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ABSTRACT

One in a series of core instructional materials for apprentices to use during the first or second years of apprentice-related subjects training, this booklet deals with basic measurement. The first section consists of an outline of the content and scope of the core materials as well as a self-assessment pretest. Covered in the four instructional chapters included in the booklet are units and tools of measurement, surface measurement, volume and weight measurement, and accuracy and precision. Each chapter contains an overview; an introduction and objectives; principles, examples, and applications; additional information; and self-test exercises. Appended to the booklet are answers to the self-assessment pretest, answers to the self-test exercises, a posttest, and answers to the posttest. (MN)

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BASIC MEASUREMENT

Apprentice Related Training Module

Eric Rice

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Glossary

The words on this list are used in this booklet. Please review the terms and learn the definitions. The meaning of the words in the text may not be the form of the word with which you are familiar.

Words/Terms

1. *Accuracy* Without error
2. *Approximate* To estimate to a close degree
3. *Calculate* To determine by computation or mathematic means
4. *Converse* Reversed so that two parts are interchanged
5. *Conversion* A process of changing from one form to another
6. *Cubic* Having dimensions of length, width and height
7. *Dilute* To reduce the strength or concentration of something
8. *Dimension* Any measurable extent
9. *Equivalence* Equal in value, meaning, force or effect
10. *Formula* An exact method, prescription or recipe for doing something
11. *Heaped bushel* A dry volume measure used for fruits like apples that fill above the rim
12. *Intersect* To cross or meet
13. *Magnitude* An amount, size or extent
14. *Medium of exchange* A system of equivalent amounts
15. *Notation* A system of signs or abbreviations that stand for certain units or quantities
16. *Precision* Exact in amount
17. *Proportion* Relative magnitude of two things to each other or a part of the whole
18. *Quantify* To make into a specified or indefinite number, amount or weight
19. *Scale* A system of spaced graduations for measurement; the instrument for measurement
20. *Standardize* To compare with an established measure of extent, value or quantity
21. *Struck bushel* A dry volume measure used for grains that means full exactly to the rim

1. How To Use This Booklet

What Is This Series About?

Basic Measurement is one of ten booklets written as core instructional materials for apprentices to use during the first or second years of apprenticeship related subjects training. Nine of the booklets are about critical subject areas for apprentices, as determined by a national group of experts on apprenticeship and training. The tenth booklet introduces the other booklets and explains how to use the materials in the instructional setting.

The materials are designed to be used with other related subjects instructional materials. They can be employed in one of two ways: (1) the materials can be used as the total instructional materials package for some trades, in subjects such as basic science, measurement, and working in organizations, or (2) they can be used as supplementary, introductory or practice materials in subjects such as basic mathematics, safety and an introduction to apprenticeship.

The booklets are written in a self-instructional, self-paced format. They can be used either in instructor supervised or independent study arrangements. *Each booklet and each chapter is written as a distinct unit and is addressed to a single major topic.* This means that you or your instructor can select individual booklets or chapters without necessarily using every booklet or every chapter within a booklet.

The booklets emphasize application of facts, concepts and skills. Material is presented by means of written information, visual illustration and applied example. The discussion for most major topics also includes an application section that requires you as a learner to demonstrate what you are learning. In addition, each chapter contains a section entitled Self-Test Exercises that contains questions, problems and exercises for you to work through as a final application of the knowledge or skill and to show that you have mastered the materials.

The titles of the booklets in the core materials are:

1. A Basic Core Curriculum
2. Introduction to Apprenticeship
3. Basic Mathematics
4. Basic Safety I
5. Basic Safety II
6. Basic Measurement
7. Sketching, Drawing and Blueprint Reading
8. Basic Physical Science
9. Working in Organizations
10. Interpersonal Skills and Communication

What Is This Booklet About?

Imagine a world in which there was no standard way to measure or estimate quantities. You would not be able to determine the weight of an object before trying to lift it. You would not be able to mass produce a machine with interchangeable parts because there would be no standard size for the parts. You would not be able to build a house because you would not be able to *calculate* how much building material would be needed and you would not be able to *communicate* to someone else exactly how much material would be required. Work activity would stop, and advancing technology and productivity would be impossible. To insure that these problems do not happen, successful craftworkers and tradespersons must command measurement skills particular to their chosen occupations.

There are five basic characteristics of the physical world: (1) space, (2) mass, (3) energy, (4) time, and (5) temperature. While difficult to define in words, each of these characteristics can be expressed as a magnitude. Magnitude means amount or quantity and is determined by measurement. There is a separate category of measurement for each of the five basic physical characteristics: (1) space—length, area and volume; (2) mass—weight; (3) energy—work; (4) time—hours/minutes/seconds, and (5) temperature—degrees. This booklet is about measuring space and mass because these characteristics are of greatest concern in most apprenticable trades and occupations. Specific topics covered in this booklet are:

1. Units and Tools of Measurement
2. Surface Measurement
3. Volume and Weight Measurement
4. Accuracy and Precision

Measurement of energy and temperature are addressed in the apprentice training module entitled *Basic Physical Science.*

What Must I Do To Complete My Work In This Booklet?

Working your way through this booklet will require you to read the text, to answer the questions, to perform the exercises and to complete the pretest and posttest instruments. Expect to spend about five hours working through the materials. The only resources you need to complete your work in this booklet are. (1) a copy of the booklet; (2) a pencil or pen, (3) a ruler; and (4) about five hours of time.

The materials are written in a self-instructional, programmed format. You may work through the text, examples, and questions at your own pace and leisure. You need not complete your work in the booklet at one sitting.

Each chapter in the booklet is devoted to a single skill, competency or unit of knowledge. The general format of the chapters is similar, with the following parts:

1. A *chapter overview* containing all the necessary information you need to know in order to work through the chapter.
2. An *introduction* describing the knowledge or skill and the instructional objectives for the information.
3. *Principles, examples, and applications* presenting and explaining the content as well as offering you practice opportunities to apply the information.
4. Additional sources of *information.*
5. A *self-test exercise* for applying the information under consideration.

This booklet concludes with an appendix that contains the answers to the pretest, the self-test exercises from each chapter and the posttest.

How Much Do I Know About The Subject As I Begin?

Begin your work in *Basic Measurement* by completing the self-assessment pretest that follows. When you have completed the pretest as directed in the assessment instructions and have finished reading the other material in this introductory section, continue your work in this booklet, one chapter at a time. Begin with Chapter 2 unless the results of your self-assessment indicate that you should do otherwise.

In each chapter, do the following:

1. Read:
   - Background information
   - Steps and procedures for performing skilled activities and explanations of major points and ideas
   - Examples illustrating use of information, performance or skill, or application of material
2. Consider the questions and exercises in the text. Work the questions and check your answers.
3. When you believe that you have mastered the material, take the Self-Test at the end of the chapter.
4. Check your answers with those provided in the Appendix at the end of the booklet. If you achieve at least the minimum acceptable score, move to the next chapter. If your score is below acceptable levels, work through the chapter again.

Self-Assessment Pretest

Directions. The self-assessment will help you focus on specific strengths and limitations of your measurement knowledge and skills. Select the best answer for each question and record it in the appropriate space. After you have worked through the entire pretest, score your test following the directions at the bottom of the test.

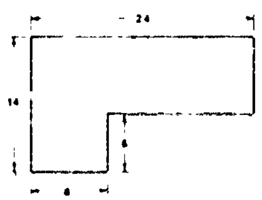
1. Express 100 yards in meters. Answer: ____________________
2. How many centimeters are there in a foot? Answer: ____________________
3. Express 130 lbs. in kilograms. Answer: ____________________
4. A room that is 12′ on each side contains how many cubic meters? Answer: ______________
5. When your truck takes 38 liters to fill, how many gallons did it equal? Answer: __________
6. How many feet and inches are there in 3.2 miles? Answer: ____________________
7. Express 4.5 yards in inches. Answer: ____________________
8. What is the perimeter of a rectangle 13½′ wide and 11 feet long? Answer: _______________
9. How many square feet of carpet are required to cover a semi-circular room that is 26 feet across its base? Answer: ____________________
10. What is the perimeter (circumference) of a circle with a diameter of 7 feet? Answer. _______
11. The area of a circular floor with a radius of 10′ is how many square feet? Answer: ________

12. Circle the letter that indicates the constant value of π.
    a. 3.14
    b. 3.17
    c. 3.41
    d. 3.64

13. What is the area in square feet of a triangular deck that contains one right angle and measures 6′ on its shortest side and 12′ on its next longest side? Answer: ____________

14. How many 9″ × 9″ wood shingles will be required to cover a roof that measures 30′ long and 14′ wide? Answer: ____________

15. If paving costs $20/square foot, how much would it cost to pave a driveway that looked like this? Answer: ____________



16. How many cubic feet of concrete are in a slab that measures 1½ feet thick, 16 feet wide and 18 feet long? Answer: ____________

17. The excavation for the basement, foundation and below ground parking garage of a new office building measured 175′ long, 200′ wide, and 40′ deep. After 5000 cubic yards of dirt had been removed, how much was left to move? Answer: ____________

18. A walk-in freezer measured 10′ on all sides. How much air was there to cool? Answer: ____________

19. What is the volume of a propane cylinder that is 15″ tall and 6″ in diameter? Answer: ____________

20. How many gallons does a cylinder that is 20 feet tall and has a diameter of 12′ hold? Answer: ____________

21. If a box contains 180 cubic feet and is 10 feet long and 2 feet wide, how high is it? Answer: ____________

22. What is the volume in cubic feet of a concrete ramp that reaches the top of a 6 foot platform, given that the ramp is 15 feet long at its base and 3 feet wide? Answer: ____________

Scoring. Check your answers with those provided in the appendix. Mark each answer right or wrong. Then, grouping the answers into the sets of questions listed below, count the number correct for each set. Enter the amount in the appropriate spot on the Chapter Overview Chart that introduces each chapter, beginning with Chapter II.

Questions 1–7, number correct is ____________.
Questions 8–15, number correct is ____________.
Questions 16–22, number correct is ____________.

2. Units And Tools Of Measurement

Chapter Overview

Purpose:	To insure that each apprentice has a working knowledge of the basic units used in measurement. An apprentice will gain an ability to use the various conventional and metric units of measure to solve work-related problems and will be introduced to common tools of measurement.
Preassessment Score:	Write in the following space the number of correct answers from pretest questions 1–7. ________ If you answered all seven questions correctly, skip to Chapter 3. If you missed at least one question, work through this chapter.
Prerequisites:	Chapter 1 of this booklet Basic Mathematics module or its equivalent for solving for unknowns, working with fractions, and doing multiplication and division.
Resources:	Time—about 75 minutes to completion. Materials—paper, pencil.
Performance Measure:	A ten-minute, paper and pencil posttest, to be taken in the related subjects setting.
Standards:	To be successful, you must answer correctly at least 80% of the posttest items.
Activities:	1. Read the text, examples and illustrations and commit information to memory. 2. Work questions, examples and problems. 3. Complete and check the self-test exercises and posttest.

Introduction and Objectives

Measurement is the science of approximation. It is the ability to quantify and describe in uniform and precise terms the magnitude or amount of an "object." The "object" can be space as expressed in volume, area and distance. It can be temperature as expressed in degrees. It can be energy as expressed in terms of work. It can be time as expressed in hours, minutes and seconds, or it can be mass as expressed in weight. In each instance, measurement answers the question of "how much." Measurement answers the question of "how much" in a uniform and standardized way to provide a common medium of exchange and reference for business, manufacturing, work and research.

This chapter deals with the issue of basic units and tools of measure. Also, it reinforces several critical mathematic skills necesary to work with the units. When you have completed your work in this chapter, you will demonstrate your competence with the materials in this chapter by being able to:

1. Perform and check metric to conventional and conventional to metric conversions, and
2. Explain and demonstrate principles of other ideas related to the use of measurement systems.

Principles, Examples and Applications

To be an effective worker, you must be able to work with the basic units of measure in the conventional (or English) and metric systems. You also must be familiar with procedures for converting measures from one unit to another within the same system or from one system to the other. Each system is discussed in the following sections, along with conversion charts for use in linear, area, volume and weight unit conversions. In addition, each chart is accompanied by a set of example problems that will assist you in mastering the materials.

Conventional System Units of Measure

You are most familiar with the conventional or English system of measure because it is the one used in most homes and on most jobs in the United States. Conventional units of length measure are inches, feet, yards and miles. The units of area measure are square inches, square feet, square yards, and square miles. The units of volume measure are cubic inches, cubic feet, cubic yards, cubic miles, bushels, pints, quarts and gallons. The units of time measure are minutes, seconds, hours, and days. The units of weight measure are ounces, pounds and tons. Figure 2 shows the units of measure in the conventional system and their relationship to each other.

Figure 2: Conventional System Units of Measure

Linear Units	**Time Units**
1 foot = 12 inches	1 minute = 60 seconds
1 yard = 3 feet or 36 inches	1 hour = 60 minutes
1 mile = 5280 feet or 1760 yards	1 day = 24 hours
Weight Units	**Volume Units**
1 pound = 16 ounces	1 gallon = 231 cubic inches
2000 pounds = 1 ton	1 cubic foot = 7½ gallons
1 pint = 1 pound	1 cubic foot (water) = 62½ pounds
	1 gallon (water) = 8⅓ pounds
Area Units	1 bushel (struck) = 2150.5 cubic inches
1 square foot = 144 square inches	1 bushel (heaped) = 2747.7 cubic inches
1 square yard = 9 square feet	1 cubic foot = 1728 cubic inches
1 square mile = 3,097,600 square yards	1 cubic yard = 27 cubic feet

Some conversions between units of measure are possible. For example, you can convert measures of volume to measures of weight. However, such conversions in the conventional system usually require you use fractions to solve equations.

Within the same unit or type of measure, conversion to equivalent measures usually involves division or multiplication. For example, to find the number of cubic feet required to hold 20 gallons of water, you would divide the 20 gallons by the conversion equivalent of 7.5 gallons per cubic feet. You find that 20 gallons can be contained in 2.67 cubic feet. To find the number of square feet in twenty square yards you would multiply 20 yards times the 9 square feet per yard. You find that there are 180 square feet in 20 square yards.

With these examples in mind, work the following practice problems:

1. How many inches are there in 54.5 yards? Answer: ____________
2. How many cubic inches are there in 22 cubic feet? Answer: ____________
3. How much does 14 gallons of water weigh in pounds and ounces? Answer: ________
4. How many square feet are there in 2 square yards? Answer: ____________
5. How much space in cubic feet is required to contain 150 struck bushels? Answer: ____________

Answers:

1. = 1962 inches
2. = 38,016 cubic inches
3. = 116.62 pounds or 116 pounds, 10 ounces
4. = 18 square feet
5. = 186.7 cubic feet

Metric System Units of Measure

The world except for the United States uses the metric system of measures. Even within the United States, scientists more frequently use the metric system than conventional measure. The metric system has several advantages when compared to the conventional system. The major two advantages are: (1) The scales are based on units divisible by 100 or 10 and thus use whole numbers. This means that fractions, when required, are divisible by 10. (2) The units of various types of measure, such as volume and weight, are related directly to each other in easily divisible whole numbers. This permits you to convert equivalents with ease and speed.

The units of length measure in the metric system are the centimeter, meter and kilometer. The units of weight measure are grams and kilograms. The units of volume measure are cubic centimeters, cubic meters and cubic kilometers. The units of time measure are minutes, seconds and hours. The units of area measure are square centimeters, square meters and square kilometers. Figure 3 illustrates the units of measure and their equivalents for other units in the metric system.

Figure 3: Metric System Units of Measure

Linear Units
1 millimeter (mm) = 0.001 meter
1 centimeter (cm) = 0.01 meter
1 decimeter = 0.1 meter
1 meter = 10 decimeters, 100 centimeters, 1000 millimeters
1 kilometer = 1000 meters

Weight Units
1 milligram = 0.001 gram
1 centigram = 0.01 gram
1 decigram = 0.01 gram
1 gram = 1000 milligrams, 100 centigrams, 10 decigrams
1 kilogram = 1000 grams

Area Units
1 square centimeter = 100 square millimeters
1 square meter = 10,000 square centimeters
1 square kilometer = 1,000,000 square meters

Volume Units
1 milliliter = 1 cubic centimeter
1 milliliter = 0.001 liters
1 centiliter = 0.01 liters
1 deciliter = 0.01 liters
1 liter = 1000 milliliters, 100 centiliters, 10 deciliters
1 kiloliter = 1000 liters

Conversions between and across units of measure in the metric system are in whole numbers and divisible by 10. For example, each centimeter is simply 10 millimeters and 20 cubic centimeters is equal to 20 milliliters.

Work the following several practice problems and check your answers with those provided below.

1. How many meters are there in 86.2 kilometers? Answer: ____________
2. How many cubic centimeters are contained in 6 liters? Answer: ____________
3. How many square centimeters are there in 9 square meters? Answer: ____________

Answers:

1 = 86,200 meters
2 = 6,000 cubic centimeters
3 = 90,000 square centimeters

Measurement Tools in Common Use

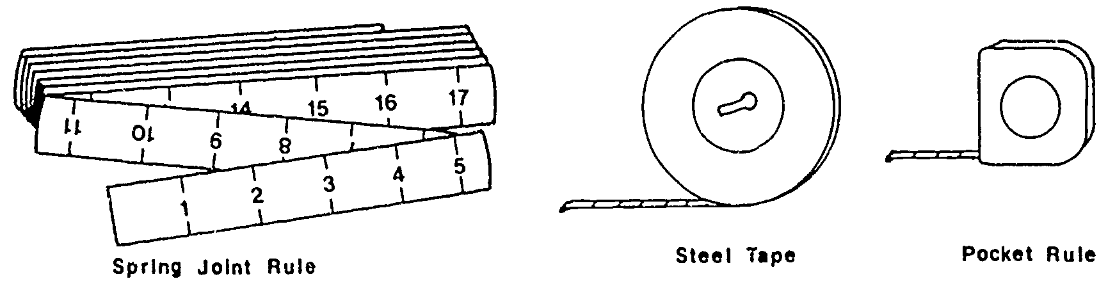
In all probability, you have been using the usual tools to measure materials either as a worker on the job or sometime in your personal history. Nevertheless, review the general description and illustrations contained in this section. The tools discussed are used to determine length or angle measure.

Rules and Tapes

Rules and tapes are used most frequently in the construction industry and are commonly of three types. (1) steel tapes, (2) pocket rules, and (3) spring joint rules. The three types are illustrated in Figure 4

Each of these three tools has particular characteristics and uses. For example, the steel tape is a rewindable flexible tape on a roll enclosed in a case. It is designed for measuring long distances and generally comes in lengths ranging from 50′ to 200′. Usually the tape has a ring or loop at the end so that you can anchor the tape and take measurements by yourself.

Figure 4: Common Tapes and Rules



The pocket rule is a second type of tape or rule. It usually is a steel tape enclosed in a case. It can be used to measure distances up to 20′ although most frequently is used to measure distances of less than 12′. Unlike the steel tape, the pocket rule is flexible enough to be bent. This flexibility enables you to measure circumferences of circular objects or perimeters of irregular objects. Pocket rules are particularly useful for measuring interior or inside surfaces due to the flexibility and because the case is a standard size of 2″ or 3″. The standard size permits you to measure a distance and add the length of the case in order to find the total distance.

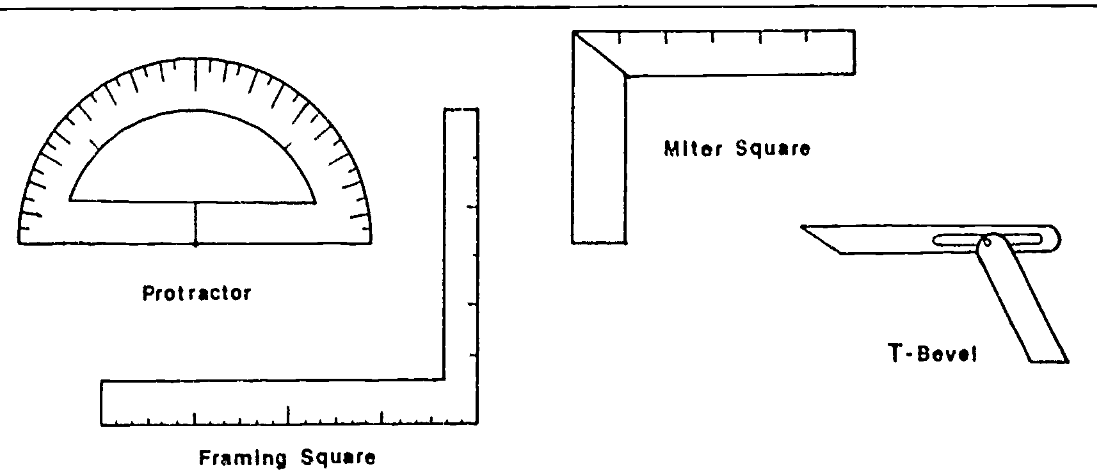
The spring joint rule is a folding ruler that usually is made of wood or metal and that can extend to 6 or 8 feet in length. They are marked on both sides of the rule and are available with a variety of scale markings. Some rules have an extension segment, usually a graduated metal slide, fitted into one end to make measuring inside openings easier.

Rules are used in most trades, especially in the construction industry. They are used for virtually all linear measures Your mastery of their use is essential.

Angle Tools

Several different types of tools are available for measuring and constructing angles. The more frequently used tools are illustrated in Figure 5.

Figure 5: Tools for Reading/Constructing Angles



Each of the tools has a specific purpose or is used in a particular way. The protractor, for example, is used to measure and construct angles. You measure an angle by placing the protractor on the lines (or points of lines) that intersect to create the angle. The reading is in a unit called degrees. Degrees are indicated by the symbol "°". There are 360° in a circle and 180° in a straight line. The most important angles with which you must be concerned are the right angle formed by two perpendicular lines (90°), the miter angle (45°) and the straight line (180°).

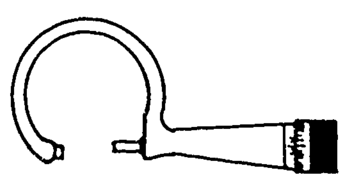
Squares are a second major category of tools related to construction or measurement of angles. The variety of squares include the steel square, the miter square, and the dry-wall square. Each is concerned with right angles or miter angles. Each is scaled so that it can be used to mark distances, to mark a straight edge and to check an angle. The steel square is particularly versatile. Often it has several types of calibration on the tool.

Combination squares and T-bevels are tools used for making straight edges and for checking angles. The handle and blade can be moved so that various angles up to 180° can be laid out. Locking devices secure the handle and the blade. Usually the T-bevel does not include graduations, so it is useful for transfering and marking angles or edges but not for measuring lengths.

Precision Measurement Tools

The most precise measurement tool in common use in the crafts and trades is the micrometer. The micrometer, as illustrated in Figure 6, is used primarily in the metals industries. It permits you to make measurements with much greater accuracy and of much smaller amounts than with other tools.

Figure 6: Micrometer



Precision depends upon the smallest fractional division or graduation used on the measuring instrument. Suppose, for example, that you need to measure the thickness of a needle that fits a valve opening. You would need a measurement instrument much finer or more precise than a ruler, in fact, you probably need a tool that can be used to measure accurately to a thousandth of an inch. Your eye cannot tell that small a difference, but the micrometer can. It is in such instances, where there is little tolerance for error, that micrometers are used.

Conversion To And From Conventional and Metric System Units of Measure

There are instances on most jobs where you will work with both conventional and metric units of measure. Increasingly, as foreign products are marketed in the U.S., as replacement parts for those items are made and used here, and as the U.S. moves toward the metric system, you will need to convert measurements from one system to the other. The following sections discuss conversion charts—conventional and metric—for the primary units of linear measurement, area measure, volume and weight. Each chart is accompanied by a set of example problems. Work the problems to practice applying the concepts and information. Use the charts for reference and work the problems using your multiplication and division skills.

Units of Linear Measure

Linear measure is the most frequently used measure in most industries, work applications, and everyday life. Usually rules or tapes are used to perform the measurement. The conversion of linear metric and conventional units is fairly simple. Equivalent values are depicted in Figure 7 Review the values in the figure and refer to the figure as needed.

Figure 7: Conventional (English)-Metric Linear Conversion Equivalents

1 inch	=	2.540 centimeters
1 foot	=	.305 meter
1 yard	=	.914 meter
1 rod	=	5.029 meters
1 mile	=	1.609 kilometers
1 centimeter	=	.394 inch
1 decimeter	=	3.937 inches
1 decimeter	=	.328 foot
1 meter	=	39.370 inches
1 meter	=	3.281 feet
1 meter	=	1.094 yards
1 kilometer	=	3280.830 feet
1 kilometer	=	1093.611 yards
1 kilometer	=	198.838 rods
1 kilometer	=	.621 miles

Adapted from. A. Sperling and M. Stuart, *Mathematics Made Simple*. Garden City, NY. Doubleday & Co., Inc., 1962.

Work the following problems associated with linear measurement:

1. Express 5 miles in terms of kilometers. Answer: ____________________
2. How many centimeters are there in 3 yards? Answer: ____________________
3. How many kilometers are there in 6.4 miles? Answer: ____________________
4. If a machine part has a length of 16 centimeters, how many inches long is it? Answer. ____________________
5. A new drive shaft had to be turned for a foreign-made truck. The old shaft was 2.3 meters long. How many inches long was the shaft? Answer: ____________________

Answers:

1. = 8.045 kilometers
2. = 274.32 centimeters
3. = 10.24 kilometers
4. = 6.304 inches
5. = 90.551 inches

Units of Area Measure

Square measure or area measure often is used in the construction industry to calculate material needs and costs. It is computed from linear measurement as explained in Chapter 3 of this module. The conversion equivalents of square measure — the outcome of area measurement — are illustrated in Figure 8.

Figure 8: Area Measure Equivalents

1 sq. inch	=	6.452 sq. centimeters
1 sq. foot	=	.093 sq. meter
1 sq. yard	=	.836 sq. meter
1 sq. rod	=	25.293 sq. meters
1 acre	=	4046.873 sq. meters
1 acre	=	.405 hectare
1 sq. mile	=	259.000 hectares
1 sq. mile	=	2.590 kilometers
1 sq. centimeter	=	.155 sq. inch
1 sq. decimeter	=	15.500 sq. inches
1 sq. meter	=	1550.000 sq. inches
1 sq. meter	=	10.764 sq. feet
1 sq. meter	=	1.196 sq. yards
1 hectare	=	2.471 acres
1 hectare	=	395.367 sq. rods
1 hectare	=	24.710 sq. chains
1 sq. kilometer	=	247.104 acres
1 sq. kilometer	=	.386 sq. mile

The hectare is the unit of land measure

Adapted from. A. Sparling and M. Stuart. *Mathematics Made Simple*. Garden City, NY: Doubleday & Co., Inc., 1962.

Work the following problems associated with area or square measurement:

1. Express 3 square feet in terms of square meters. Answer: ____________
2. How many square inches are contained in one square meter? Answer: ____________
3. How many square inches are contained in 16 square centimeters? Answer: ________

Answers:

1. = .279 square meters
2. = 1550.0 square inches
3. = 2.48 square inches

Units of Weight Measure

Weight measure is important in many jobs either because you need to estimate effort and time required to do a job or because you may need to choose among machines to perform a specific task The conversion equivalents of metric and conventional units for weight are presented in Figure 9.

Figure 9: Weight Unit Equivalents

1 grain	=	.065 grams
1 ounce troy	=	31.100 grams
1 pound troy	=	.373 kilogram
1 ounce standard	=	28.350 grams
1 pound standard	=	.454 kilograms
1 short ton	=	.907 tonneau
1 long ton	=	.016 tonneaus
1 gram	=	15.432 grains
1 gram	=	.032 ounce troy
1 gram	=	.035 ounce standard
1 kilogram	=	2.679 pounds troy
1 kilogram	=	2.205 pounds standard
1 tonneau	=	1.102 short tons
1 tonneau	=	.984 long ton
1 tonneau	=	2204.622 pounds standard

Adapted from. A. Sparling and M. Stuart. *Mathematics Made Simple.* Garden City, NY. Doubleday & Co., Inc., 1962.

Work the following problems associated with weight measure:

1. How many ounces (standard) are there in a kilogram? Answer: ____________
2. How many grams are there in a pound (standard)? Answer: ____________
3. How many grams are there in 4 ounces (standard)? Answer: ____________
4. How heavy, in standard pounds and ounces, are 235 grams? Answer: ____________

Answers:

1. = 35.28 ounces
2. = 454 grams
3. = 113.4 grams
4. = 0 lbs. 8.225 ounces

Units of Volume Measurement

Many work applications of measurement require computing volume measures for containers, loads to be moved, and time or cost estimates. Volume measurement, as will be explained in Chapter 4 of this booklet, uses units of cubic measure such as cubic inches, cubic feet or cubic yards. It also can use units of liquid or dry measure called pints, quarts, gallons and bushels. The conversion equivalents of metric and conventional units for volume measure are presented in Figure 10.

Figure 10: Volume Unit Equivalents

1 cu. inch	=	16.387 cu. centimeters
1 cu. foot	=	28.317 cu. decimeters
1 cu. yard	=	.765 cu. meter
1 cord	=	3.620 cu. meters
1 cu. centimeter	=	.061 cu. inch
1 cu. decimeter	=	.035 cu. foot
1 cu. meter	=	1.308 cu. yards
1 cu. meter	=	.276 cord
1 minim	=	.062 milliliters
1 fluid dram	=	3.697 milliliters
1 fluid ounce	=	29.573 milliliters
1 gill	=	118.292 milliliters
1 liquid pint	=	.473 liter
1 liquid quart	=	.946 liter
1 gallon	=	3.785 liters
1 milliliter	=	16.231 minims
1 milliliter	=	.271 fluid dram
1 milliliter	=	.034 fluid ounce
1 liter	=	2.113 liquid pints
1 liter	=	1.057 liquid quarts
1 liter	=	.264 gallon
1 dry quart	=	1.101 liters
1 dry peck	=	.881 dekaliter; 8.81 liters
1 bushel	=	.352 hectoliter; 35.2 liters
1 liter	=	.908 dry quart
1 dekaliter	=	1.135 pecks
1 hectoliter	=	2.838 bushels

Notes:

The cubic meter when used for measuring wood is called a ster.
The liter is used for both liquid and dry measure.
The milliliter is equivalent in volume to a cubic centimeter.

Adapted from. A. Sparling and M. Stuart. *Mathematics Made Simple*. Garden City, NY. Doubleday & Co., Inc., 1962.

Work the following problems associated with volume measurements:

1. Express 14 cubic inches in cubic centimeters. Answer: ____________________
2. Express 27 cubic yards in cubic meters. Answer: ____________________
3. If your truck requires 63 liters of gas to fill the tank, how many gallons did it take? Answer: ____________________
4. If the drum holds 24 bushels of corn, how many liters does it hold? Answer: ________

Answers:

1. = 229.418 cubic centimeters
2. = 20.655 cubic meters
3. = 16.6 gallons
4. = 844.8 liters

Additional Information

For additional information about conversions of units of measure, you may wish to read.

A. Sperling and M. Stuart. *Mathematics Made Simple*. Garden City, NY. Doubleday & Co., Inc., 1962

Most standard high school mathematics text books.

Also, you may find the approximate conversion summary chart included in the appendix of this booklet to be a handy reference.

Self Test Exercises

Work the following problems and check your answers with those in the Appendix. If you answer 75% of the items correctly, continue work in the next chapter. If you score less than 75%, repeat your work in Chapter 2. Use the figures in the chapter for reference charts.

1. How many inches long is a kitchen work surface that is 12′6″ long? Answer: ________
2. Express 75 feet in meters. Answer: ____________________
3. If your truck weighs 2,150 lbs. without gas and 2,275 lbs. with a full tank of gas, approximately how many gallons does your truck hold, assuming gasoline and water weigh the same? Answer: ____________________
4. If an oil drum holds 55 gallons, how many cubic centimeters is the capacity of the barrel? Answer: ____________________
5. Express 15 cubic feet in cubic inches. Answer: ____________________
6. How many gallons are there in 82 liters? Answer: ____________________
7. How many centimeters are there in 3 meters? Answer: ____________________
8. How many inches are there in 14 meters? Answer: ____________________

3. Surface Measurements

Chapter Overview

Purpose:	To insure that each apprentice can determine surface measurements of shapes and figures. An apprentice will gain an ability to compute the perimeter and area of any geometric figure.
Preassessment Score:	Write in the following space the number of correct answers from pretest questions 8–15__________. If you answered at least seven of the questions correctly, skip to Chapter 4. If you missed two or more questions, continue with Chapter 3.
Prerequisites:	Chapters 1 and 2 of this booklet Basic Mathematics module or its equivalent for solving for unknowns, working with fractions and doing multiplication and division.
Resource:	Time—About 60 minutes to completion Material— Pencil, Paper, Ruler
Performance Statement:	At the conclusion of this unit you will calculate and check surface measurements comparable to those you might encounter in the work place.
Standards:	To be successful, you must answer at least 80% of the posttest items correctly.
Activities:	1. Read text, examples and illustrations and commit information to memory. 2. Work questions, examples and problems. 3. Complete and check the self-test exercises and posttest.

Introduction and Objectives

The most important measurements you make on the job are surface measurements. Your ability to calculate the surface measures of areas and perimeters is essential regardless of whether you work in manufacturing, construction, graphics or many services industries. For example, in graphics, you must determine perimeters and areas to cut and print specific sizes of paper. In manufacturing you must measure perimeters and areas in order to size and make machine tool parts. In construction, you must calculate perimeter and area measures to determine material needs and in order to build a structure. In each instance, the surface may be of regular or irregular shape. Regardless, you must be able to find the perimeter and area of the surface with which you are working.

This chapter will teach you the fundamental skills of determining surface measures. When you have completed your work in this unit, you will demonstrate your ability to calculate surface measurements by being able to:

1. Compute surface perimeters and areas of most figures, given the dimension.
2. Check and correct calculations or estimations of surface measures; and
3. Solve problems related to covering surface areas with given amounts of materials.

Perimeters

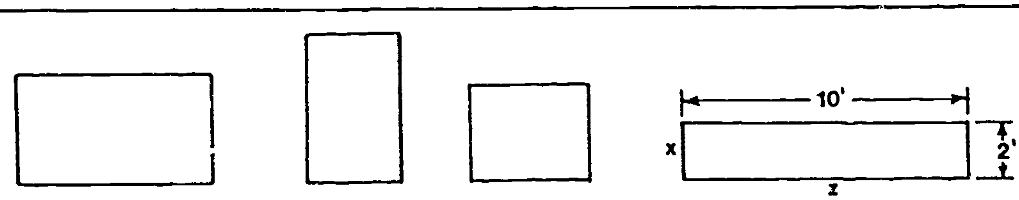
A perimeter of an object is the distance around the object. It is measured in any standard linear unit including miles, feet, inches, kilometers, meters, centimeters or millimeters. Usually it is calculated by adding together the length of the outer edges of the figure for most shapes. For circles and some irregular figures, simple formulas will help you to calculate perimeters.

Most frequently, tools called rules or rulers are used to take linear measurements such as length, width, and height. Rules usually are divided into fractions of inches with the standard division in the United States for metalworking at 1/64" and the standard division for woodworking at 1/16".

Rectangle

The rectangle is the most familiar geometric shape. It is a four sided object and has a right angle or 90° angle at each corner. The page you are reading is a rectangle; most walls and floors are rectangles; even a square is a rectangle. Several rectangles are illustrated in Figure 11.

Figure 11: Common Rectangles

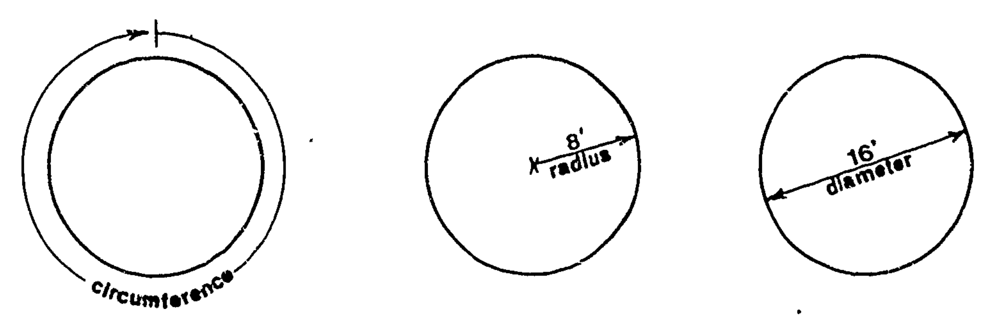


Rectangles have two pairs of sides. Each pair is equal in length, as illustrated in pairs X and Z in Figure 11. To find the perimeter you add together the length of all the sides. For example in Figure 11, you would add the length of the two 10' sides together with the length of the two 2' sides to find that the perimeter is 24 feet. If all four sides were of equal length, you could have found the perimeter by multiplying the length of one side times four.

Circle

The perimeter of a circle is called the circumference. To find the circumference, you must know the diameter or the radius of a circle. The diameter is the length of a straight line that begins on one side, passes through the center and ends at the other edge. The radius is a straight line from the center of the circle to the outer edge. It is equal to one-half the length of the diameter. Figure 12 illustrates a circle with a radius of 8' and a diameter of 16'.

Figure 12: Circle



You must use a formula to determine the circumference of a circle. The formula is:

Circumference (C) = π × Diameter (D)

"Pi", the term written as π, is always used in the formula for finding the circumference of a circle. It is a number called a constant. It does not change, regardless of the size of the circle. It is equal to 3.14 or $3\frac{1}{7}$. It means that the circumference of circle always is 3.14 or 31/7 times longer than the diameter of a circle.

Using the formula, suppose you want to find the circumference of the circle in Figure 12. Recall that the circle has a radius of 8'. You would complete the following steps in the process.

Step 1: Set up formula C = π × D

Step 2: Find the diameter at twice the length of the radius

8 ft. × 2 = 16 ft.

Step 3. Place values into the formula, multiply numbers and solve for the circumference

C = 3.14 × 16 ft.

C = 50.24 feet

The same process in reverse will enable you to determine the diameter or radius of a circle if you know the circumference. To find the diameter, you divide the circumference by π. For example, the diameter of a circle with a circumference of 35 feet is 11.15 feet.

Work Applications

The important thing to remember about work applications of perimeters is that in every case, the perimeter is determined by adding together the length values of all the sides. Actual applications are numerous. For example, they include determining amount of pipe or ducting required to do a job as well as calculating the amount of insulating material necessary to cover the pipe or duct.

Try your hand at solving the several problems on perimeters that follow:

1. What is the perimeter of a triangle that is 7.5 ft. on each side? Answer:__________
2. What is the circumference of a circle that has a diameter of 3 feet, 6 inches? Answer:__________
3. How many feet of electrical wire will be required to encircle a square building that is 12 feet on a side? Answer:__________
4. A carpenter is putting baseboard around a room that is 12 ft. long and 10 ft. wide. The room has 3 doorways, each 3 feet wide that will not be covered. How many linear feet of molding does the carpenter need? Answer:__________
5. Suppose you must enclose an equipment yard with fencing and you have 48 feet of fencing. The yard must be at least 4 feet wide and be rectangular in shape. What

several whole number dimensions might you consider for the pen.
Answer:________________

Answers:

1. 22.5 feet
2. 10.99 feet
3. 48 feet
4. 35 feet
5. 12′ × 12′ or 10′ × 14′

Areas

An area is the number of square units of space on the surface of the figure enclosed by the perimeter. Area calculation utilizes several simple formulas, each of which is suited to a specific geometric shape. Areas are expressed in units of square measure such as square feet, square inches or square meters.

To illustrate the difference between length and area, look at this page. If you were to measure it with a rule, you would find that it is 11" long and 8.5" wide. Its perimeter is 39". Now imagine the page covered by a grid of square boxes, one inch on a side. There would be eleven such boxes, top to bottom, along the side of the page. There would be 8.5 such boxes, side-to-side across the bottom of the page. The page would be covered with rows and columns of boxes. Each box is one square inch If you count the boxes, you will find there are 93.5 square inches on the pages. You also could find this by multiplying the length (11") by the width (8.5"). Ninety-three and one-half square inches is the area of the page.

Rectangle

For rectangles, the formula for determining area is length (l) × width (w) with the result being in units of square measure. For example the area of a rectangular room that is 8′ × 12′ is 96 square feet Regardless of the actual shape of the rectangle, the area always is found by multiplying the length time the width.

Conversely, if you know the square measure of the area and the length of one side, you can divide the area by the length of one side to find the length of the other side. For example, if the area of a rectangle is 180 sq. ft. and you know one side is 10 feet long you can divide 180 sq. ft. by 10 ft. to find that the other side is 18 feet long.

Solve the following practice problems:

1. What is the area in square feet of a room 22′3" long and 12′ wide?
   Answer:________________
2. What is the length of a room that contains 252 square feet and is 18 feet wide?
   Answer:________________

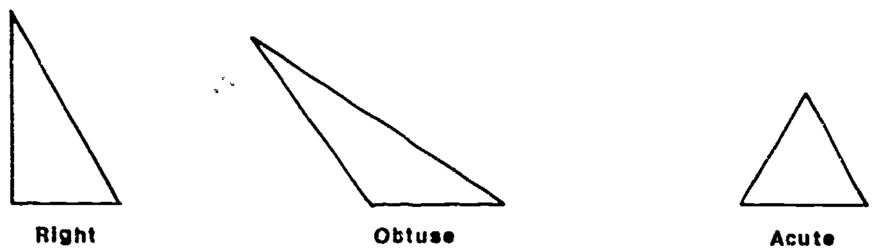
Answers:

1. = 267 sq. feet
2. = 14 feet

Triangle

The triangle is a figure with 3 sides, each of which is a straight line and intersects one other line at one of three angles. The three kinds of triangles are illustrated in Figure 13. They are named the right triangle, the obtuse triangle, and the acute triangle. The name of the type of triangle describes the major angle of the triangle. In a right triangle, two lines intersect in an exact perpendicular thus creating a right angle. In an obtuse triangle, two lines intersect such that one angle is greater than that of a right triangle. In an acute triangle, none of the angles is as large as a right angle. The total degrees of the angles in a triangle always equal 180°.

Figure 13: Kinds of Triangles

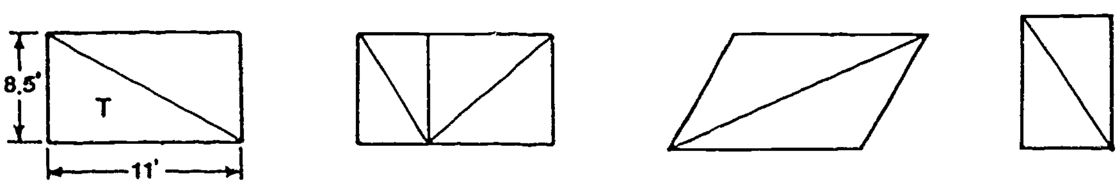


The area of a triangle is found by using the formula:

A = ½ base (b) × height (h)

A = ½ bh

Figure 14: Relationship of Rectangle to Triangle



This formula is based on the notion that a triangle is nothing more than half of a rectangle as illustrated in Figure 14. Since the area of a rectangle is found by multiplying its base times its height, a triangle uses the same idea, but takes only half the amount.

The triangle labeled T in figure 14 is a good example of how you use the formula for area of a triangle. Note that the base is 11 feet and the height is 8½ feet long. Using the formula for area of triangle, you will find that the area of the triangle is 46.75 square feet:

A = ½ base × height

A = ½ 11' × 8.5'

A = ½ × 93.5 square feet

A = 46.75 square feet

Work the following practice problems:

1. What is the area of a triangular sheet of metal with a base of 12 feet and a height of 24 feet 3 inches? Answer:____________
2. If a triangle contains 48 square feet and has a base that is 3 feet long, what is the height of the triangle? Answer:____________

Answers:

1. 145.5 square feet

2. 32 feet

Circle

To find the area of a circle, you again will use a formula that contains the constant, π, as well as the value of the radius. The specific formula is written as:

Area = $\pi \times r^2$

Recall that the value of π is 3.14 or 3-1/7. the r stands for radius. The r^2 means the radius is squared. The radius squared means that you multiply the radius of the circle under consideration by itself before multiplying the squared product by 3.14. The symbol for squaring is a 2 that is placed slightly above and following the number to be squared. For example, the value of 2 squared $(2)^2$ is 2 times 2. The value of $(4)^2$ is 16. The value of $(10)^2$ is 10 times 10, or 100.

Suppose you want to find the area of a circle that has a diameter of 16 feet. You would work the problem in the following steps:

Step 1:

Set up the equation:

$A = \pi r^2$

Step 2:

Find the radius by dividing the diameter by two:

r = d/2

r = 16/2

r = 8 feet

Step 3:

Fill the known values to the equation. Remember that π is equal to 3.14:

$A = 3.14 \times 8^2$

Step 4:

Perform operations to solve for square feet by multiplying:

$A = 3.14 \times 64$

A = 200.96 square feet

Work the following several problems about the area of circles:

1. What is the area in square inches of a circle that has a diameter of 2 feet 4 inches?
   Answer:________________
2. What is the radius in feet of a circle that contains 78.5 square feet?
   Answer:________________

Answers:

1. 615.44 square inches

2. 5 feet

Cones, Spheres and Sectors

Occasionally in construction and manufacturing trades you will need to determine the area of a cone. A cone is a figure that may be of any size and generally has a shape ranging from that of an ice cream cone to a pyramid. The surface area of a cone is called the lateral face or surface. An element is a straight line on the surface from the top of the cone to the point on the circumference of the base of the cone, the base is most often a circle. The surface area is found by calculating one-half the product of the length of an element and the circumference of the base. The formula can be written as.

A = ½ element × circumference

A = ½ E × C

As an example, consider a situation where an element of the cone is 12 feet and the radius of its circular base is 6 feet. You would perform each of the following steps:

Step 1:

Find the diameter of the base:
diameter = 2 × radius
d = 12 feet

Step 2:

Solve for circumference of the base:
$C = \pi d$
C = 3.14 × 12 feet
C = 37.68 feet

Step 3:

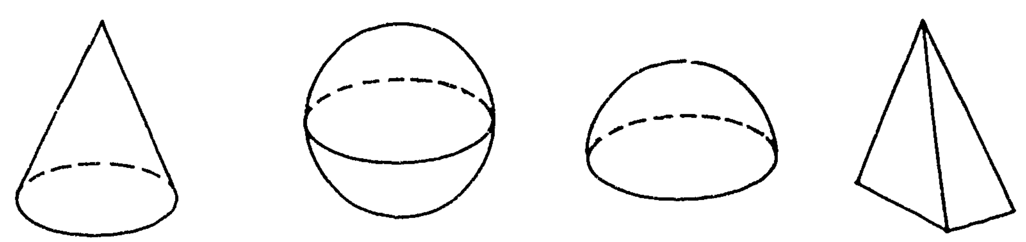
A = ½ EC
A = ½ 12′ × 37.68′

Step 4:

Perform calculations:
A = 226.08 square feet

More frequently than solving for areas of cones, you are likely to need to calculate the area of a sphere or a dome or hemisphere (half a sphere). A sphere is simply a round ball or globe as noted in Figure 15.

Figure 15. Spheres and Cones



The formula is a modification of the formula for calculating the area of a circle. It is written as.

Area = $2 \pi r^2$ (for the area of a hemisphere)

Area = $4 \pi r^2$ (for the area of a sphere)

You use the formula for areas of spheres and hemispheres like the other area formulas in that you multiply the length values by π as well as by the constant 2 or 4, depending on whether it is a hemisphere or sphere. In addition, the formulas again square the length of the radius. This means, for example, that if you wanted to determine the area of a hemisphere that had a radius of 15 feet, you would square 15, and multiply by the constants 2 and 3.14. The result is an area calculation of 1413 square feet:

$A = 2 \pi r^2$
$A = 2 \pi 15^2$
$A = 2 \times 3.14 \times 225$
$A = 1413$ square feet

A sector is a portion of a circle located between the circumference and the center and within a given angle. A sector is like a piece of circular pie. The area of a sector is equal to the area of the circle times the fraction the sector is of the total circle. You find this fraction by dividing the degrees of the sector's angle by the total degrees in a circle (360°):

$$\text{Area} = \frac{°\text{Sector}}{360°} \times \text{Area of Circle}$$

Calculate the answers to the following practice problems about spheres, sectors, hemispheres, and cones:

1. What is tha area in square feet of a hemisphere with a radius of 10 feet?
   Answer:________________
2. What is the surface area in square feet of a sphere with a diameter of 10 feet?
   Answer________________
3. What is the area in square feet of a cone with a circumference of 4 feet and an element height of 10 feet?
   Answer:________________
4. What is the area of a sector that has radii for sides and an angle of 45°, given that the area of the circle is 154 square feet and the radius is 7'? Answer:________________

Answers:

1. = 628 square feet
2. = 314 square feet
3. = 20 square feet
4. = 19.25 square feet

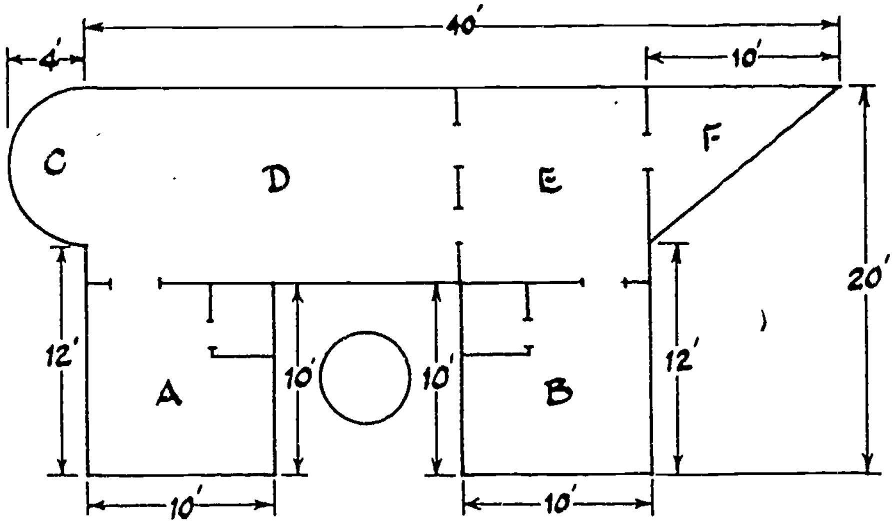
Using Area Measures

Area measures are used in most apprenticable trades for several purposes. For example they are used to estimate and buy amounts of materials necessary to do a job. Also, they are used to estimate materials and labor costs associated with performing a particular piece of work. Take, for example, a case when you want to calculate how many acoustic ceiling tiles that measure 9" square will be required to finish the ceiling of the social hall at the Moose Lodge. The dimensions of the hall are 55 feet long by 40 feet wide.

In order to work this problem you would first convert the hall dimensions to inches, finding that the new dimensions are 660 inches by 480 inches. Next you would divide each of the hall dimensions by the size of single ceiling tile 9". You will find that the ceiling is 73.33 (rounded off to 74) tiles long and 53.33 tiles (rounded off to 54) wide. Next, these new dimensions of length and width in terms of tiles are multiplied to answer the question about how many tiles are required to cover the ceiling. The answer is 3996 tiles. If tiles come in cases of 50, this means you would have to purchase 80 cases to complete the ceiling, assuming no waste.

Area also is used to estimate costs. For example, assume the average cost for home building in the Seattle area in 1982 was $32 per square foot finished. If a prospective buyer was looking at the floor plan in Figure 16 and wanted a rough estimate of the cost, area calculations would be necessary to derive the estimates.

Figure 16: Sample Floor Plan



In this particular example, you must calculate the area of each smaller block of space and add the totals together. Therefore, you would solve for areas of rectangular, circular and triangular areas. The end result would be total square footage. This total square footage could be multiplied by the cost per square foot to derive the estimate. For the example displayed in Figure 16 the total square footage is 565 square feet. The estimated cost for the house in Figure 16 is then $18,080.00.

Area also is used to estimate labor and materials costs for specific projects. Take for example, the case of a painter who was bidding on a job to paint a government water tower. He knew (1) that he could cover about 300 sq. feet an hour on irregular surfaces with his sprayer; (2) that the diameter of the water tank was 50 feet, (3) that a gallon of paint covered 1000 square feet; (4) that a gallon of paint cost $25.00. and (5) that his labor charge was $15.00/hour. He developed his bid int he following steps.

Step 1:

Solve for the surface area of the sphere:
$A = 4 \pi r^2$
$A = 4 \times 3.14 \times (25)^2$
$A = 12.56 \times 625$
A = 7850 square feet

Step 2:

Solve for number of gallons of paint needed:
Gallons = 7850 sq. ft. ÷ 1000 sq. ft./gallon
Gallons = 7.8 rounded to 8

Step 3:

Solve for time needed to paint:
Time = 7850 sq. ft. ÷ 300 square feet an hour
Time = 26.16 hours

Step 4:

Solve for cost of paint:
Paint Cost = 8 gallons × $25/gallon
Paint Cost = $200

Step 5:

Solve foı cost of labor:
Labor Cost = 26.16 hours × $15/hr.
Labor Cost = $392.40

Step 6:

Add estimated materials and labor costs for bid:
$392.40 labor
$200.00 paint
592.40 estimated labor and paint costs

Solve the following several problems related to using area estimates in the trades:

1. Carpeting costs $8.95 square yard and is sold only in square yard amounts. You need to cover a room that measures 12′ × 21′. How much will your carpet cost?
   Answer:________________
2. Rustproofing paint is only sold by the gallon, costs $20/gallon and each gallon covers 1000 square feet of surface. You need to order enough paint to paint sixteen steel beams with the dimensions of 20′ × 1.6′ × 8″.
   How many gallons of paint will you need and how much will it cost?
   Answer________________________and________________________

   How many gallons of paint will you need and how much will it cost?
   Answer:________________________and________________________

Answers:
1. =. $250.60
2. = 2 gallons and $40.00

Additional Information

For additional information about surface measurements, you may wish to read:

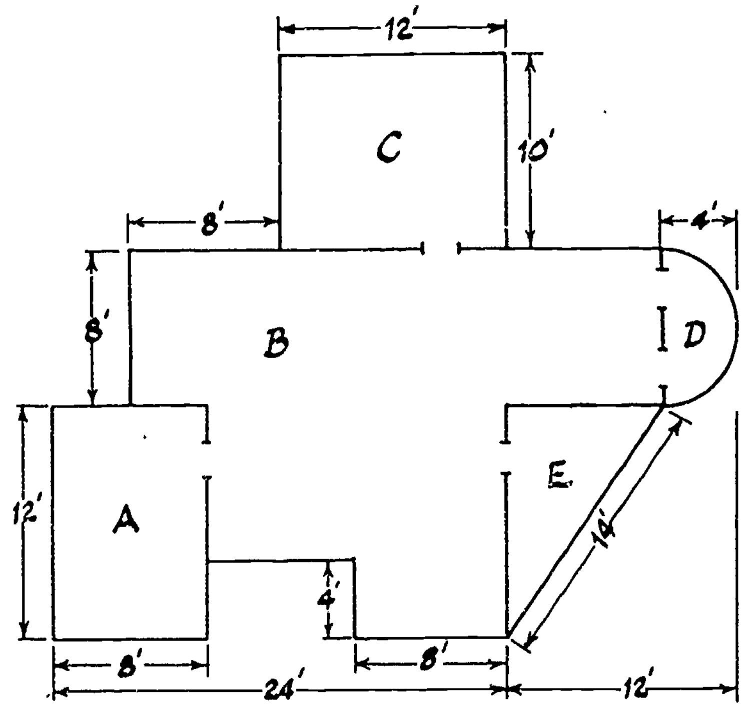
L.A. Ringenberg. *Informal Geometry*. New York: John Wiley & Sons, Inc, 1967.
H. Eves. *A Survey of Geometry*. Boston: Allyn & Bacon Co., 1972.
C.T. Olivo and T.P. Olivo. *Basic Mathematics Simplified*. Albany, NY: Delmar Publications, 1972.

Self Test Exercises

Work the following problems and check your answers with those in the Appendix. If you answer 75% of the items correctly, continue the work inthe next chapter. If you score less than 75%, repeat your work in the chapter.

Examine the shape in Figure 17 and solve problems 1-4 based on the information.

Figure 17: Self-Test



1. What is the perimeter in feet of the total illustration?
   Answer: ________________
2. What is the area in square feet of area C? Answer: ________________
3. What is the area in square yards of area D? Answer: ________________
4. At a cost of $46/square foot, finished, how much would you estimate that it wou' l cost to build the structure?
   Answer: ________________
5. A bathroom floor is tiled with ceramic tiles that measure 1″ × 1″. The floor contains 2660 of these tiles. What is the area of the floor in square feet? Answer: ________________
6. A rectangle lawn measures 110 feet × 140 feet. The lawn is being seeded with grass and the directions on the box of seed says that one pound of seed covers 250 square feet. How many pounds of seed are needed andhow much will it cost at $3.95 a pound.?
   Answers: ________________ and ________________

4. Volume and Weight Measurement

Chapter Overview

Purpose:	To insure that each apprentice can determine measures of weight and volumes. An apprentice will gain an ability to compute the weight and volume of any geometric figure.
Preassessment Score:	Write in the following space the number of correct answers from pretest questions 16–22____________. If you answered at least six of the questions correctly, skip to Chapter 5. If you missed two or more questions continue to work through this chapter.
Prerequisites:	Chapters 1 and 2 of this booklet Basic Mathematics module or its equivalent for solving for unknowns, working with fractions and doing multiplication and division.
Resource:	Time—About 45 minutes to completion Material— Pencil, Paper
Performance Statement:	At the conclusion of this unit you will calculate and check weight and volume measurements comparable to those you might encounter in the work place.
Performance Measure:	A fifteen-minute paper and pencil posttest, to be taken in the related subjects setting.
Standards:	To be successful, you must answer at least 80% of the posttest items correctly.
Activities:	1. Read text, examples and illustrations and commit information to memory. 2. Work questions, examples and problems. 3. Complete and check the self-test exercises and posttest.

Introduction and Objectives

Weight and volume, like perimeters and areas, are frequently used measures on the job. Weight is a measure of the strength of the pull of gravity on an object. It can be used in calculating volume. Volume is a measure of three dimensional space, sometimes called a solid.

Measures of weights and volumes are important on the job in situations like the selection of the correct machine to lift or move materials; construction of holding containers based upon use requirements; construction of supports; production of parts; and selection of materials and design for stress.

At the conclusion of your work in this unit you will demonstrate your understanding of measures of weight and volume by being able to:

1. Compute volumes and weights of most figures, given essential information;
2. Check and correct calculations or estimations of volume and weight measures,
3. Solve problems related to use of volume and weight measures on the job

Principles, Examples and Applications

Weight

When you weigh something, you determine how heavy something is by measuring the object through comparison with a standard. You can do this either by balancing the object against a standard weight or by stretching a spring. In either instance, the tool used to weigh an object is called a scale. Scales come in all sizes and shapes. They can be used with objects of any shape or size and with quantities as small as fractions of grams an as large as tons.

For purposes of this module, and indeed in your everyday work experience, the terms mass and weight may be considered to be the same thing and usually are called weight. The only time the difference would be important is at very high altitudes. The units of weight in the conventional system are the ounce, the pound and the ton. The units of weight in the metric system are the gram, the hectogram, and the kilogram.

In many ways the metric measure of weight is easier to use because the weight and volume measures are related in whole number terms. Specifically, 1 gram (weight) of water is equal to 1 cubic centimeter (volume) of water as well as to 1 milliliter (volume) of water. In terms of comparing conventional and metric weight units, remember that one ounce is equal to 28.35 grams, that one pound is equal to .45 kilograms and that one ton is equal to 900 kilograms.

How do you determine how sturdy storage areas for containers must be? For example, how would you calculate the required strength of a storage platform on which you had to stack full cube-like containers that measure three feet on a side and weigh 1500 pounds each? You know that the sturdiest platform you have will support only 175 pounds per square foot.

This is a question of volume and weight. More specifically, it is a question of density, which is the weight per unit volume of a material. You find density by using the formula: Density = Weight/Volume. For the above problem you would substitute the known values for weight and volume into the formula and solve for density:

Weight = 1500 pounds

Volume = 3′ × 3′ × 3′ = 27 cubic feet

$$\text{Density} = \frac{\text{Weight}}{\text{Volume}}$$

$$= \frac{\text{1500 Pounds}}{\text{27 Cubic Feet}}$$

= 55.6 Pounds/Cubic foot

The density is equal to 55.6 lbs./cubic ft. Given the shape of the container, this means that each square foot of platform has to support 3 cubic feet of container, or about 167 pounds. This amount of weight is barely within the 175 pounds per square foot tolerence limit of the platform.

Specific gravity is the way you determine the weight of a given volume of a particular material. You compare the weight of a volume of the particular material in question to the weight of an equal volume of water. This means, for example, you would divide the weight of a cubic foot of alcohol by the weight of a cubic foot of water to find the specific gravity. If you do this, you will find that alcohol has a specific gravity of .79 and that a cubic foot of it weighs about 49 lbs. A cubic foot of water weighs about 62.5 pounds.

Specific gravity has important work applications for safety. For example, alcohol, benzene, gasoline, and turpentine all have a specific gravity of less than 1.0 and therefore float on water. That is why an oil fire spreads if you throw water on it. Other substances, particularly acids, have a specific gravity just greater than 1.0. This means they can be washed away and neutralized by water since they will sink beneath the surface of water. However, their specific gravity is close enough to that of water that it takes generous amounts of water to cover, dilute and flush away acid.

Solve the following practice problems related to weight and volume:

1. If you have a volume of water that measures 1200 cubic feet that has a density of 62.5 lbs. per cubic foot, how much does the water weigh? Answer:________________
2. If a railroad car measuring 14′ × 4′ × 6′ is completely filled with sulpher—a material with a specific gravity of 2— what is the weight of the sulpher in the car? Answer?________________

Answers:

1. = 75,000 lbs.
2. = Approximately 42,000 lbs.

Volume

Have you ever wondered how much water was contained in a reservoir or how much silage was held in a silo? If you have you were thinking about volume. Volume is the amount of space occupied by an object. It can be expressed in units of cubic measure such as cubic inches, cubic yards and cubic feet. Also, it can be expressed in units such as gallons, quarts ounces and bushels. Volume is measured by calculating the number of times that the unit you are using to measure goes into the subject or object you are measuring. For example, if you are measuring in cubic inches and are examining a room, the question is how many single cubic inches are contained in the room, given the dimensions of the room in inches.

The two major types of units of measure for volumes—cubic feet (or inches) and gallons or bushels—can be compared through conversion. Standard conversion amounts for these units are:

1 cubic foot is equal to 7.48 U.S. gallons or 7.5 gallons
1 gallon is equal to 231 cubic inches
1 struck bushel is equal to 2150.5 cubic inches
1 struck bushel is equal to 1.24 cubic feet
1 cubic foot is equal to .8 struck bushels

Rectangles and Squares

To calculate the volume of a figure that contains all right angles, such as a cube, rectangle or square, you multiply the length, width and height dimensions of the figure together, once they are all in the same unit of measure. So, for example, to find the volume of a rectangular box that is 4′ long, 2′ wide and 6 inches high, you would convert each dimension to the same unit of measure such as feet or inches. Then you would multiply the dimensions together. For the rectangular box described, the cubic measure would be 4′ × 2′ × .5′ which equals 4 cubic feet. In inches you would have, 48″ × 24″ × 6″ or 6912 cubic inches. Notice that you also can find the third dimension of a rectangular solid when the other two dimensions and the cubical value are given. To do this, you simply divide the cubical value by the product of the two dimensions that you know.

The applications of rectangular volume calculations on the job are numerous. Storage bins and reservoirs for water and other materials must be built to specification or to function. Frequently in building to function, you must determine or calculate size of the receptacle. This requires working with volume, both in cubic units of measure and perhaps in liquid and solid units of measure.

Solve the following practice problems:

1. What is the volume in cubic inches of a rectangular solid that is 6 feet long, 16 inches high and 3'6" wide? Answer?_______________
2. If a rectangular storage bin measures 18' × 12' × 12', how many struck bushels of wheat would it hold? Answer:_______________

Answers:

1. = 48,384 cubic inches
2. = 2090.3 struck bushels

Regular Shaped Objects

In some regular shapes, the ends or top and bottom of the object are exactly alike, on opposite sides of the figure and parallel. If the lines that are the sides of the object are straight and parallel to each other, you can find the volume by first finding the area of one end, top or bottom and then by multiplying that area by the height of the object. Figure 18 illustrates some of the objects whose volume can be determined in this way. For example, the cylinder has a radius of 6" and is 4' long. You would solve for volume with the following steps:

Step 1: Solve for area of circular end:

$A = \pi r^2$

$A = 3.14 \times 6^2$

A = 113.04 square inches

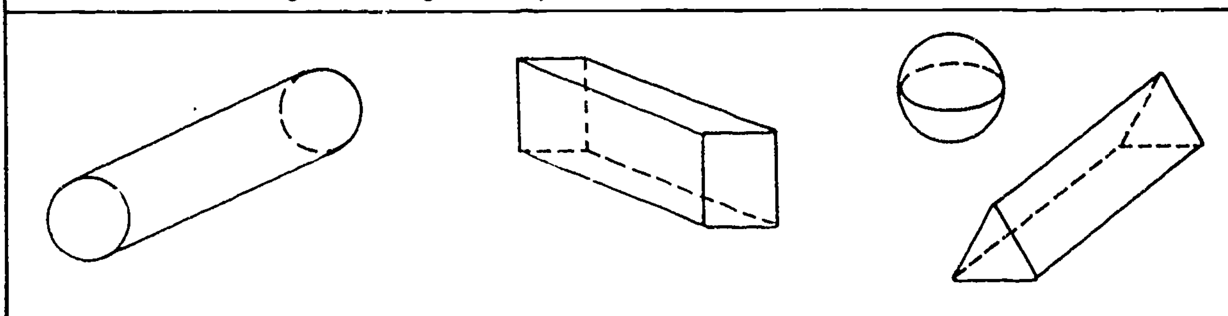
Step 2: Solve for volume of cylinder:

$V = a \times h$

V = 113.04 square inches × 4' (48")

V = 5425.92 cubic inches

Figure 18: Regular Shaped Objects For Volume Calculations



Sphere

The volume of a sphere is calculated by using the formula:

$V = 4/3\ \pi r^3$

Remember that r stands for radius. In this case, rather than squaring the radius, you must cube the number. This means multiplying the radius by itself three times. For example, if you wanted to know the volume in cubic inches of a sphere with a radius of 8 inches you would set up the formula as:

$$V = 4/3 \times 3.14 \times 8^3$$

and solve for V. You would find that the volume in cubic inches was 2143.57 cubic inches.

Solve the following practice problems associated with volume of a sphere:

1. What is the volume in cubic feet of a spherical storage tank that measures 20 feet in diameter? Answer:________________
2. If the interior of a cube is 1 foot, what is the volume of the largest sphere it will hold? Answer:________________
3. How many gallons can be stored in a sphere that measures 12 feet in diameter? Answer:________________

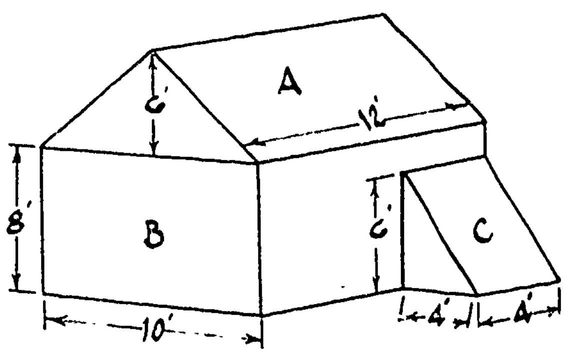
Answers:

1. = 4186.67 cubic feet
2. = 904.32 cubic inches
3. = 6764.31 gallons

Irregular Shapes

To find the volume of irregular shaped objects like those illustrated in Figure 19, you must find the volumes of the component parts. After finding the space of the smaller, more uniform shapes, you can add together the different volumes of the component parts to derive total volume.

Figure 19: Irregular Shapes



This means, for example, that you would solve for the volume of shapes A, B, and C in Figure 19 and sum them to find the total value. When you add the volume of each smaller unit together, you find the total volume of the object to be 1368 cubic feet. If you wanted to convert this space to bushel capacity, you would divide the total cubic feet by the space required for a single bushel, 1 24 cubic feet, to find that the total number of bushels that could be held in the example structure. The answer for this problem is 1103 bushels.

Additional Information

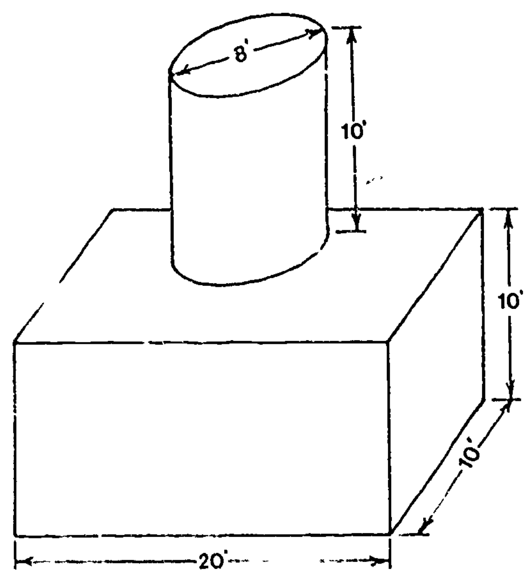
For additional information about the information in this chapter, you may wish to read or refer to:

L.A. Ringenberg. *Informal Geometry*, New York: John Wiley & Sons, Inc., 1967.
H. Eves. *A Survey of Geometry*, Boston: Allyn & Bacon Co., 1972

Self Test Exercises

Answer the following questions in the space provided check your answer with the Self-Test answers located in Appendix. If you answer 75% of the items correctly, continue work in Chapter 5. If you score less than 75% repeat your work in this chapter.

1. What is the volume in cubic inches of a hemisphere 6′ in diameter?
   Answer:________________
2. How many cubic yards of concrete will be required to pour an 18″ concrete slab for a basement if the basement measures 33′ × 18′?
   Answer:________________
3. What is the volume in gallons of a cylinder that is 14.5 feet long and has a diameter of 6′? Answer:________________
4. What is the volume in cubic feet of an 8″ cube? Answer:________________
5. How many cubic inches are there in 20 gallons? Answer:________________
6. Calculate the volume of the object depicted below: Answer:________________



5. Accuracy and Precision

Chapter Overview

Purpose:	To insure that each apprentice has a working knowledge of the measurement terms of accuracy and precision. An apprentice will gain an ability to reason the degrees of accuracy and precision of various measures.
Preassessment Score:	Regardless of your preassessment score, you need to work through this chapter.
Prerequisites:	Chapters 1, 2, 3 and 4 off this booklet. Basic Mathematics module or its equivalent for doing multiplication and division.
Resource:	Time—About 20 minutes to completion Material— Pencil, Paper
Performance Statement:	At the conclusion of this unit you will explain and employ the rules of accuracy and precision in making measurement calculations.
Performance Measure:	A ten-minute, paper and pencil posttest, to be taken in the related subjects setting.
Standards:	To be successful, you must answer at least 80% of the posttest items.
Activities:	1. Read text, examples and illustrations and commit information to memory. 2. Work questions, examples and problems. 3. Complete and check the self-test exercises and posttest.

Introduction and Objectives

Measurement is the science of approximation. The approximation is based upon your use of a tool or instrument with which you can determine a reasonable estimate of a quality of the material being measured. However, there are many possible places for error to occur when making a measurement. The two most important causes of error are an error in the calibration or graduation of the instrument or an error in your use of the instrument. In this chapter you will consider two important ideas dealing with the exactness of a measure— accuracy and precision—as well as the notion of proportion. When you have completed your work you will demonstrate your competence by being able to:

1. Indicate the number of significant figures in numbers, round-off according to the appropriate rules, and indicate error estimates.

Principles, Examples and Applications

Precision

Precision means the exactness of the amount being measured. It assumes that the material being measured can be counted and subdivided into parts on some predetermined scale. Moreover, it is based upon the calibration or graduation of the scale being used to make the measurement, because the measurement can only be expressed in terms of the smallest unit onthe instrument used. Therefore, if your rule is graduated into 1/8 inches as its smallest unit of measure, then your measurement is exact to the nearest 1/8 inch. If your rule is graduated into ¼ inches as its smallest unit of measure, then your measurement is exact to the nearest ¼ inch. If your ruler is graduated into 1 inch units as its smallest units of measure then your measurement is exact to the nearest 1 inch.

Obviously, any measurement is an estimate at best. For example, if you are using a ruler that is graduated into 1/8 inches and you measure a board that you find to be 6' 1-3/8" long. This means the exact length of the board actually lies between 6' 12/8" and 6' 14/8". This means the exact length of the board lies within this ¼" range between 6' 1¼" and 6' 1½" and the best estimate is 6' 13/8". Likewise, if you weigh a cask of nails on a scale that is calibrated in 1 pound units and find it to be 110 lbs., it is assumed that the weight is approximately 110 lbs. The weight may be anywhere from 109 to 111 lbs. The calibration of the instrument will permit no finer measure.

It is this need for additional precision—the need for a finer measure—that causes machinists to work with a micrometer. Machine parts frequently have less tolerance for variance in size than materials for which the quality standard is the trained eye.

The standard rule of precision is to compensate for possible error in either the instrument graduation or in its use by working on the assumption that the possible amount of error is plus-or-minus one calibration/graduation value on either side of the measured value. This can be written using the notation ±. It means, for example, that the instance of weighing the nails, the measure could have been written as 110 ± 1 lb. or the weight ranged from 109 lbs. to 111 lbs.

What is the precision of the following measures?

	Measure	Range	Possible Error
1.	1024 lbs.		
2.	6'6"		
3.	23 yards 11 inches		
4.	8 1/32"		

Answers

Range	Possible Error
1023-1025 lbs.	± 1 lb.
6'5"-6'7"	± 1 inch
23 yards 10"-23 yards 12"	± 1 inch
8"-8 1/8"	± 1/8

Accuracy

Accuracy is a measure of the confidence you have that your use of a measure in making a computation is without error. It is determined by the number of significant figures in the numbers with which you are working. Significant figures are counted from the left in any number and stop one short of the last number in a measure. In other words, the significant figure recognized that the smallest calibration of a measure may be off within a certain range. Therefore, if a board was measured as 6.78 feet or 6 9 3/32' long, in terms of significant figures, only the 6.7 feet or the 6'9" would be considered in performing calculations.

Stated differently, the idea of significant figures is a rounding-off for performing calculations. It is rounding-off according to certain rules. The basic rule is that when you multiply or divide, you never have more significant figures in the answer than there are in the least accurate measurement So, for example, if there are three significant numbers in the least accurate measurement, there should be only three significant numbers in the answer.

To illustrate with an example, say you measured a box and wanted to determine its volume in cubic inches. Your ruler measures to ¼" graduations. The dimensions of the box are 2'4½" long × 6" wide × 1 11" high. If you multiply the dimensions in inches (28.5" × 6" × 23") you get an answer of 3933 cubic inches. Using the rule of significant numbers, you would only count th. significant numbers. This means the volume would be rounded off to 3930 inches for purposed of estimation

Try your hand at answering the following questions:

1. How many significant numbers are there in 16.42? Answer: ____________
2. How would you round off the answer to 3.4 × 2.16? Answer: ____________

Answers:

1. 3
2. 7.34 ounded off to 7.3 because 2 significant figures is the number in the least accurate measure

Additional Information

For additional information on the topics of accuracy and precision, it is recommended that you read any standard high school mathematics text on the topics.

Self Test Exercises

1. What is the range and possible error of the following measures?
   (a) 6.47 feet
   (b) 2.457 lbs.
   (c) 26 3/4 inches
2. Solve the following problems and round-off according to significant figures:
   (a) 3.47" × 3.5" =
   (b) 15.25' × 26.5' =

6. Appendix

Answers to Self-Assessment Pretest

1. 91.4 meters
2. 30.48 centimeters
3. 59.02 kilograms
4. 48.96 cubic meters
5. 10.04 gallons
6. 16.896 feet
7. 162 inches
8. 49 feet
9. Approximately 265 to 269 square feet
10. 21.98 feet
11. 314 square feet
12. a.
13. 36 square feet
14. 760 shingles
15. $4,800
16. 432 cubic feet
17. 46,852 cubic yards
18. 1,000 cubic feet
19. 423.9 cubic inches
20. 16.956 gallons
21. 9 feet
22. 135 cubic feet

Self-Test Answers

Chapter 2: Units and Tools of Measurement

1. 150 inches
2. 22.875 meters
3. 15 gallons
4. 208,175 cubic centimeters
5. 25,920 cubic inches
6. 21.664 gallons
7. 300 centimeters
8. 551.18 inches

Chapter 3: Surface Measurements

1. Approximately 130 feet
2. 120 square feet
3. Approximately 2.79 square yards
4. Approximately $30,963.00

5. 18.47 square feet
6. 61.6 lbs. and $244.90

Chapter 4: Volume and Weight Measurements

1. 97,666 cubic inches
2. 33cubic yards
3. 409.77 cubic feet and 3073.28 gallons
4. .296 cubic feet
5. 4620 cubic inches
6. 2502.4 cubic feet

Chapter 5: Accuracy and Precision

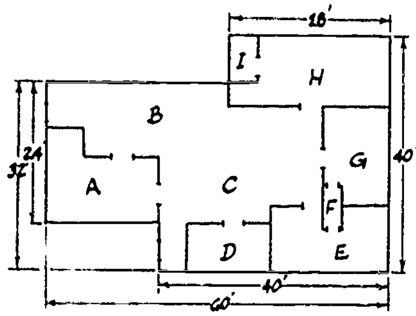
1.a. 6.46′ to 6.48′ ±.01′
1.b. 2,456 lbs. to 2,458 lbs. ± 1 lb.
1.c. 26½″ to 27″ ±½″
2.a. 12.1 square inches
2.b. 404.1 square feet

Posttest

Directions. Answer the following questions and check your answers that follow. You may use the Approximate Conversion chart at the end of this chapter in your calculations. If you score 80% or better, continue your work in the next booklet. If you score less than 80%, repeat the portions of this module with which you had difficulty.

1. If a cylinder measures 4′ tall and has a diameter of 3′, how many gallons of water will it hold? Answer:________________
2. How many cubic yards of earth must be removed from a basement that measures 30′ long, 22′ wide and 8′ deep? Answer:________________
3. If a machine part measures 28 centimeters in length, how long is the part in inches? Answer:________________
4. A case of tiles contains 50 tiles and cost $9.50. Each tile measures 7″ square. What will it cost to tile an area that is 20 feet long and 8½ feet wide? Answer:________________
5. What is the perimeter of a circular wood disc with a radius of 3 feet? Answer________________
6. How many inches long is a board that is 14.25 feet in length? Answer:________________
7. If the weight capacity of a bridge is 3¾ tons, how many pounds will the bridge hold? Answer:________________
8. Suppose scaffolding will support 250 lbs. per square foot and you must place a barrel weighing 1000 lbs. with the dimensions of 3′ diameter and 8′ tall on the scaffolding. What tolerance is required to support the barrel? Answer:________________
9. If you put 96 liters of gas into your truck's tank, how many gallons did you buy? Answer:________________
10. A crate weighs 20,000 kilograms. How many pounds does it weigh? Answer:________________

Examine the drawing below and answer questions 11, 12, 13, 14 and 15 based upon the drawing.



11. What is the perimeter of the figure? Answer: ____________
12. What is the area in square feet of the figure? Answer: ____________
13 Given that the total square footage of bathroom floors is 64 square feet, how many 3" square tiles will be needed to cover the floor? Answer: ____________
14. Assuming 8 foot ceilings throughout how many cubic feet of air must be cooled and heated? Answer: ____________
15. At a finished cost of $42/sq. foot, how much would it cost to build the structure? Answer: ____________
16. How much does the water in a swimming pool weigh if the pool is 6' deep, 10' wide and 16' long? Answer: ____________
17. Round off to significant numbers the product of 16.2' × 15'. Answer: ____________
18. What is the precision of the number 50.6'? Answer: ____________
19. What is the volume in square feet of a box that measures 12' × 10' × 9'? Answer: ____________
20. How many boards of 8" in width will it take to panel a room on four sides that is 19' × 14'? Answer: ____________

Answers to Posttest

1. 211.95 gallons
2. 195.55 cubic yards
3. Approximately 11 inches
4. $104.50 for tile (remember that estimates are based on whole tiles)
5. Approximately 19 feet
6. 171 inches
7. 7,500 pounds
8. Approximately 140-145 pounds per square foot
9. Approximately 25 gallons
10. 44,400 pounds
11. 200 feet
12. 1984 square feet
13. 1,024 tiles will be needed
14. 15,872 cubic feet
15. Approximately $83,328
16. 600,000 pounds
17. 240 square feet
18. $\pm.1'$
19. 1080 cubic feet
20. Either 99 or 100 boards

APPROXIMATE CONVERSION CHARTS

FROM METRIC TO CONVENTIONAL

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Farenheit temperature	°F

FROM CONVENTIONAL TO METRIC

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^2	cubic yards	0.76	cubic meters	m^2
		TEMPERATURE (exact)		
°F	Farenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Taken From:

The New York State Department of Education. *Mathematics. A Core Curriculum of Related Instruction for Apprentices*. Albany, NY: State Department of Education, 1976, p. 19.