract, multiply, divide, and convert from proper fractions to improper fractions and vice versa:

Simplify:
Fractions can be simplified by dividing out the common fractions:

$$\frac{5}{15}=\frac{5}{5\times 3}=\frac{1}{3},\qquad \frac{6}{8}=\frac{3\times 2}{4\times 2}=\frac{3}{4},\qquad \frac{12}{28}=\frac{3\times 4}{7\times 4}=\frac{3}{7},$$

Add and subtract:
To add or subtract find a common denominator, multiply numerator and denominator by a number to make the denominators equal to this common denominator:

$\frac{3}{4}+\frac{7}{8}$ least common denominator is 8, multiply numerator and denominator of $\frac{3}{4}$ by 2

$$\frac{3}{4}+\frac{7}{8}=\frac{6}{8}+\frac{7}{8}=\frac{6+7}{8}=\frac{13}{8}$$

$\frac{7}{8}-\frac{3}{4}$ least common denominator is 8, multiply numerator and denominator of $\frac{3}{4}$ by 2

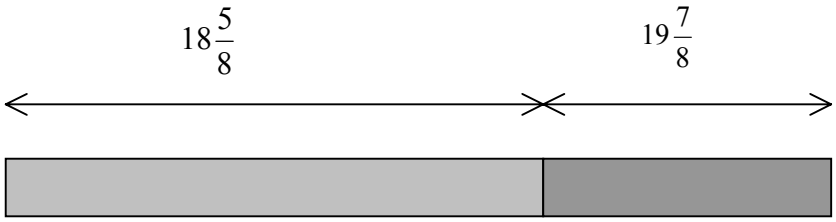
$$\frac{7}{8}-\frac{3}{4}=\frac{7}{8}-\frac{6}{8}=\frac{7-6}{8}=\frac{1}{8}$$

$\frac{7}{6}-\frac{3}{4}$ least common denominator is 12, multiply numerator and denominator of $\frac{7}{6}$ by 2,

and the numerator and the denominator of $\frac{3}{4}$ by 3

$$\frac{7}{6}-\frac{3}{4}=\frac{14}{12}-\frac{9}{12}=\frac{14-9}{12}=\frac{5}{12}$$

Two pieces of steel one $18\frac{5}{8}$ inches long, the other $19\frac{7}{8}$ inches long are to be welded together. Find total length.



Solution:
A number with a whole number and a fraction is called a mixed number. To add or subtract mixed numbers, add or subtract the whole numbers, and add or subtract the fractions:

$$18\frac{5}{8}+9\frac{7}{8}=27\frac{12}{8}$$
$$=28+1\frac{4}{8}$$
$$=29\frac{1}{2}$$

Proper and improper fractions:
An improper fractions is a fractions whose numerator is bigger that its denominator, like $\frac{12}{8}$ or $\frac{29}{4}$. To turn a improper fraction into a proper one divide the denominator into the numerator, the whole number from the division is written in front, the remainder is the numerator, and the denominator stays as is:

$\frac{12}{8}=1\frac{4}{8}$ (8 goes into 12 one times, remainder is 4)

$\frac{29}{4}=7\frac{1}{4}$ (4 goes into 29 seven times, remainder is 1)

To turn a mixed number into an improper fraction multiply the whole number by the denominator and add the result to the numerator. This will be the numerator of the improper fraction. The denominator stays as is:

$$7\frac{1}{4}=\frac{7\times4+1}{4}=\frac{29}{4}$$
$$9\frac{7}{8}=\frac{9\times8+7}{8}=\frac{79}{8}$$

Multiply and divide fractions:
To multiply fractions multiply the numerators and multiply the denominators:

$$\frac{7}{8}\times\frac{3}{5}=\frac{21}{40}$$

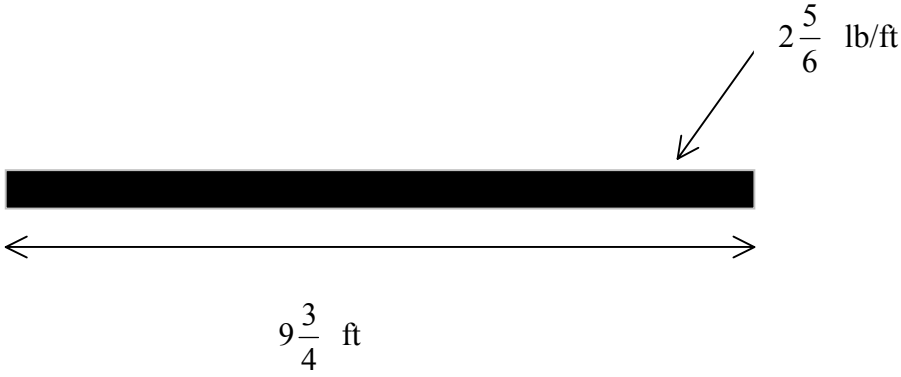
To divide fractions invert the denominator and multiply:

$$\frac{\frac{7}{8}}{\frac{3}{5}}=\frac{7}{8}\times\frac{5}{3}=\frac{35}{24}$$

To multiply a whole number by a fraction, multiply the whole number by the numerator:

$$4\times\frac{9}{13}=\frac{36}{13}$$
$$=2\frac{10}{13}$$

A $9\frac{3}{4}$ ft long pieces of quarter inch steel weighs $2\frac{5}{6}$ lb/ft. Find total weight.



Solution:
To multiply mixed numbers first turn them into improper fractions then multiply:

$$9\frac{3}{4}\ \text{ft} = \frac{39}{4}\ \text{ft}$$

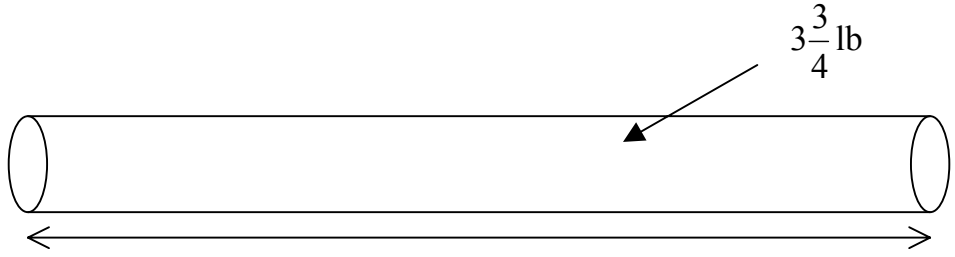
$$2\frac{5}{6}\ \text{ft/lb} = \frac{17}{6}\ \text{lb/ft}$$

$$\text{Total weight} = \frac{39}{4}\ \text{ft} \times \frac{17}{6}\ \text{lb/ft}$$

$$= \frac{663}{24}\ \text{lb}$$

$$= 27\frac{15}{24}\ \text{lb}$$

A steal rod weighs $3\frac{3}{4}$ pounds, and is $4\frac{5}{8}$ feet long. Find the weight per foot.



$4\frac{5}{8}$ ft

Solution:

Weight per foot is weight divided by length.
To divide mixed numbers turn them into improper fractions, then divide:

$$\frac{3\frac{3}{4}\ \text{lb}}{4\frac{5}{8}\ \text{ft}} = \frac{\frac{15}{4}}{\frac{37}{8}} = \frac{15}{4} \times \frac{8}{37} = \frac{15}{1} \times \frac{2}{37} = \frac{30}{37}\ \frac{\text{lb}}{\text{ft}}$$

Other solved exercises:

Simplify the fractions:

$$\frac{4}{32}=\frac{1}{8}, \qquad \frac{4}{1}=4$$

Add or subtract fractions and mixed numbers:

$$\frac{5}{8}+\frac{2}{3}=\frac{31}{24}, \qquad 6\frac{1}{2}+5\frac{3}{4}=11\frac{5}{4}, \qquad 6\frac{1}{2}-5\frac{3}{4}=\frac{3}{4}$$

Turn an improper fraction to a mixed number, and a mixed number to an improper fraction:

$$\frac{31}{24}=1\frac{7}{24}, \qquad 2\frac{3}{4}=\frac{11}{4}$$

Multiply or divide whole numbers and fractions and mixed numbers:

$$2\times\frac{3}{5}=\frac{6}{5}, \qquad \frac{\frac{2}{3}}{\frac{5}{4}}=\frac{2}{3}\times\frac{4}{5}=\frac{8}{15}, \qquad \frac{2}{3}\times\frac{5}{4}=\frac{5}{6}$$

$$6\frac{7}{8}\times 2\frac{3}{5}=\frac{55}{8}\times\frac{13}{5}=\frac{715}{40}=17\frac{35}{40}$$

$$\frac{9\frac{3}{8}}{3\frac{5}{6}}=\frac{\frac{75}{8}}{\frac{23}{6}}=\frac{75}{8}\times\frac{6}{23}=\frac{75}{4}\times\frac{3}{23}=\frac{225}{92}=2\frac{41}{92}$$

Exercises:

1)Two pieces of steel one $12\frac{7}{8}$ inches long, the other $7\frac{3}{4}$ inches long are to be welded together. Find the total length.

2)A $13\frac{7}{8}$ ft long pieces of quarter inch steel weighs $3\frac{4}{7}$ lb/ft Find total weight.

3)A steal rod weighs $7\frac{5}{8}$ pounds, and is $14\frac{3}{4}$ feet long. Find the weight per foot.

4)Simplify the following fractions:

$\frac{7}{21}$, $\frac{4}{12}$, $\frac{9}{36}$, $\frac{15}{55}$, $\frac{12}{68}$

5)Add or subtract fractions and mixed numbers:

$\frac{7}{16}+\frac{4}{8}$, $8\frac{3}{4}+12\frac{5}{6}$, $8\frac{3}{4}-5\frac{1}{2}$

6)Turn improper fractions to mixed numbers:

$\frac{41}{18}, \quad \frac{25}{16}, \quad \frac{44}{7}, \quad \frac{24}{16},$

7)Turn mixed numbers to improper fractions:

$3\frac{7}{8}, \quad 9\frac{3}{4}, \quad 16\frac{5}{4}, \quad 2\frac{3}{8},$

8)Multiply or divide the following:

$3\times\frac{4}{7}, \quad \frac{\frac{3}{4}}{\frac{7}{8}}, \quad \frac{7}{8}\times\frac{5}{4}$

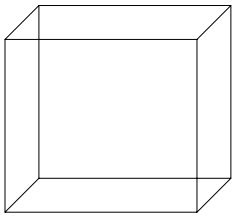
$2\frac{3}{4}\times 7\frac{7}{8}, \quad 4\frac{3}{4}\times 5\frac{2}{7}, \quad 7\frac{3}{8}\times 4\frac{1}{8},$

$\frac{4\frac{3}{4}}{5\frac{2}{7}}, \quad \frac{7\frac{3}{8}}{4\frac{1}{8}}$

2) Powers

Find area of square , and volume of cube:

side = a



side = a

Area of square : $A = a^2$

Volume of cube : $V = a^3$

Solved exercises:

Find the area of a square with sides equal to 3 in.
Area of square is the square of one side:

$A = 3^2$

$= 9 \ \text{in}^2$

Find the volume of a cube with sides equal to 4 in.
Volume of cube is the cube of one side:

$$V = 4^3$$
$$= 64 \text{ in}^3$$

Find the area of a square with sides equal to $5\frac{3}{4}$ inches:

Solutions:
Turn the mixed number into an improper fraction first, then square. To square fractions square the numerator and square the denominator. Turn the answer into a proper fraction.

$$A = (5\frac{3}{4})^2$$
$$= (\frac{23}{4})^2 \qquad \text{Convert mixed number to improper fraction.}$$
$$= (\frac{529}{16}) \qquad \text{Square numerator and denominator.}$$
$$= 33\frac{1}{16} \text{ square inches} \qquad \text{Convert back to mixed number.}$$

Find the area of a square with sides equal to 5.6 feet and the volume of a cube with sides equal to 7.8 inches:

Solution:

$$A = 5.6^2 = 31.36 \qquad \text{square feet } (\text{ft}^2)$$
$$\text{V} = 7.8^3 = 474.552 \qquad \text{cubic inches } (\text{in}^3)$$

Exercises:

1) Find the area of a square sheet metal with sides equal to 6 inches.

2) Find the area of a square sheet metal with sides equal to $6\frac{3}{4}$ inches.

3) Find the area of a square sheet metal with sides equal to 6.75 inches.

4) Find the volume of a cube with sides equal to 6 inches.

5) Find the volume of a cube with sides equal to 6.75 inches.

B) Algebra:

1) Manipulate equations with whole numbers and fractions:

The equation : $C = \frac{5}{9}(F - 32)$ converts degrees Fahrenheit to degrees Centigrade.

The equation : $F = \frac{9}{5}C + 32$ converts degrees Centigrade to degrees Fahrenheit .

Solved Exercises:
Given the temperature 350 in degrees Fahrenheit (^{o}F), use the conversion equation to find the temperature in degrees Centigrade (Celsius) (^{o}C) :

$C = \frac{5}{9}(F - 32)$ Fahrenheit to Centigrade conversion equation

$C = \frac{5}{9}(350 - 32)$ plug in 350 for F

$C = \frac{5}{9}(318)$ simplify inside the paretheses

$C = 176.67 \ ^{\circ}\text{C}$ multiply 318 by 5

Given the temperature 750 in degrees Centigrade (Celsius) (^{o}C), use the conversion equation to find the temperature in degrees Fahrenheit (^{o}F):

$F = \frac{9}{5}C + 32$ Centigrade to Fahrenheit conversion equation

$F = \frac{9}{5}(750) + 32$ plug in 750 for C

$F = 1710 + 32$ multiply before adding

$F = 1742 \ ^{\circ}\text{F}$ add

Exercises:
1) Given the temperature 575 in degrees Fahrenheit (^{o}F), use the conversion equation to find the temperature in degrees Centigrade (Celsius) (^{o}C)

2) Given the temperature 280 in degrees Centigrade (Celsius) (^{o}C), use the conversion equation to find the temperature in degrees Fahrenheit (^{o}F)

2) Create tables of values for linear algebraic equations:
Solved exercises:
Make a table of values for Celsius (Centigrade) to Fahrenheit conversion equation

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

when C varies from 20^{o} to 40^{o} in 10^{o} intervals.

Solution:
plug in 20, 30, and 40 in the above equation for C and calculate F:

$$F = \frac{9}{5}(20) + 32 \qquad F = \frac{9}{5}(30) + 32 \qquad F = \frac{9}{5}(40) + 32$$
$$= 36 + 32 \qquad = 54 + 32 \qquad = 72 + 32$$
$$= 68 \qquad = 86 \qquad = 104$$

C	F
20	68
30	86
40	104

Make a table of values for Fahrenheit to Centigrade conversion equation for F ranging from 500 to 700 ^{o}F in 50 degree steps:

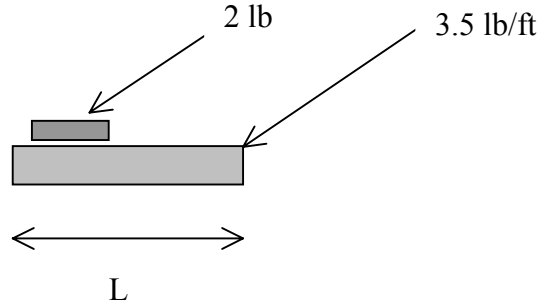
$$C = \frac{5}{9}(F - 32)$$

Solution:
Plug in 500, 550, 600, 650, and 700 in the above equation for F and calculate C:

$$C = \frac{5}{9}(500 - 32) \qquad C = \frac{5}{9}(550 - 32) \qquad C = \frac{5}{9}(600 - 32) \qquad C = \frac{5}{9}(650 - 32)$$
$$= \frac{5}{9}(468) \qquad = \frac{5}{9}(518) \qquad = \frac{5}{9}(568) \qquad = \frac{5}{9}(618)$$
$$= 268 \qquad = 287.8 \qquad = 315.6 \qquad = 343.3$$

F	C
500	260
550	287.8
600	315.6
650	343.3
700	371.1

Find the equation for total weight and make a table for weight vs. L for L varying from 2 feet to 4 feet in increments of 1 foot:



Solution:
The equation for total weight is 3.5 times length plus 2 pounds (3.5L + 2):

W = 3.5L + 2 lb.

Make a table of W vs. L :

$W = 3.5(2) + 2$ $W = 3.5(3) + 2$ $W = 3.5(4) + 2$

$= 7 + 2$ $= 10.5 + 2$ $= 14 + 2$

$= 9$ $= 11.5$ $= 16$

L (ft)	W (lb.)
2	9
3	12.5
4	16

Exercises:
1) Make a table of values for

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

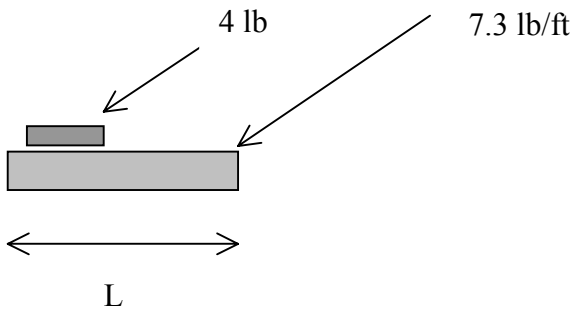
when C varies from 75° to 100° in 5° intervals.

2) Make a table of values for

$$C = \frac{5}{9}(F - 32)$$

for F ranging from 100 to 200 °F in 25 degree steps

3) Find equation for total weight and make a table for weight vs. L for L varying from 2 feet to 4 feet in increments of 1 foot:



3) Electric Power:

Given voltage (V) in volts, current(I) in amperes or amps, and resistance (R) in ohms, power (P) in watts is:

$P = I^2 R$ or $P = IV$

Solved Exercises:

Find power if current is 5 amps, and resistance is 12 ohms.
Solution:

$P = I^2 R$ write the equation

$P = 5^2 \times 12$ plug in the values for I and R

$= 25 \times 12$ square 5 first before multiplying

$= 300$ watts

Find current if power is 12 kw (12 kilowatts or 12,000 watts) and voltage is 120 volts.
Solution:

$P = IV$ write the equation

$12000 = I \times 120$ plug in the values for P and V

$\frac{12000}{120} = I$ divide both sides by 120 to solve for I

$I = 100$ amps

Find current if power is 8 kw and resistance is 120 ohms.
Solution:

$P = I^2 R$ write the equation for power

$8000 = I^2 \times 120$ plug in values for P and R

$\frac{8000}{120} = I^2$ divide both sides by 120 solve for I^2

$I^2 = 66.67$

$I = \sqrt{66.67}$ take the square root of both sides to solve for I

$I = 8.16$ amps

Exercises:
1)Find power if current is set at 10 amps, and resistance of welding rod is 14 ohms.

2)What should the current be set to if welding power is specified to be 15 kw (15 kilowatts or 15,000 watts) and voltage is 120 volts?

3)What should the current be set to if power is specified to be 8 kw and welding rod resistance is 80 ohms?

4) Heat input

Given Current (I) in amperes or amps (A), voltage (V) in volts (V), and welding travel speed (S) in inches per seconds (in/s), heat input H in Joules per inch (J/in) is given by:

$$H = \frac{I \cdot V}{S}$$

Solved exercises:

Calculate the heat input in kJ/in and convert to metric (kJ/mm) when automatic GMAW is being performed using the following settings:

Current (I) = 300 A
Voltage (V) = 30 V
Travel Speed (S) = 8 in / min

Solution:
Convert speed to inches per second (in/s):

$$\begin{aligned}\text{Speed} &= 8\frac{\text{in}}{\text{min}} \cdot \frac{1}{60}\frac{\text{min}}{\text{sec}} \\ &= \frac{8}{60}\frac{\text{in}}{\text{s}} \\ &= \frac{2}{15}\frac{\text{in}}{\text{s}}\end{aligned}$$

Plug values into the heat input equation:

$$\begin{aligned}\text{Heat input} &= \frac{\text{I} \cdot \text{V}}{\text{S}} \\ &= \frac{300\text{A} \cdot 30\text{V}}{\frac{2}{15}\frac{\text{in}}{\text{sec}}} \\ &= \frac{300\text{A} \cdot 30\text{V} \cdot 15\text{s}}{2\,\text{in}} \\ &= 67500\,\text{J/in} \\ &= 67.5\,\text{kJ/in}\end{aligned}$$

Convert to metric units:

$$\begin{aligned}\text{Heat input} &= 67.5\frac{\text{kJ}}{\text{in}} \cdot \frac{1}{25.4}\frac{\text{in}}{\text{mm}} \\ &= 2.7\frac{\text{kJ}}{\text{mm}}\end{aligned}$$

Exercises:
1)Calculate the heat input in kJ/in and convert to metric (kJ/mm) when automatic GMAW is being performed using the following settings:

Current (I) = 250 A
Voltage (V) = 35 V
Travel Speed (S) = 12 in / min

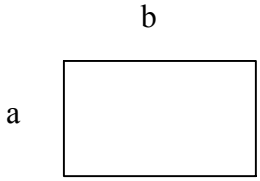
2)Calculate the heat input in kJ/in and convert to metric (kJ/mm) when automatic GMAW is being performed using the following settings:

Current (I) = 280 A
Voltage (V) = 25 V
Travel Speed (S) = 6 in / min

C) Geometry

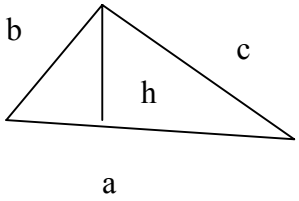
1) Two dimensional forms:

Rectangle:



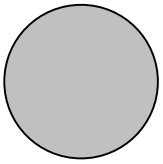
Area = $a \times b$,
Circumference = 2a + 2b

Triangle:



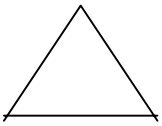
Area = $(1/2)a \times h$,
Circumference = a + b + c

Circle:

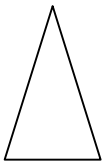


Radius = r, Diameter = D =2 r
Area = πr^2,
Circumference = $2\pi r = \pi D$

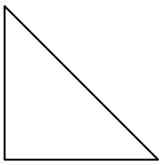
Equilateral, isosceles, and right triangles.



Equilateral
All sides are equal



Isosceles
Two sides are equal



Right triangle
One angle is 90 degrees

Solved Exercises:

Find circumference of a triangle with sides equal to 3, 7.5, and 10 inches.
Solution:

$$C = a + b + c$$
$$C = 3 + 7.5 + 10 = 20.5 \text{ in.}$$

Find the area of a triangle with base equal to 2 ft and height equal to 3.5 ft.
Solution:

$$A = (\frac{1}{2})(2)(3.5)$$
$$A = 3.5 \text{ sq. ft. } (\text{ft}^2)$$

Find the area of a circle with radius equal to 1.5 ft:

Solution:

$A = \pi \cdot r^2$

$A = \pi \cdot (1.5)^2$

$A = 3.14 \times 2.25$

$A = 7.07 \text{ sq. ft. } (\text{ft}^2)$

Find the circumference of a circle with radius equal to 1.5 ft.:

$C = 2\pi \cdot r$

$C = 2 \times \pi \times 1.5$

$C = 2 \times 3.14 \times 1.5$

$C = 9.42 \text{ ft.}$

Find the radius of a circle with area equal to 12 ft^2

Solution:

$A = \pi \cdot r^2$	equation of the area of a circle
$12 = \pi \cdot r^2$	plug in 12 ft^2 for area A
$\frac{12}{\pi} = r^2$	to solve for r divide both sides by π
$r^2 = 3.82$	use calculator to find $\frac{12}{\pi}$
$r = \sqrt{3.82}$	take the square root of both sides to find r
$r = 1.95 \text{ ft}$	use calculator to find square root of 3.82

Exercises:

1) Find circumference of a triangle with sides equal to 4.8, 7.9, and 12.6 cm.

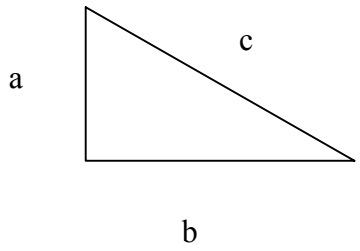
2) Find the area of a triangle with base equal to 3.4 ft and height equal to 1.7 ft.

3) Find the area of a circle with radius equal to 2.3 ft.

4) Find the circumference of a circle with radius equal to 2.2 ft

5) Find the radius of a circle with area equal to 18 ft^2

2) Pythagorean Theorem:



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

"c" is called hypotenuse, "a" and "b" are called legs or sides.

Solved exercises:

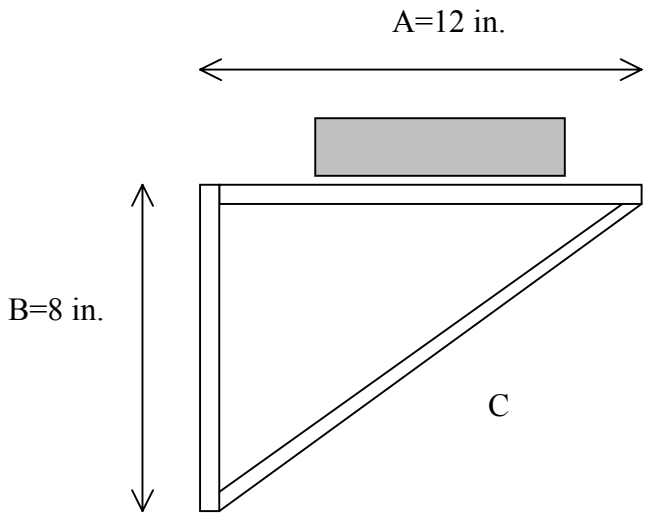
Given a = 4.5 in. and b = 6.7 in., calculate c .
Solution:

$c^2 = a^2 + b^2$	Pythagorean equation
$c^2 = 4.5^2 + 6.7^2$	plug in numbers for a and b
$= 20.25 + 44.89$	square numbers
$= 67.14$	
$c = \sqrt{67.14}$	take the square root of both sides to solve for c
$= 8.19$ in.	

If the hypotenuse of a right triangle is 8 ft, and one leg is 5 feet, find the other leg.
Solution:

$c^2 = a^2 + b^2$	Pythagorean equation
$8^2 = 5^2 + b^2$	plug in numbers for c and a
$65 = 25 + b^2$	square 8 and 5
$65 - 25 = b^2$	subtract 25 from both sides to solve for b
$40 = b^2$	
$b = \sqrt{40}$	take the square root of both sides
$b = 6.32$ ft.	use calculator to find $\sqrt{40}$

A steel bar (C) is to be welded to the shelf shown to strengthen it. Find the length of this bar .



Solution:

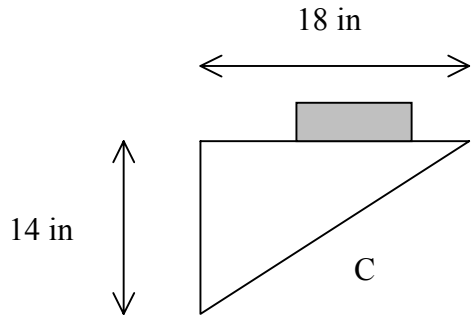
$C^2 = A^2 + B^2$	Pythagorean equation
$C^2 = 12^2 + 8^2$	plug in numbers for sides A and B
$C^2 = 144 + 64$	square 12 and 8
$C^2 = 208$	add
$C = \sqrt{208}$	take the square root of both sides to solve for C
$C = 14.4$ in.	use calculator to find $\sqrt{208}$

Exercises:

1) Given the two sides of a right triangle equal to 5.6 in. and 8.2 in., calculate the hypotenuse.

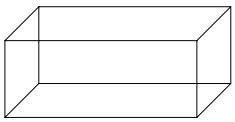
2) If the hypotenuse of a right triangle is 10 ft, and one leg is 7 feet, find the other leg.

3) Find the length of the steel bar (C) to be welded to the shelf shown.

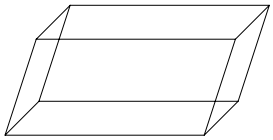


3) Three dimensional forms:

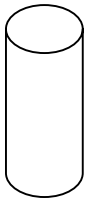
Volume of three-dimensional forms:



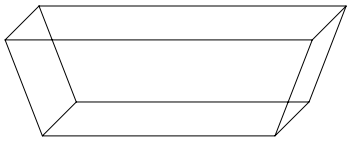
Solid Rectangle



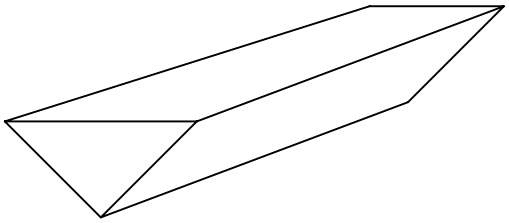
Solid parallelogram



Cylinder



Solid Trapezoid



Solid triangle

Volume of solid rectangle = length $\times$ width $\times$ height

Volume of solid rectangle = area of base $\times$ height

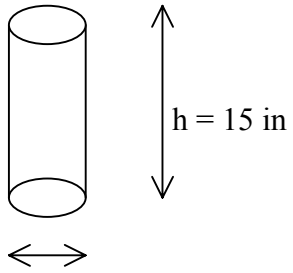
Volume of solid triangle = area of cross section $\times$ length

Volume of cylinder = $\pi \times r^2 \times$ height

Volume of cylinder = area of base $\times$ height

Solved exercises:

Find volume of the cylinder shown:



Solution:

$r = D/2$ radius is 1/2 of diameter

$= 1.5$

$V =$ Area of base $\times$ height

$= (\pi \cdot r^2) \times h$ equation of volume of cylinder

$= (3.14 \times 1.5^2) \times 15$ plug in numbers

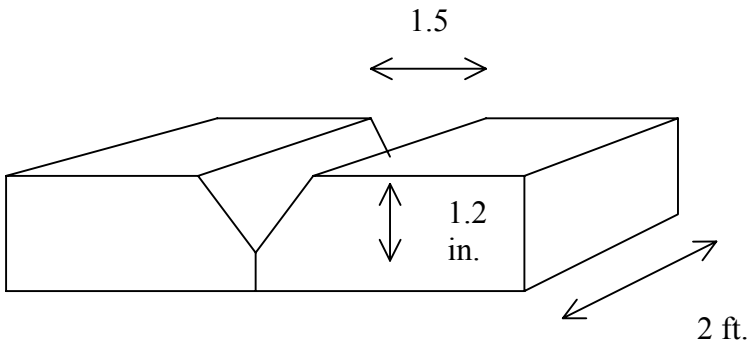
$= 106 \ \text{in}^3$ and use calculator to find volume

Find the weight of the above cylinder if the weight density is 0.35 lb/in ^{3}.

Solution:

Weight = volume $\times$ weight density
= 106 in3 $\times$ 0.35 lb/in ^{3}
= 37.1lb.

Find weld weight of the following welded groove. The groove width is 1.5 inch (in.), the groove height is 1.2 inch (in.) and the length of the groove is 2 feet (ft). The weight density of the welding metal is 0.283 pound per cubic inch (lb/in^3).



Solutions:

Volume of grove = area of cross section $\times$ length of groove

Weight = volume $\times$ weight density
= area of cross section $\times$ length $\times$ weight density

$$= \frac{1}{2} \times 1.5\,\text{in} \times 1.2\,\text{in} \times 2\,\text{ft} \times 12\,\frac{\text{in.}}{\text{ft.}} \times 0.283\,\frac{\text{lb}}{\text{in}^3}$$
$$= 6.11 \text{ lb.}$$

Exercises:

1) Find volume of a cylinder with radius equal to 3 in. and height equal to 3.5 feet.

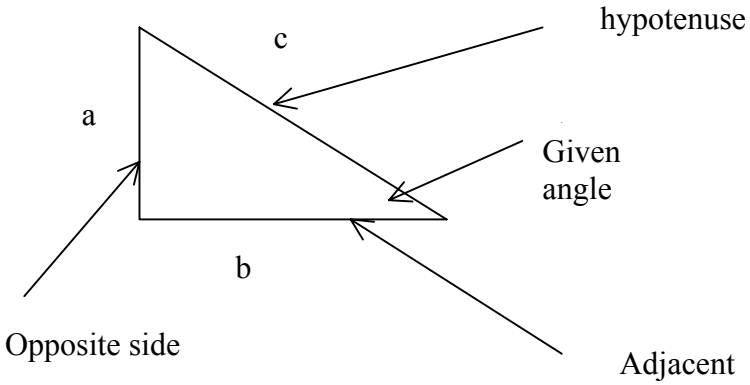
2) Find the weight of the above cylinder if the weight density is 0.3 lb/in^3.

3) Find the weight of a weld in a groove with width of 0.75 in., height of 1.0 in., and weld weight density of 0.32 lb/in ^{3}.

D) Right Triangle Trigonometry

1) Given sides, find cosine and sine of angles

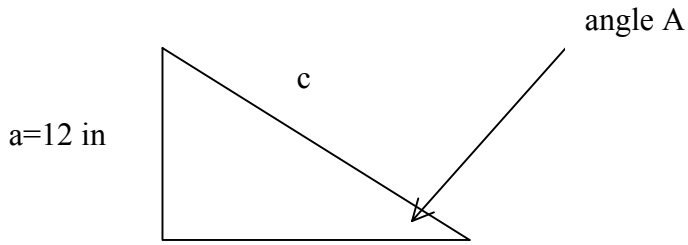
Angles in triangles are written using upper-case letters like A, B, or C and their opposite sides are written by lower-case letters like a, b, or c.



The cosine of the angle A , $\cos(A)$, and the sine of the angle A , $\sin(A)$, are given by:

$$\cos(A) = \frac{\text{Adjacent}}{\text{Hypotenuse}}, \qquad \sin(A) = \frac{\text{Opposite}}{\text{Hypotenuse}}$$

Solved exercises:



b=14 in

Find sine and cosine of the angle A shown:

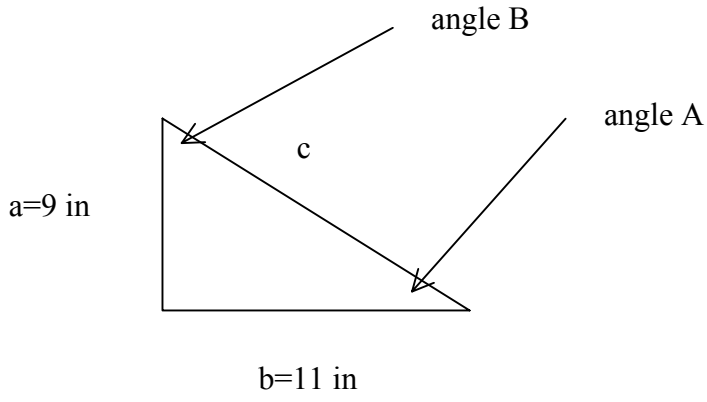
Solution:
Find c (the hypotenuse) first:

$a^2 + b^2 = c^2$	Pythagorean Theorem
$12^2 + 14^2 = c^2$	plug in numbers for the two sides a and b
$c^2 = 340$	square 12 and 14 and add and change sides
$c = \sqrt{340}$	take the square root of both sides t solve for c
$c = 18.44$	use calculator to find $\sqrt{340}$

Now find the cosine and the sine of angle A:

$$\cos(A) = \frac{\text{Adjacent}}{\text{Hypotenuse}}$$
$$= \frac{14}{18.44}$$
$$= 0.76$$
$$\sin(A) = \frac{\text{Opposite}}{\text{Hypotenuse}}$$
$$= \frac{12}{18.44}$$
$$= 0.65$$

Exercises:



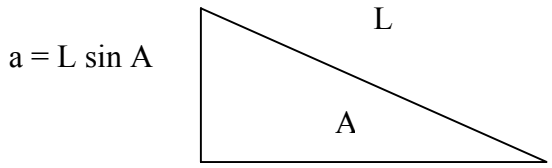
1) For the above triangle find cos(A), sin(A).

2) For the above triangle find cos(B), sin(B).

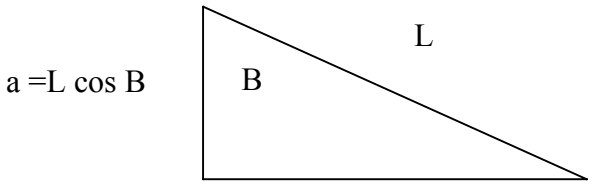
2) Given the hypotenuse and angles, find the sides

Given the hypotenuse of a right triangle and one of the angles, we can find the sides by the following formulas:

$$\text{Adjacent} = \text{Hypotenuse} \times \cos(\text{angle})$$
$$\text{Opposite} = \text{Hypotenuse} \times \sin(\text{angle})$$



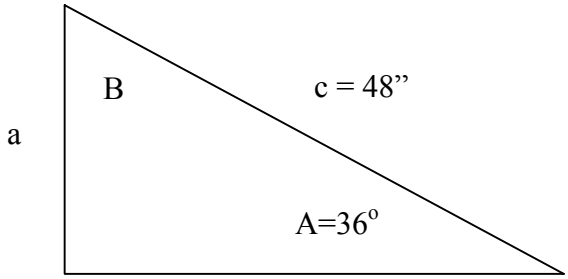
b = L cos A



b = L sin B

Solved Exercises:

Given the following right triangle, find all the side and angles:



b

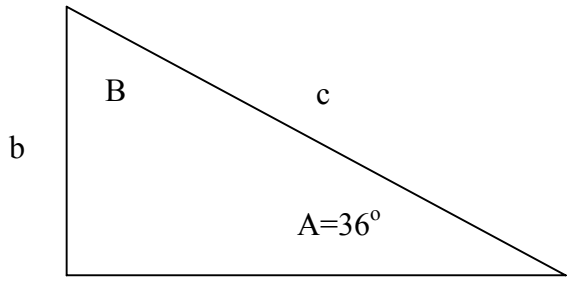
Solution:

$b = c \times \cos(36^o)$
$= 48 \cos(36^o)$
$= 48 \times 0.809$
$= 38.8$ in.

$a = c \times \sin(36^o)$
$= 48 \sin(36^o)$
$= 48 \times 0.588$
$= 28.2$ in.

$B = 90^o - 36^o$
$= 54^o$

Given the following right triangle, find all the side and angles:



Solution:

$a = c \cdot \cos(36°)$ adjacent = hypotenuse × cos (A)

$25 = c \times 0.809$ plug in 25" for a, use calculator to find cos(36)

$\frac{25}{0.809} = \frac{c \times 0.809}{0.809}$ divide both sides by 0.809 to solve for c

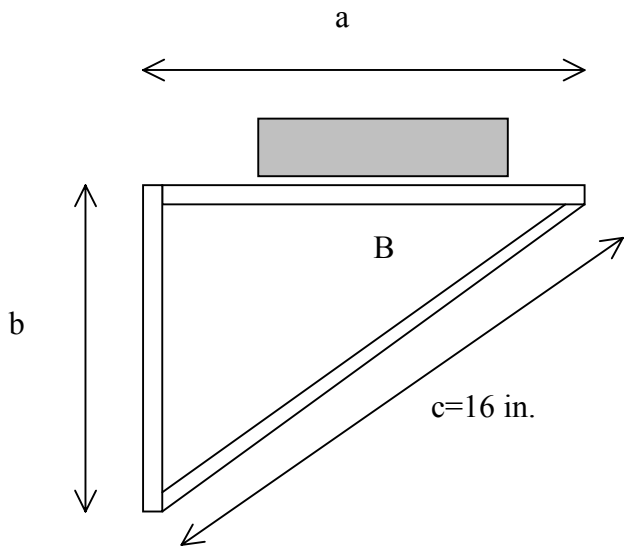
$c = 30.9''$

$b = c \times \sin(36°)$ opposite = hypotenuse × sin(A)

$b = 30.9 \times 0.588$ plug in 30.9 for c , use calculator to find sin(36)

$b = 18.17''$

The shelf shown is to be constructed with the steel bar c equal to 16 inches, and the angle B equal to 30°. Find the lengths a and b.



Solution:

$a = c \cdot \cos(B)$ adjacent = hypotenuse × cos(B)

$= 16 \cdot \cos(30°)$ plug in 16 for c and 30 for B

$= 16 \times 0.866$ use calculator to find cos(30)

$= 13.85$ in.

$b = c \cdot \sin(B)$ opposite = hypotenuse × sin(B)

$= 16 \cdot \sin(30°)$ plug in 16 for c and 30 for B

$= 16 \times 0.5$ use calculator to find sin(30)

$= 8$ in.

Exercises:

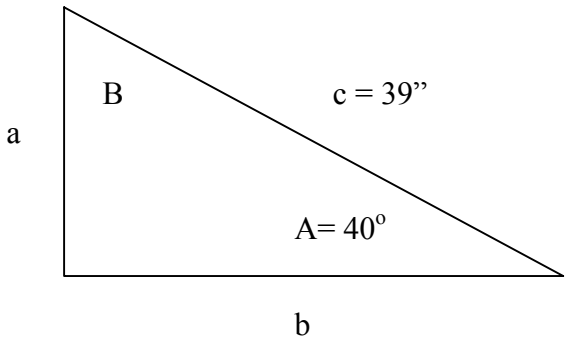


Fig. 1

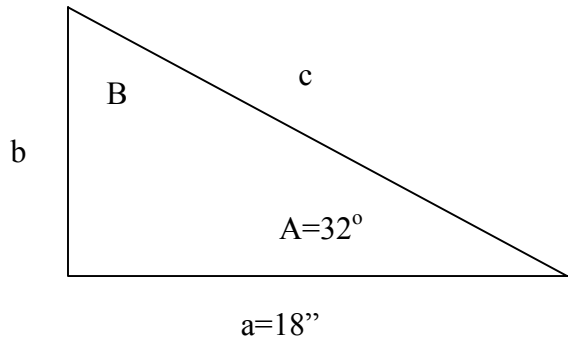
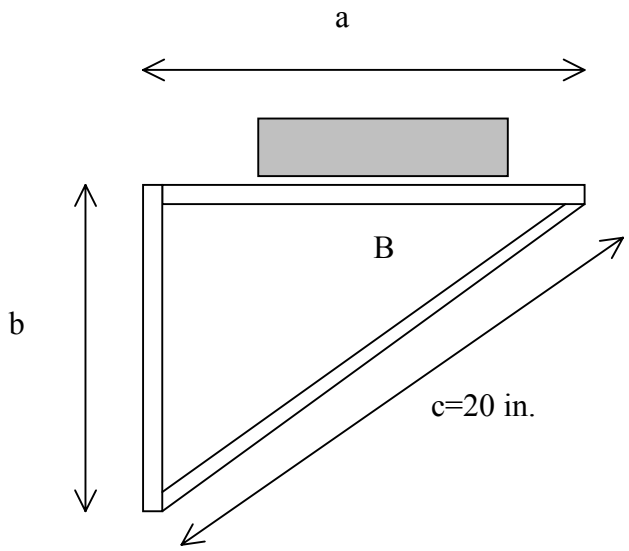


Fig. 2

1) Given the right triangle in Fig. 1, find sides a and b and angle B:

2) Given the right triangle in Fig 2, find sides b and c and angle B:

3) The shelf shown is to be constructed with the steel bar c equal to 20 inches, and the angle B equal to 32 ° . Find the lengths a and b.



E) Units and Unit Conversions

1) Units

Property	Unit	Symbol
length	centimeter, meter, inch, foot	cm, m, in.,ft
area	square centimeter, square meter, square inch, square foot	cm^2,m^2, in^2,ft^2
volume	cubic centimeter, cubic meter, cubic inch, cubic foot, cubic liter	cm^3, m^3, in^3,ft^3, L^3
mass	gram, kilogram, pound	g, kg, lb
temperature	degree centigrade degree Fahrenheit	^oC, ^oF
time	second, minute, hour	sec, min, hr
pressure	pascal (Newtons/sq. meter) pounds/square inch	Pa (N/m^2) psi
speed	meter/second, foot/second	m/s, ft/s
electric resistance	ohm	Ω
electric current	ampere (amp)	A
electric voltage	volt	V
power	watt (Joule/secon)	W (J/s)
energy	Joule	J
frequency	Hertz (cycles/s)	Hz
Heat input	Joule/inch, kilo Joules/inch, Joule/millimeter	J/in, kJ/in, J/mm
deposition rate	kilogram/hour	kg/h
electrode force	Newton	N
wire feed speed	millimeters/second	mm/s
flow rate	liter/minute	L/m

2)Unit Conversions:

There are:

12 in/ft	144 in^2/ft^2
2.54 cm/in	6.45 cm^2/in^2
25.4 mm/in	
100 cm/m	10,000 cm^2/m^2
1000 mm/m	
3.28 ft/m	
0.305 m/ft	
6895 Pa/psi	

1000 g/kg
2.2 lb/kg
1000 J/kJ
1000 kW/W
1000 Hz/kHz

Solved Exercises:

The length of a piece of steel is 8 feet. Find the length in meters and centimeters.
Solution:

$$8\,\text{ft} = 8\,\text{ft} \times \frac{0.305\,\text{m}}{\text{ft}}$$
$$= 2.44\,\text{m}$$

$$2.44\,\text{m} = 2.44\,\text{m}\frac{100\,\text{cm}}{\text{m}}$$
$$= 244\,\text{cm}$$

A piece of sheet metal is 156 square feet. Convert the area to square inches:
Solution:

$$156\ \text{ft}^2 = 156\,\text{ft}^2 \times 144\,\frac{\text{in}^2}{\text{ft}^2}$$
$$= 22{,}464\,\text{in}^2$$

Heat input is 67500 J/in. Convert to kJ/in and metric units:
Solution:

$$\text{Heat input} = 67500\ \text{J/in}$$
$$= 67500\,\frac{\text{J}}{\text{in}} \times \frac{1\,\text{kJ}}{1000\,\text{J}}$$
$$= 67.5\ \text{kJ/in}$$

Convert to Metric Units :

$$\text{Heat Input} = 67.5\frac{\text{kJ}}{\text{in}} \cdot \frac{1}{25.4}\frac{\text{in}}{\text{mm}} \qquad \text{multiply by } \frac{1}{25.4}\frac{\text{in}}{\text{mm}}, \text{ so inches cancel}$$

$$= 2.7\frac{\text{kJ}}{\text{mm}}$$

Convert 70 psi to Pascals:

Solution:

$$70 \text{ psi} = 70 \text{ psi} \times \frac{6895 \text{ Pa}}{\text{psi}} \qquad \text{multiply by } \frac{6895 \text{ Pa}}{\text{psi}}, \text{ so psi's cancel}$$

$$= 482{,}650 \text{ Pa}$$

Welding speed is specified to be 24 inches per minute. Convert to centimeters per seconds:

$$24\frac{\text{in}}{\text{min}} \times 2.54\frac{\text{cm}}{\text{in}} \times \frac{1}{60}\frac{\text{min}}{\text{sec}} = \qquad \left(\text{multiply by } 2.54\frac{\text{cm}}{\text{in}} \text{ and } \frac{1}{60}\frac{\text{min}}{\text{sec}}, \text{ so inches and minutes cancel}\right)$$

$$1.02\frac{\text{cm}}{\text{sec}}$$

Exercises:

1)The length of a piece of steel is 12 feet. Find the length in inches, meters and centimeters.

2)A piece of sheet metal is 230 square feet. Convert the area to square inches.

3)Heat input is 82,000 J/in. Convert to kJ/in and metric units.

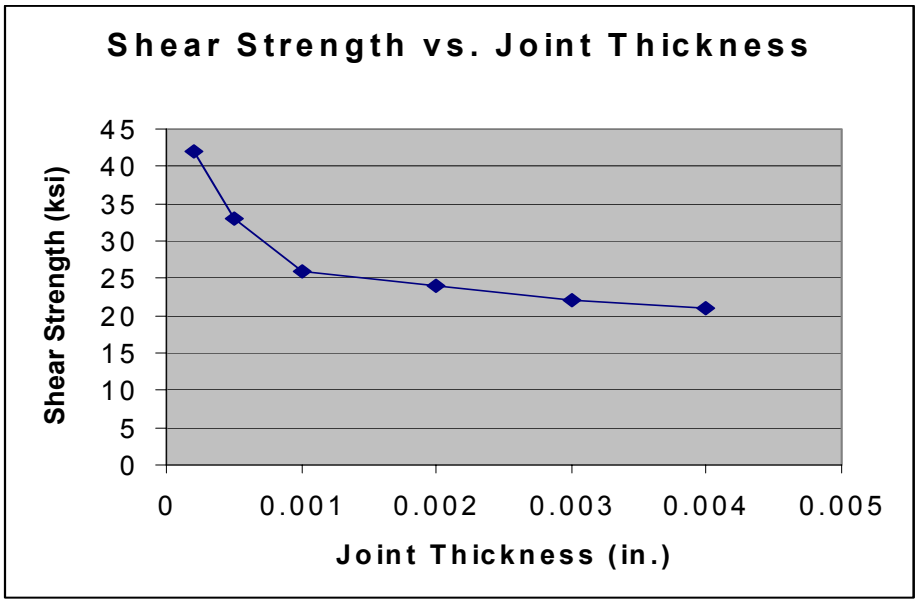
4) Welding speed is 8 inches per minute. Convert to cm/sec.

F) Reading Graphs:

To read graphs, locate the value on the horizontal axis, draw a vertical line (up or down) to meet the graph, then draw a horizontal line (left or right) to meat the vertical axis. Read the number on the vertical axis.

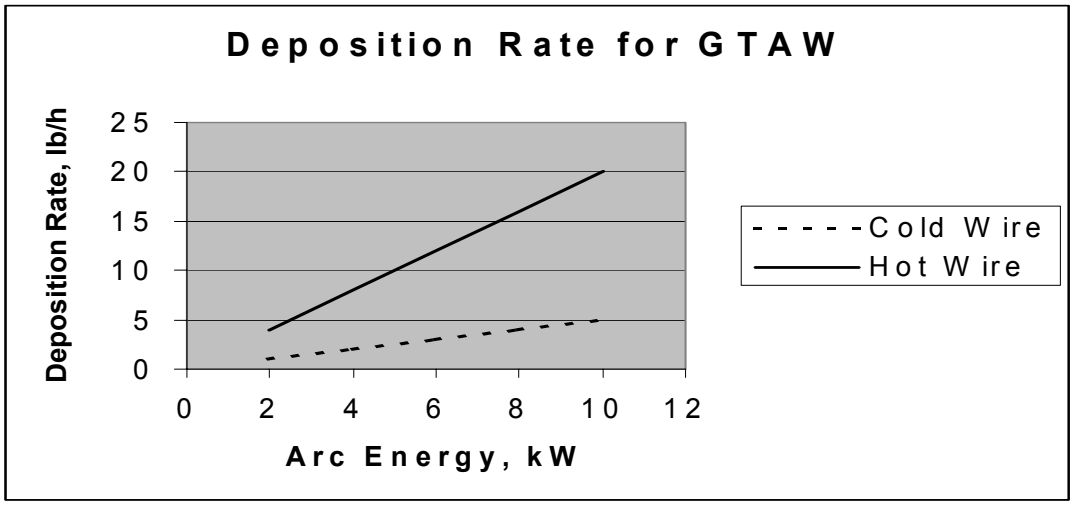
Solved Exercises:
1) Shear strength in ksi is given as a function of joint thickness in inches for pure silver joints for 0.5 inch diameter steel drill rod by the following graph. Find shear strength when joint thickness is 0.001 and 0.004 inches.

Solution:
Vertical lines at joint thickness of 0.001 and 0.004 are drawn up to meet the graph and horizontal lines are drawn from those points to the left to meet the vertical axis. Shear strength values are read as respectively 26 and 21 ksi.



2) The following figure gives deposition rate in pounds per hour (lb/h) versus arc energy in kilowatts (kW) for gas tungsten arc welding with cold and hot steel filler wires. Find deposition rates for cold and hot filler wires when arc energy is 8 kW.

Solution:
Vertical lines at arc energy of 8 kW are drawn up to meet the graphs and horizontal lines are drawn from those points to the left to meet the vertical axis. Deposition rate values are read as respectively 4 and 16 lb/h.

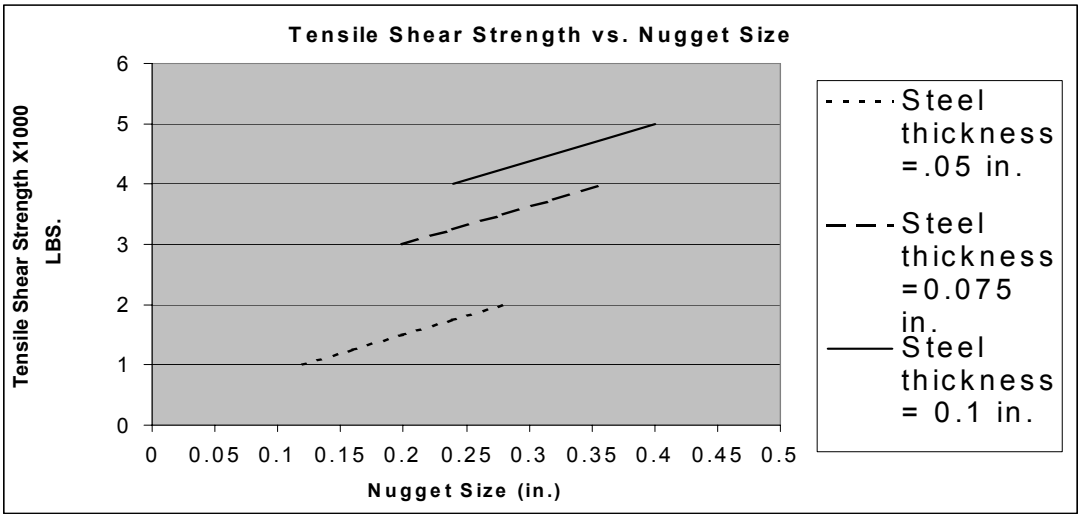


Exercises:

1) The following graph shows tensile shear strength in 1000's of lbs. vs. weld nugget diameter in inches for three different sheet metal thickness.

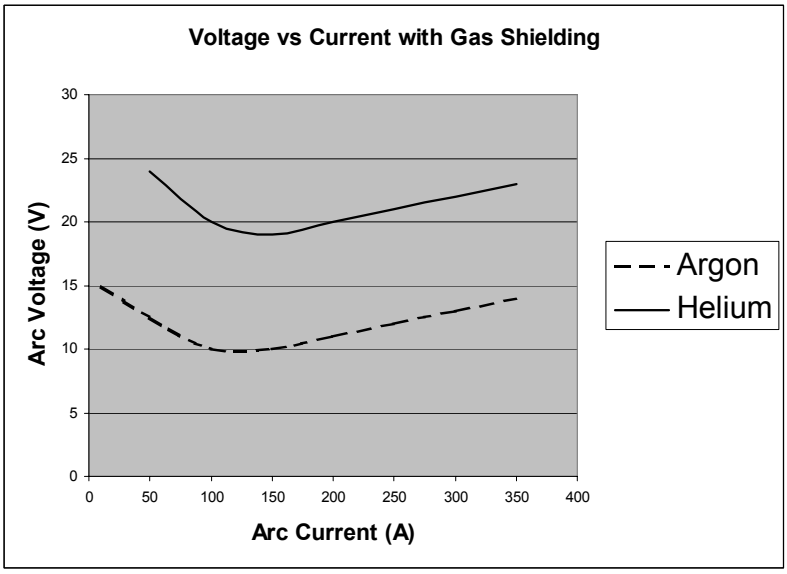
a)Find tensile shear strength for a 0.075 in. thick sheet steel when weld nugget diameter is 0.25 in.

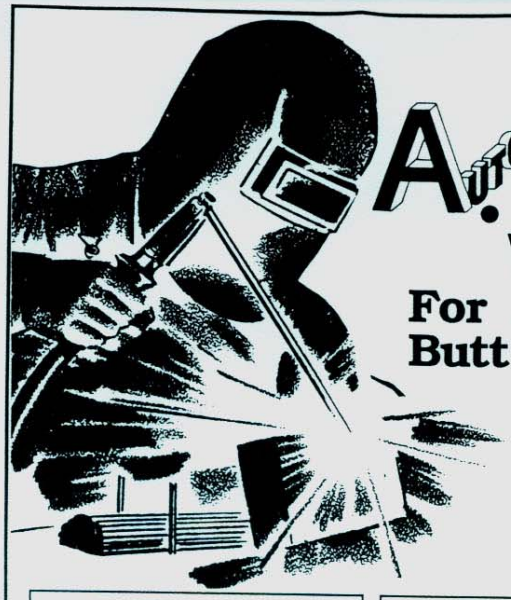
b)Find tensile shear strength for a 0.1 in. thick sheet steel when weld nugget diameter is 0.4 in.



2) Voltage versus current for aluminum tungsten arc welding with gas shielding is given in the graphs below.
a) Find voltage when current is set at 250 Amps with argon gas shielding.

b) Find voltage when current is set at 100 Amps with helium gas shielding.



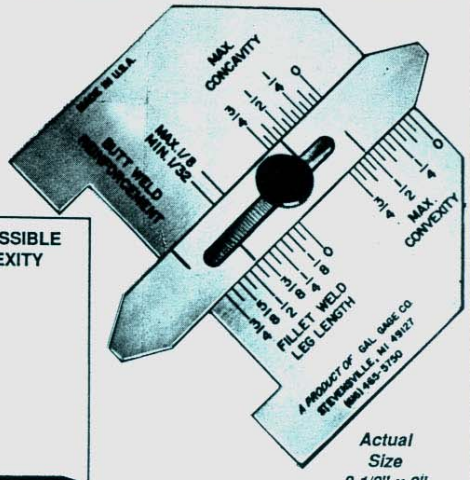


A.W.S.

AUTOMATIC WELD SIZE

WELD GAUGE

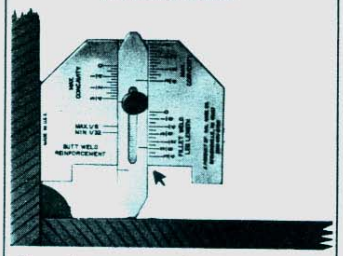
For Accurate Calibration of Butt and Fillet Type Welds.



Actual Size 2 1/2" x 3"

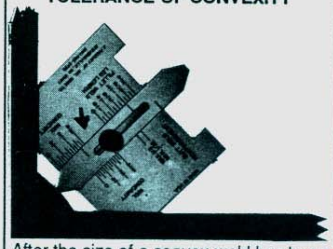
Cat. # 6

1. TO DETERMINE THE SIZE OF A FILLET WELD



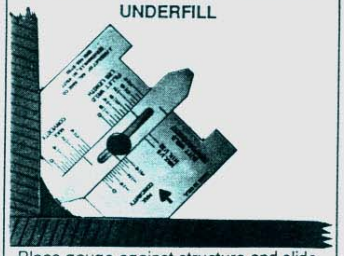
Place the gauge against the toe of the fillet weld and slide pointer out until it touches structure as shown. Read "Size of the Fillet Weld" on face of gauge as indicated by arrow.

2. TO CHECK THE PERMISSIBLE TOLERANCE OF CONVEXITY



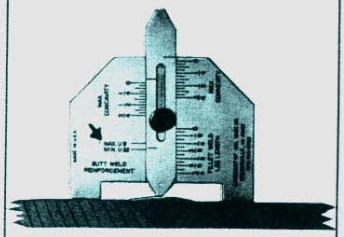
After the size of a convex weld has been determined, place the gauge against the structure and slide pointer until it touches face of fillet weld as shown. The maximum convexity should not be greater than indicated by "Maximum Convexity Scale" as indicated by arrow for the size of fillet being checked.

3. TO CHECK THE PERMISSIBLE TOLERANCE OF CONCAVITY AND UNDERFILL



Place gauge against structure and slide pointer out until it touches the face of the fillet weld as shown. If the pointer does not touch as shown, the fillet requires additional weld metal.

4. TO CHECK THE PERMISSIBLE TOLERANCE OF REINFORCEMENT



Place gauge so that reinforcement will come between legs of gauge and slide pointer out until it touches the face of weld as shown.

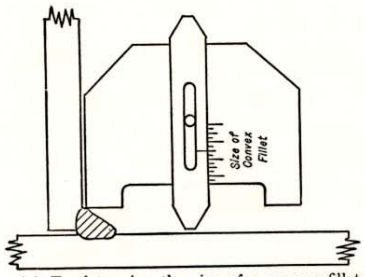
With the new improved A.W.S. Gauge shown above it is possible to meet specifications of butt and fillet type welds. New redesigned instrument is pocket sized and easy to operate, new feature includes thumb screw which replaces old hard to operate rivet type.

Diagrams at left illustrate the ease with which welders and inspectors may accurately check sizes of convex or concave fillets as well as butt weld reinforcements.

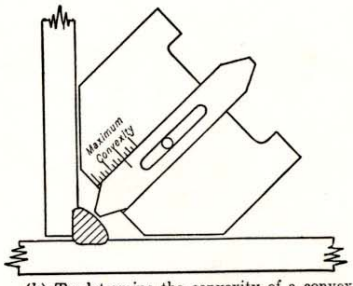
The convexity and concavity sizes have automatically been predetermined in accordance with American Welding Society D1.1. Paragraph 3.6.

Instrument is precision built of stainless steel with dimensional readings chemically etched and filled for easier reading.

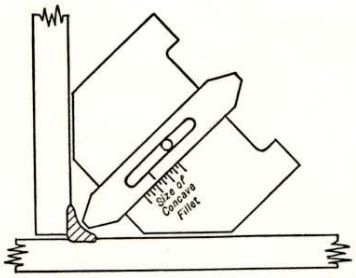
Gal Gage Co.
P.O. Box 23
Stevensville, MI 49127
(616) 465-5750
Fax: (616) 465-6385



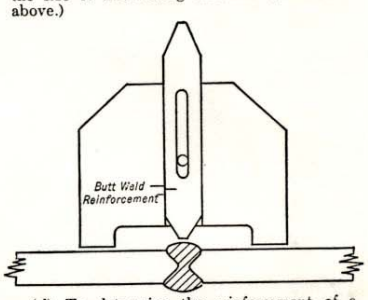
(*a*) To determine the size of a convex fillet weld, place gage against the toe of the shortest leg of the fillet and slide pointer out until it touches structure. Read "size of convex fillet" on face of gage. (See sketch above.)



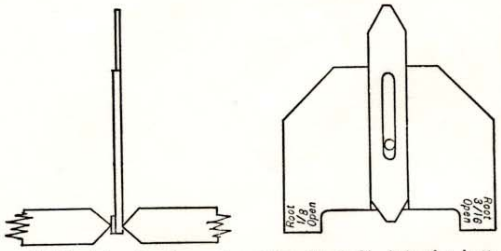
(*b*) To determine the convexity of a convex fillet weld after its size has been determined, place gage against structure and slide pointer out until it touches the face of the fillet weld. The maximum convexity should not be greater than indicated by "maximum convexity" for the size of fillet being checked. (See sketch above.)



(*c*) To determine the size of a concave fillet weld, place gage against structure and slide pointer out until it touches the face of the fillet weld. Read "size of concave fillet," on face of gage. (See sketch above.)



(*d*) To determine the reinforcement of a butt weld, place gage so that reinforcement will come between legs of gage and slide pointer out until it touches the face of the weld. The permissible reinforcement is that indicated on the face of the gage. (See sketch above.)



(*e*) To determine the root opening (⅛ or 3/16 in.) of a butt joint, place one or the other leg of gage in the space separating parts. If gage fits snugly, the root opening is that indicated on the face of the gage. (See sketch above.)

FIG. 192. BUTT AND FILLET WELD GAGE, SHOWING METHOD OF USING.

NEW IMPROVED

THE MULTI-PURPOSE WELDING GAUGE

MODEL TWO

Inspectors, supervisors, engineers, surveyors — in fact all who need to examine welds and check their size — know a need exists for a device which will quickly measure the important dimensions of both weld preparations and completed butt and fillet welds.

Intratec now has such an instrument available, ruggedly made in stainless steel to withstand continuous use in shop or on site. The multi-function gauge with permanent color-coded scales, covered with a removable, transparent protective film, measures in addition, features of particular value to the pipeline industry such as misalignment (high low), depth of pitting and wall thickness. Many thousands of these gauges are already in use in industry.

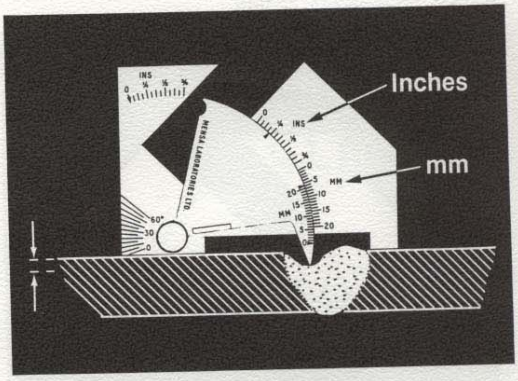
This new direct reading pocket-size instrument will save valuable time and produce readings of high reliability. Diagrams illustrating the principal applications are shown overleaf.

The following measurements can be made with the gauge and read off in imperial or metric units.

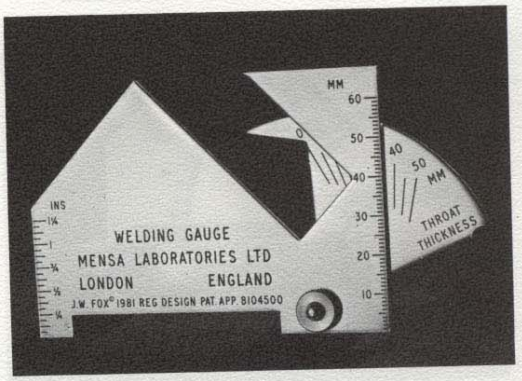
- **Material thickness, maximum ¾″ (20 mm)**
- **Angle of preparation, 0°-60°**
- **Excess weld metal (capping size)**
- **Depth of undercut, 0-¾″ (20 mm)**
- **Depth of pitting, 0-¾″ (20 mm)**
- **Electrode diameter, 0-¾″**
- *• **Fillet weld throat size, 0-50 mm**
- **Misalignment (high-low), 0-¾″ (20 mm)**
- **Fillet weld leg length, 0-¾″ (20 mm)**

The gauge weighs 100g and the overall size is approx. 10cm × 7cm.

*The Model Two allows measurement of throat thickness of fillet welds in plates welded at right angles to each other and at angles up to 30° from the right angle improving its facility for structural weld inspection.



Depth of Undercut or Pitting



Price: (Complete with Pocket Case)

$65 postpaid ~~Minimum order $100~~

INTRATEC DIVISION
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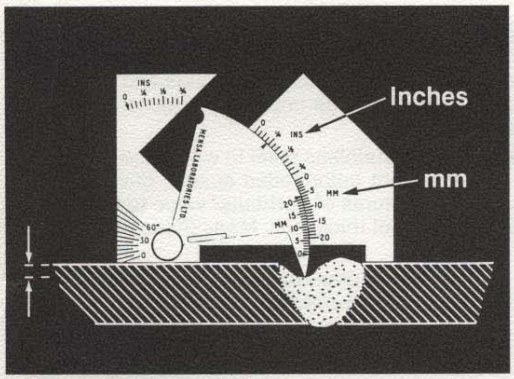
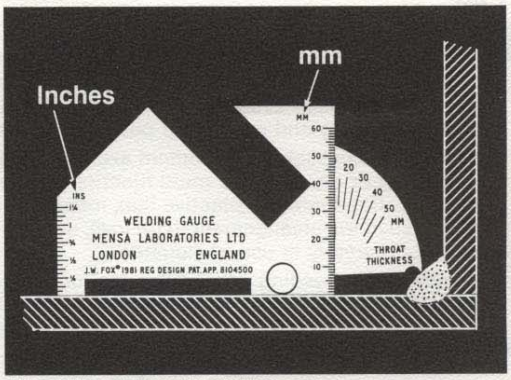
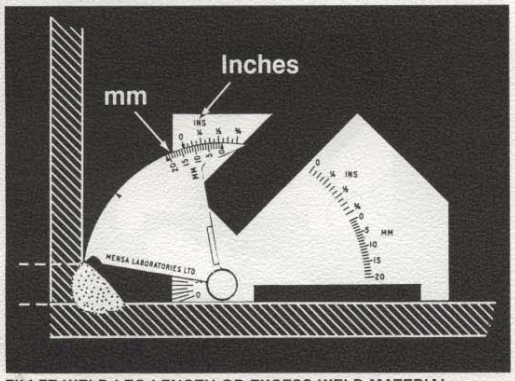
Multi-purpose welding gauge



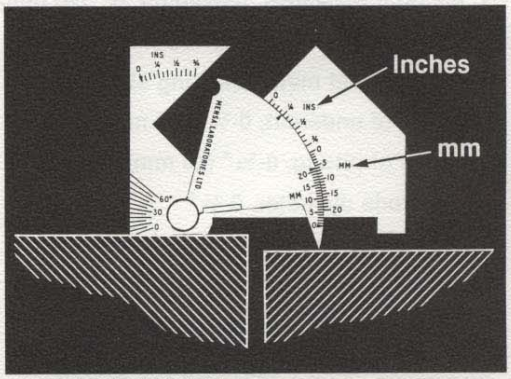
DEPTH OF UNDERCUT OR PITTING



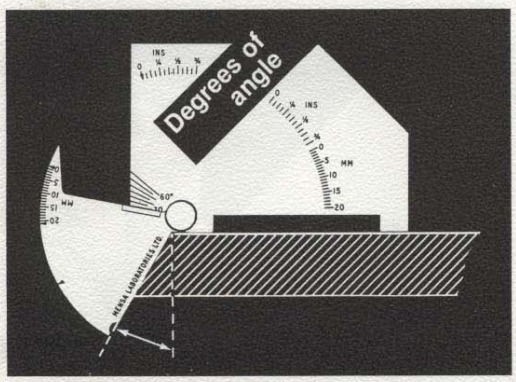
FILLET WELD THROAT THICKNESS



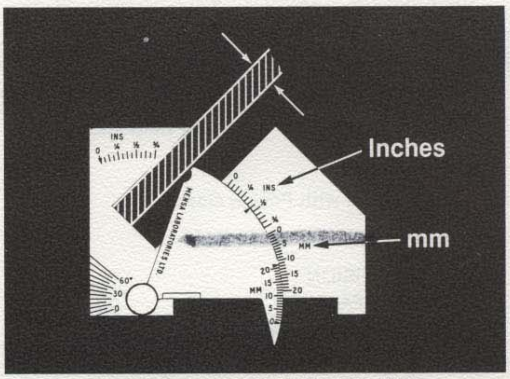
FILLET WELD LEG LENGTH OR EXCESS WELD MATERIAL



MISALIGNMENT (HIGH/LOW)



ANGLE OF PREPARATION



MATERIAL THICKNESS (ELECTRODE DIAMETER, ETC.)