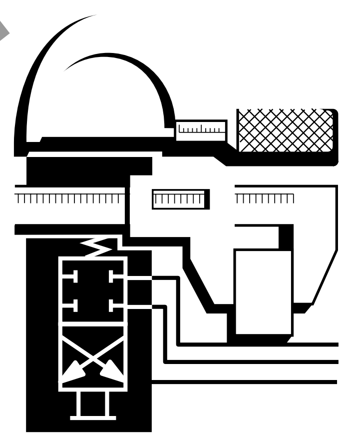
Table of Contents

09-1

MAKING MEASUREMENTS

Lesson One

Units of Measurement



TPC Training Systems

10401

Lesson

1 Units of Measurements

TOPICS

Kinds of Units
Length
Area
Volume
Angles
Time
Speed and Velocity
Mass and Weight
Force
Work and Power
Pressure
Temperature
Electricity

OBJECTIVES

After studying this lesson, you should be able to…

- Identify various units of measurement.
- State the definition of the joule, the coulomb, and the horsepower.
- Explain how to calculate pressure.
- Explain the difference between mass and weight.
- Demonstrate how to measure the volume of an object.
- Explain the difference between the Celsius scale and the Fahrenheit scale.

KEY TECHNICAL TERMS

Unit 1.01 standard size, accepted by everyone
Linear measurement 1.06 measurement along a straight line
Degree 1.19 angle equal to $^1/_{360}$ of a circle
Speed 1.26 distance traveled per unit of time
Velocity 1.27 speed in a specific direction
Weight 1.29 force of gravity on an object
Mass 1.33 amount of matter in an object
Work 1.51 product of force on an object and the distance it moves
Power 1.53 rate of doing work
Pressure 1.57 force per unit of area
Temperature 1.60 the reading on a thermometer
Volt 1.68 unit of electrical potential difference
Ampere 1.69 unit of electrical current
Ohm 1.71 unit of electrical resistance

Measurement is a part of everyday life. Think of all the things you do in a typical day. You dress yourself in clothing measured in inches. You drive a car, measuring your speed in miles per hour. You work, measuring your time in hours. You buy the family groceries, measuring various goods in pounds, quarts, and other units.

All measurements are made in units. Without units, measurements would have no meaning. You must understand units to understand measurements on the job.

This lesson explains the basic units of measurement. It explains the difference between so-called "base" units and those that are "derived" from the base units. It also explains the origins of metric units and U.S. Standard units.

Kinds of Units

1.01 Whenever you measure something, you measure it in *units*. These units are standard sizes, known and accepted by everyone who uses measurements. Thus, when you communicate with someone else in writing or by voice, both of you establish the same knowledge of the measurement. If you did not share an understanding of the size of units, you could not understand each other. The numbers alone could not carry the information.

1.02 You already know and accept many of the standard units used in industry. You know the units called inches, pounds, seconds, kilograms, degrees, and so on. When someone tells you to cut a pipe 78 in. long, you know where to cut the pipe. If you tell someone the temperature is 120°F, that person knows how hot it is. But if someone told you to bring 30 furlongs of wire to a job site, you might not know whether to carry the wire in your pocket or on a forklift truck.

1.03 Certain units are called *base units*. They go with the simplest and most basic kinds of measurements, including length, time, mass, electric current, and temperature.

1.04 Other units are called *derived units*. They are combinations of the base units, even though many of them have separate names. For example, *area* is a derived unit based on *length*. An area of one acre is 43,560 ft^2. *Speed* is another derived unit based on *length* and *time*. A speed of one mile per hour is 1.467 ft/sec.

1.05 The paragraphs that follow will explain some of the most common units—both base units and derived units. They have been grouped loosely according to the base units.

Length

1.06 One of the most common of all measurements is the measurement of *length*. It is usually measured along a straight line. Therefore, this kind of measurement is called a *linear measurement*.

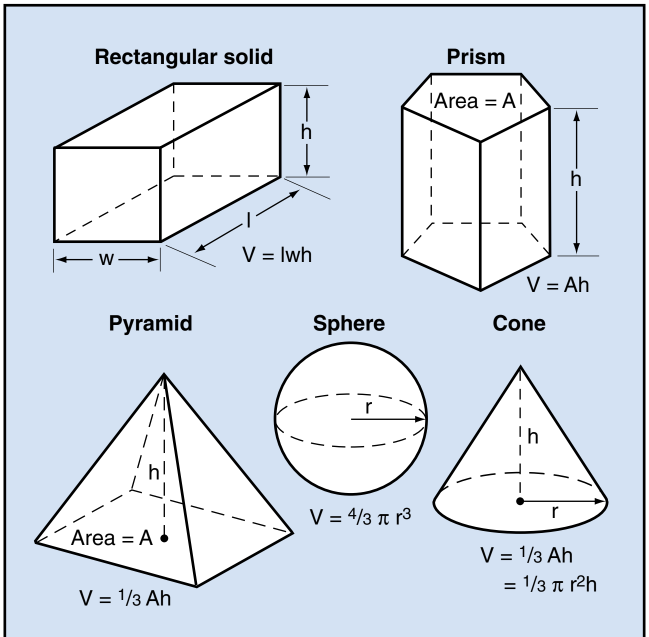
1.07 You make linear measurements, either "by eye" or with a rule, almost every day of your life. For example, when driving a car, you constantly estimate distances. Linear measurements are also important because they are used in defining many other measurements.

1.08 Many different units of linear measurements have been used over the years. The ancient Egyptians and Greeks measured distances in cubits. A *cubit* is the length of the human forearm. The Romans measured distances on land in miles. They defined a mile as 1000 steps. Greater distances on land were measured by a day's march by many ancient societies.

1.09 You can see that the cubit and mile were not defined very accurately in these ancient times. The length of the forearm varies among people. The length of a single step also varies, making a distance of 1000 steps different for different people. However, the inch, foot, yard, and mile as we know them today had their beginnings in these early measurements.

1.10 Throughout the world today, the standard unit of linear measurement is the *meter*. One meter was defined in 1793 as one ten-millionth of the distance from the North Pole to the Equator. Today, the meter

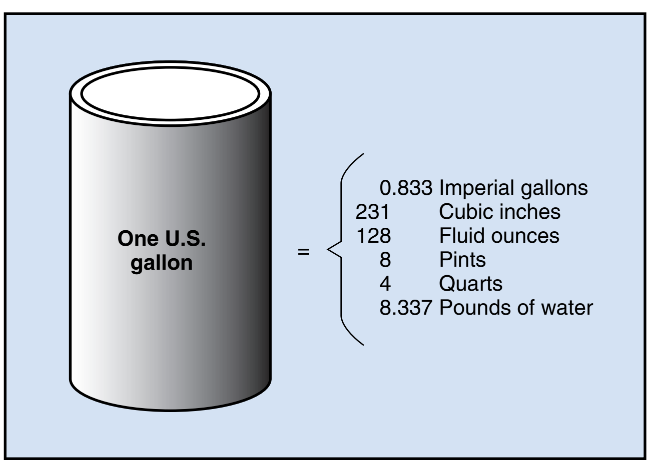
Fig. 1-1. Formulas for calculating volume



is defined in terms of light waves that can be produced and measured in the laboratory.

1.11 Historically, linear measurement in Great Britain was not based on the meter. It was based on the inch, foot, and mile. These units of measurement spread to English colonies all over the world, including the colonies in North America. As a result, the United States and Canada used these units of linear measurement for many years. Canada has officially converted its linear measurement to units based on the meter. The United States is gradually converting also so that its products and technical documents will match those of other countries in world trade.

Fig. 1-2. Equivalents of U.S. gallon



1.12 Linear measurements—and all other measurements—are made in multiples and fractions of the basic units. In countries that followed the English system, the inch was divided into fractions. The most common fractions had denominators that were powers of two—1/2, 1/4, 1/8, 1/16, 1/32, and 1/64. Machinists used fractions that had denominators that were powers of ten—1/10, 1/100, 1/1000, and 1/10,000. Very precise scientific measurements were made in millionths or even billionths of an inch.

1.13 Larger measurements required multiples of the inch, rather than fractions. Twelve inches made a unit called the *foot* (ft). Three feet made a unit called the *yard* (yd), and 5280 ft made a unit called the *mile* (mi). Other units were used for special purposes. Examples include the *rod* (16 1/2 ft) and the *chain* (4 rods) used in measuring land, the *furlong* (220 yd, one-eighth of a mile) used in measuring distances along roads, and the *nautical mile* (6000 ft) used in measuring distances at sea and in aviation.

Area

1.14 The area of a surface is calculated by multiplying its length by it width. For example, this page is 11 in. long and 8.5 in. wide. If you multiply the length by the width, you will find the area of this page is 93.5 square inches (8.5 in. × 11 in. = 93.5 in^2). Other units of area commonly used include square feet, square yards, and square miles.

Volume

1.15 *Volume* is the amount of space an object occupies. Volume is calculated by multiplying the object's length, width, and height. The units of volume depend on the units of those three dimensions. The most common units of volume are cubic inches, cubic feet, and cubic yards.

1.16 For example, the volume of a block of wood 3 ft long by 2 ft wide by 1 ft thick is calculated as shown below:

$$\text{Volume} = 3\ \text{ft} \times 2\ \text{ft} \times 1\ \text{ft}$$

$$= 6\ \text{ft}^3$$

Figure 1-1 shows some three dimensional objects and the formulas used in calculating their volumes.

1.17 The *gallon* (gal) and the *liter* (l) are the units of volume usually used for liquids. The standard U.S. gallon has a volume of 231 in^3. The liter has a volume of 1000 cm^3. Figure 1-2 shows equivalents of a U.S. gallon.

1.18 The gallon is divided into four equal parts called *quarts*. Each quart is divided into two equal parts called *pints*. For smaller amounts of liquids, the pint is sometimes divided into sixteen equal parts called *fluid ounces*. The fluid ounce is not related in any way to the ounce of weight. The liter is divided into *deciliters* ($^1/_{10}$ l) and *milliliters* ($^1/_{1000}$ l).

Angles

1.19 An angle is measured by the size of a circular arc between the two sides of the angle. To establish standard units, a circle is divided into 360 equal arcs, as shown in Fig. 1-3. The angle spanned by each arc is called one *degree* (°). Each degree is divided into 60 *minutes*, and each minute is divided into 60 *seconds*. Minutes and seconds are small units. They are used mainly in very precise measurements.

1.20 The device normally used for measuring angles, especially on drawings and charts, is called a *protractor*. An example is shown in Fig. 1-4. Notice how the protractor index is placed over the point where the two sides of the angle meet. The protractor is then rotated until the zero mark is aligned with Line 1. Where Line 2 passes under the protractor scale, you can read the number of degrees in the angle directly from the scale.

1.21 Most protractors can measure angles to within 1°. Some protractors can measure to within 1 minute. If your job requires angle measurements accurate to within seconds or fractions of seconds, it may be necessary to use special scientific equipment. In some cases, angles can be calculated by mathematics.

Time

1.22 Throughout the ages, the motions of the moon, the sun, and the stars have been used as a basis for measuring time. For many years, the standard unit of time was the *mean solar day*. It was defined as the average duration of one complete revolution of the earth compared to the sun—the period of time from noon to noon. This average duration was divided into 24 *hours* (hr). Each hour was further divided into 60 *minutes* (min), and each minute into 60 *seconds* (s).

1.23 The mean solar day was an average, and therefore it did not provide the accuracy required for very precise scientific measurement. In 1961, the second was chosen to replace the mean solar day as the standard unit of time. One *second* is now defined as 9,192,631,770 cycles of radiation of the Cesium atom, under special conditions. With this new basis for standardization, the duration of 1 s can be duplicated exactly in almost any well-equipped laboratory, allowing extremely accurate time measurement.

Fig. 1-3. Divisions of a circle

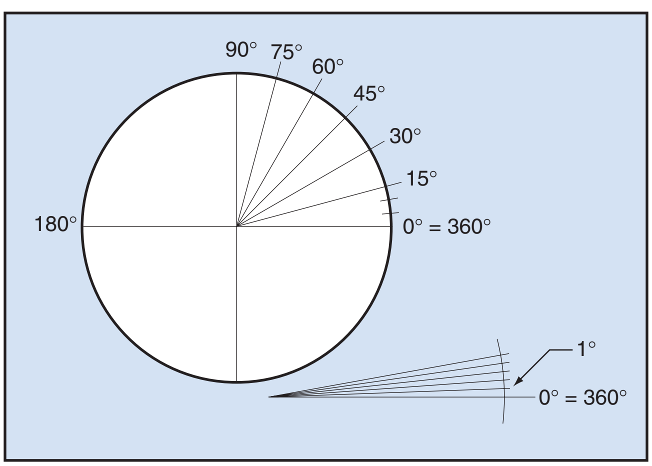
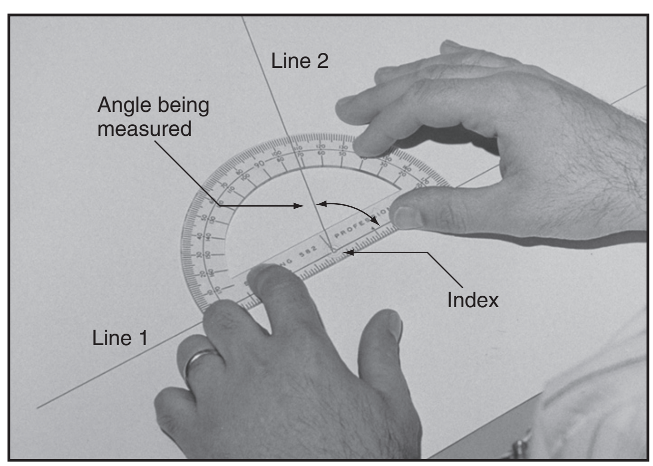


Fig. 1-4. Protractor



1.24 Time intervals were once measured by observing how long it took a smoldering rope to burn between evenly spaced knots on the rope. The falling sand of an hourglass also provided a means of measuring time. An adaptation of the hourglass is still occasionally used in the kitchen as a timer when preparing "three-minute" eggs. Longer periods of time were measured by observing changes in the phase of the moon.

1.25 To obtain the accuracy needed in industry today, time is generally measured with a clock or stopwatch. Time-measuring devices are available in a wide range of styles and forms. Special elapsed-time meters measure the operating hours of an engine or the duration of a process.

Speed and Velocity

1.26 To describe the motion of an object, the first thing to specify is its speed. *Speed* is defined as the distance traveled divided by the time elapsed. Some common units of speed include feet per second (fps), miles per hour (mph), meters per second, and kilometers per hour.

1.27 Sometimes you need to specify both speed and direction of a moving object. This combination of speed and direction is called *velocity*. For example, a car traveling west at a speed of 60 mph has a velocity of *60 miles per hour west*. The term velocity should be used only when you are referring to both speed and direction.

The Programmed Exercises on the following page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of your book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

1-1. The units of length, time, and mass are examples of ________ units.	1-1. BASE Ref: 1.03
1-2. Measurements along a straight line are called ________ measurements.	1-2. LINEAR Ref: 1.06
1-3. In the commonest fractions of an inch, the denominator may be a power of either ________ or ________.	1-3. TWO, TEN Ref: 1.12
1-4. An angle equal to $^1/_{360}$ of a circle is called one ________.	1-4. DEGREE (1°) Ref: 1.19
1-5. What is the standard unit of time?	1-5. SECOND Ref: 1.23
1-6. The distance an object travels, divided by the time elapsed, is called the ________ of the object.	1-6. SPEED Ref: 1.26
1-7. Velocity is the combination of ________ and ________.	1-7. SPEED, DIRECTION Ref: 1.27
1-8. What is the volume of a rectangular box measuring 10 cm × 10 cm × 25 cm?	1-8. 2500 cm^3 Ref: Fig. 1-1

Mass and Weight

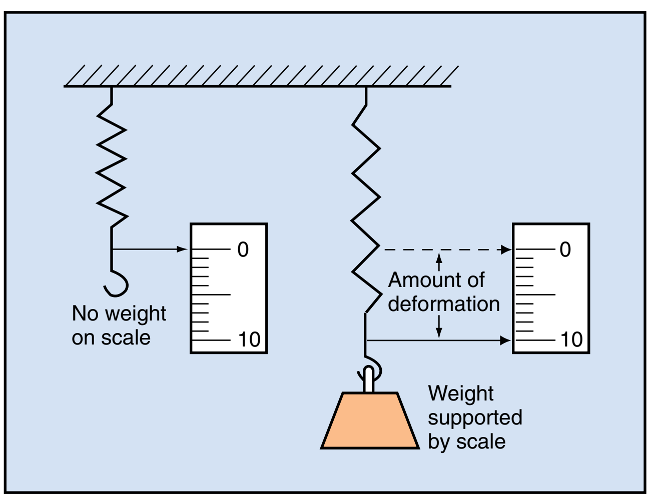
1.28 Many people confuse mass and weight. There is good reason for the confusion, even though mass and weight are very different properties of an object. The reason is that mass and weight are measured in similar ways. Both measurements involve the pull of gravity on an object.

1.29 You probably understand what weight is, even if you cannot put it into words. *Weight* is the force of gravity on an object. Your body has weight because the earth's gravity pulls on you. If you could travel to the surface of the moon, you would weigh less, because the moon's gravity is not as strong as the earth's. It does not pull on objects as hard as the earth does.

1.30 If you could travel far into space—away from the pull of the earth, the moon, the sun, and all other objects in the universe—you would be truly weightless. But if you were in orbit around the earth—within, say, a few hundred miles of its surface—you would not be weightless. The earth would pull on you and keep you going around the earth instead of drifting off into space.

1.31 In orbit, you would be in a constant state of free-fall. Other objects in orbit with you—your spaceship, for example—would also be in free-fall. Everything around you would be falling together, and you would have the impression of weightlessness. Because of your forward speed, you would actually be "falling around the earth." You would not get closer to the earth, but remain in orbit, pulled by the force of gravity.

Fig. 1-5. Spring scale measures weight



1.32 You can see from these paragraphs that weight depends on where an object is. If it is near a planet, a moon, or a star, the object has weight. If the object is far away from any planets, moons, or stars, it has no weight. But mass is entirely different.

1.33 The mass of an object is a property of the object. It does not depend on where the object is. Your body has a certain mass. This mass is the same whether you are on the earth, on the moon, or in outer space. *Mass* is a measure of how much matter is in an object. It does not change when gravity changes.

1.34 Isaac Newton discovered the relationship between mass and weight in the 1600s. He discovered that the force of gravity acts between every pair of objects, no matter how large or small they are. The force is proportional to the product of the masses of the two objects. That is, if the product of the two masses doubles, the force of gravity acting between them doubles. If the product of the masses triples, the force of gravity triples, and so on.

1.35 That is why objects that are on the earth and have great mass have great weight. When you multiply the mass of a small object by the mass of the earth, you get a small product. When you multiply the mass of a larger object by the mass of the earth, you get a larger product. The weight of each object—that is, the force of gravity acting between the object and the earth—is proportional to this product of masses.

1.36 Newton also discovered that the force of gravity decreases as the distance between two objects becomes greater. The distance is measured from the center of one object to the center of the other. If this distance doubles, the force of attraction decreases to one-fourth of what it was. If the distance triples, the force decreases to one-ninth. In other words, the force varies *inversely* with the *square* of the distance between the centers of the objects.

1.37 An object resting on the surface of the earth is almost 4000 miles from the center of the earth. A satellite in orbit 100 miles above the surface loses only a little weight (about 5%), because its distance from the center of the earth increases by only a small fraction—from 4000 miles to 4100 miles. But a communications satellite in a "stationary" orbit 23,000 miles above the earth loses about 97% of the weight it had on the earth's surface.

1.38 Mass and weight are measured differently, using different instruments, but both measurements are related to gravity. This is one reason many people think mass and weight are the same. The other reason is that both measuring instruments are often made to read in units of either mass or weight, regardless of which quantity they actually measure.

1.39 Weight is measured by a *spring scale*. In use, a spring scale supports an object by exerting an upward force that equals the pull of gravity. In order to exert this upward force, the spring must deform. The amount of deformation shows how much force is being exerted by the spring. Figure 1-5 shows how a very simple spring scale works.

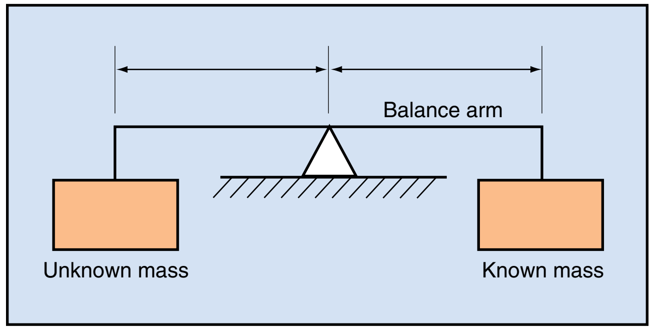
1.40 Mass is measured by balancing the object against a known mass on a *beam balance*. The balance may be very simple, as shown in Fig. 1-6, with arms of equal length. If so, the balance arm will remain level when the two masses are equal. But some balances are made with unequal arms. When the balance arm remains level, one mass is a multiple of the other. The multiple is the same as the ratio of the lengths of the arms.

1.41 A third balance, shown in Fig. 1-7, has a variable arm for the known mass. The arm pivots and swings the known mass to a greater horizontal distance from the pivot point. The unknown mass remains at a fixed horizontal distance from the pivot point. The instrument comes to rest when the known mass is at the proper horizontal distance to balance the unknown mass.

1.42 Mass-measuring balances will give the same reading under all conditions of gravity. They will indicate the same mass for a given object whether the measurement is made on the moon or on the earth. The only places they will not work is under conditions of zero gravity or in free-fall.

1.43 Spring scales, on the other hand, give different readings under different conditions of gravity. They correctly indicate that an object weighs less on the moon than on the earth. They correctly indicate that an object has no weight in places where there is no gravity. The only time they will not work is when their motion is changing, as in free-fall. If they are moving at a steady speed in a straight line (compared to the stars), they give accurate readings. If their speed is changing, or if they are moving on a curved path, they are likely to give incorrect readings.

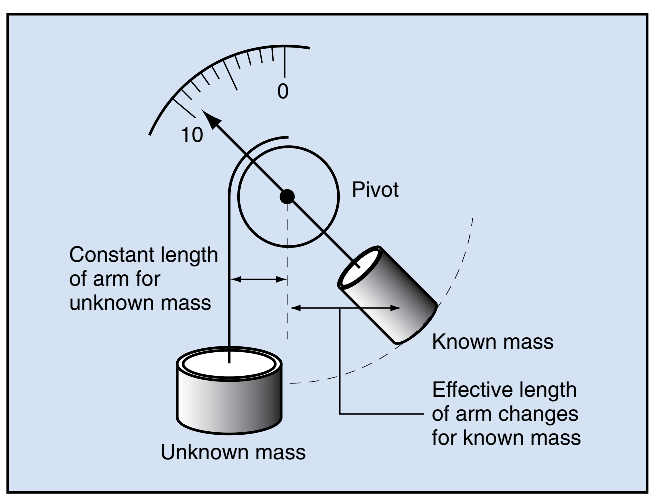
Fig. 1-6. Equal-arm balance compares masses



1.44 The units of mass and weight are often confused because of the confusion between the ideas of mass and weight. In the U.S. Standard system, the basic unit of weight is the *pound* (lb). This unit is divided into *ounces* (oz) or multiplied to *tons*. Other special weight units include the *grain* (1/480 of an ounce) used in weighing medicines and powder charges for rifle and pistol cartridges, and the *hundredweight* (100 lb) used in weighing agricultural products.

1.45 In the metric system, there are two basic units of weight, the *newton* (abbreviated N, and equal to

Fig. 1-7. Variable-arm balance



0.224 lb), and the *dyne* (abbreviated d, and equal to 1/10,000 N, or 0.00036 oz).

1.46 Mass is measured in *grams* (g) and *kilograms* (abbreviated kg, and equal to 1000 g) in the metric system. For comparison, an object with a mass of 1 kg weighs 2.2 lb (9.8 N) on the earth. An object with a mass of 1 g weighs about 1/28 oz (980 dynes) on the earth. In the U.S. Standard system, the unit of mass is called the *slug*. An object having a mass of 1 slug weighs 32.2 lb on the earth.

1.47 You probably hear and read about weights in grams and kilograms. Foods sold by weight in the United States are often marked to show their "weight" in grams as well as pounds. For example, a 1 lb box of food is likely to be marked "454 g." However, this "weight" actually indicates the mass of the contents. The correct indication of weight in the metric system would be "4.45 N."

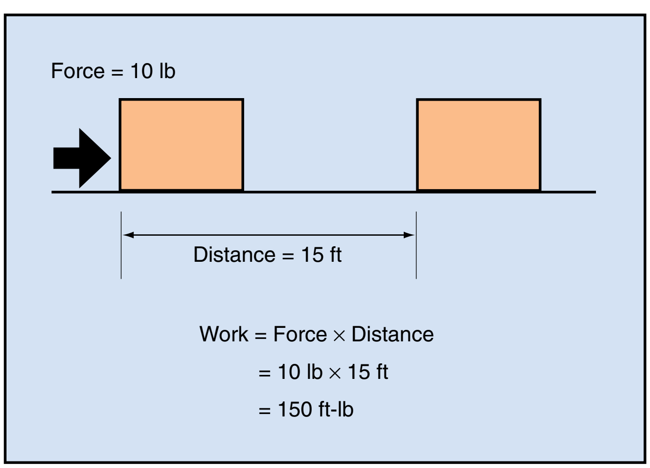
1.48 You may think we are making too much of the difference between mass and weight, and of the difference between their units. But as you work with mass and weight in the plant, there may be times when not understanding these differences will confuse you. If that happens, you may want to reread this section to strengthen your understanding.

Force

1.49 A *force* is any push or pull. It is measured in the same units as weight, because weight is one example of a force. Other forces are exerted by contact between two objects, by magnetism, by electric charges, by electric currents, and by particles within the nucleus of an atom.

1.50 The units of force are derived units. One pound is one slug-ft/sec^2. One newton is one kg-m/sec^2, and one dyne is one g-cm/sec^2. Larger and smaller units of force are multiples and fractions of these units.

Fig. 1-8. Definition of work



Work and Power

1.51 *Work* is defined mathematically. It is calculated by multiplying the force on an object by the distance the object moves. When you push a crate a certain distance across the floor, you are doing work on the crate. The units of work are the units of force multiplied by the units of distance. Examples include foot-pounds, newton-meters, and dyne-centimeters. One newton-meter is called a *joule*, and 1 dyne-cm is called an *erg*. If you apply 10 lb of force to move a box 15 ft across the floor, as shown in Fig. 1-8, you have done 150 foot-pounds (ft-lb) of work.

1.52 When you calculate work, you must multiply the distance moved by only that part of the force that acts in the same direction as the motion. If the force acts in exactly the same direction as the motion, you use the full amount of force. But if the force acts perpendicular to the direction of motion, you use zero force, because none of the force acts in the same direction as the motion. In between these two extremes, you can calculate the amount of force by using trigonometry.

1.53 The *rate* at which work is done is called *power*. To calculate power, you divide work done by the time required to do it. In Fig. 1-8, the same amount of work is expended to move the box whether it takes a minute, an hour, or all day. The power expended depends on how long it takes to move the box.

1.54 The units of power depend on the units chosen for work and time. Examples include foot-pounds per second, joules per second, and ergs per second. One joule per second is called 1 *watt* (W). A power of 550 ft-lb/s is called 1 *horsepower* (hp).

1.55 The unit called a horsepower has an interesting history. In the early 1800s James Watt concluded that the average draft horse could exert a constant force of 150 lb while walking at a rate of 2$^1/_2$ mph. From these measurements, Watt defined 1 hp as 33,000 ft-lb/min, or 550 ft-lb/s. When steam engines began to replace horses as a source of power, the horsepower was used as a unit for measuring their power.

Pressure

1.56 Sometimes it is important to know how a force is distributed over a surface. Is it concentrated in certain places, or is it spread evenly over the whole surface? In many cases, knowing how the force is concentrated on each unit of area is more important than knowing the total force acting on the entire area. An example is the amount of force exerted on each square inch by the air in a tire. No one cares how much total force the air exerts on the whole inner surface of the tire. The concentration of force is all that matters.

1.57 The concentration of force on a unit of area is called *pressure*. It is calculated by dividing the amount of force by the amount of area. For example, a force of 2000 lb acting on an area of 50 in^2 is a pressure of 40 lb/in^2. A phonograph stylus applying a force of $^1/_{20}$ oz ($^1/_{320}$ lb) on an area measuring $^1/_{300}$ in. in diameter (8.4 millionths of a square inch) produces a pressure of almost 400 lb per square inch on the record. It is this concentration of force that causes wear on the record.

1.58 Common units of pressure include pounds per square inch (lb/in^2, also abbreviated *psi*), newtons per square meter (N/m^2), and dynes per square centimeter (d/cm^2).

Temperature

1.59 Everyone is familiar with temperature. But most people cannot explain what temperature is. They know it is a measure of how hot or cold something is, but they cannot explain temperature itself. Some people can give a very complicated explanation of temperature in terms of the motion of molecules and their average kinetic energy. But molecular motion is only related to temperature. It is not temperature itself.

1.60 The definition is really quite simple. *Temperature* is what you read on a thermometer. Before there were thermometers, the idea of temperature was quite vague. Things were simply hot, or cold, or medium. The thermometer provided a way to compare things that were almost equal in "hotness" or "coldness."

1.61 Thermometers work because most materials expand and contract when they are heated and cooled. By arranging the right material in the right way, the expansion and contraction can be measured. Liquid mercury will rise or fall in a narrow tube. Alcohol will do the same. Two curved strips of metal fastened together will curl up tighter or looser. All these motions can be measured on a scale, called a *temperature scale*.

1.62 Four temperature scales are in common use today. Figure 1-9, on the following page, shows how they compare. They differ in two ways. The sizes of the degree intervals are different, and they have different locations of "zero." For example, the Celsius scale has degree intervals that are 1.8 times as large as the degree intervals in the Fahrenheit scale. In addition, zero on the Celsius scale is the freezing point of water. Zero on the Fahrenheit scale is well below the freezing point of water.

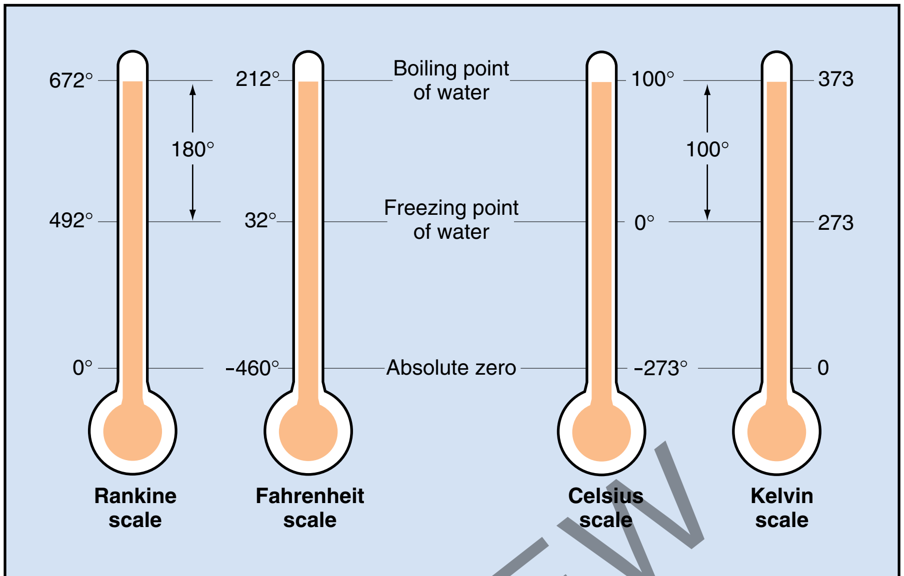
1.63 The units of temperature measurement are called *degrees*. To distinguish among the scales, you simply add the name of the scale after the word "degrees" or (with the exception of the Kelvin scale, which does not use the degree symbol) you add the first letter of the name after the degree symbol (°). For example, the freezing point of water is 492°R, 32°F, 0°C, or 273 K. All four of these values indicate the same temperature—the temperature at which water freezes.

Electricity

1.64 Electrical equipment is widely used in modern industrial plants. You are likely to be required to make measurements on electrical equipment as part of your job. The basic electrical measurements involve *voltage*, *current*, and *resistance*.

1.65 In order to understand these measurements and their units, you need to keep a few basic ideas about electricity in mind. To understand these ideas, it is helpful to imagine the simplest possible electrical system. This system consists of two plates, each connected to one terminal of a battery. In between the plates is a single particle. The particle has a neg-

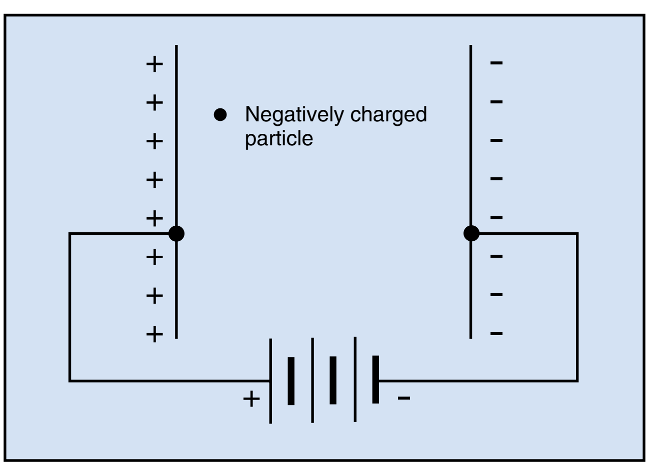
Fig. 1-9. Four temperature scales



ative electrical charge on it. Figure 1-10 shows this system.

1.66 You know that opposite charges attract, and like charges repel. Therefore, the negatively charged particle is attracted to the positive plate and repelled from the negative plate. In order to move the particle from the positive plate to the negative plate, something must force the particle to move. The amount of force, multiplied by the distance between plates, equals the amount of work necessary to move the particle across the space between the plates.

Fig. 1-10. Simple electrical system



1.67 If the particle were free to move, it would fly toward the positive plate. It could do work as it went, or it could simply pick up speed and crash into the positive plate. The crash would produce heat in the positive plate.

1.68 The amount of work the particle can do in going from the negative plate to the positive plate, divided by the amount of electrical charge on the particle, is called the *potential difference* between the plates. It is measured in joules (units of work) per coulomb (units of charge). A potential difference of 1 joule per coulomb is called 1 *volt* (V).

1.69 Suppose there is an endless supply of negative particles available at the negative plate. They can flow in a steady stream across the gap between the plates. The rate at which they carry charge across the gap is called the *electric current*. It is measured in a base unit called an *ampere* (A). A current of 1 A is equal to 1 coulomb per second flowing past a point.

1.70 Now suppose that, instead of a vacuum, there is a material between the plates. The charged particles can move through this material, but the material hampers their progress. In other words, the material limits the current. Instead of crashing into the positive plate and producing heat there, it drifts slowly through the material between the plates and produces heat all along the way. If the potential difference between the plates increases, more current will flow, producing heat more rapidly.

1.71 The ratio between the potential difference (voltage) across the plates and the current flowing through the material is called the *resistance* of the material. That is,

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

where V = potential difference
I = current
R = resistance.

A resistance of 1 V per ampere is called 1 *ohm* (Ω).

1.72 In electrical equipment in the plant, the plates are replaced by thick wires, battery terminals, contacts, and other large elements. The negatively charged particles are tiny, invisible electrons. The material between the plates is a resistor, a thin wire, the filament of a light bulb, or some other material that produces heat as electrons flow through.

1-9. Weight is defined as the force of ________ on an object.	1-9. GRAVITY Ref: 1.29
1-10. Mass is a measure of how much ________ is in an object.	1-10. MATTER Ref: 1.33
1-11. What instrument is used for measuring the weight of an object?	1-11. SPRING SCALE Ref: 1.39
1-12. What instrument is used for measuring the mass of an object?	1-12. BEAM BALANCE Ref: 1.40
1-13. Work is calculated by multiplying the ________ on an object by the ________ the object moves.	1-13. FORCE; DISTANCE Ref: 1.51
1-14. What is the name for the rate of doing work?	1-14. POWER Ref: 1.53
1-15. The concentration of force on a unit of area is called ________.	1-15. PRESSURE Ref: 1.57
1-16. How many temperature scales are in common use today?	1-16. FOUR Ref: 1.62

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. Which of the following is measured in base units?

- ☐ a. Electric current
- ☐ b. Force
- ☐ c. Pressure
- ☐ d. Speed

1-2. In 1793, the meter was defined in terms of

- ☐ a. a beam of light
- ☐ b. a prototype meter
- ☐ c. the earth's surface
- ☐ d. the standard centimeter

1-3. Degrees, minutes, and seconds are units used in measuring

- ☐ a. angles
- ☐ b. temperatures
- ☐ c. times
- ☐ d. volumes

1-4. The distance an object travels, divided by the elapsed time, is called

- ☐ a. a base unit
- ☐ b. duration of the trip
- ☐ c. speed
- ☐ d. velocity

1-5. The weight of an object is

- ☐ a. an invention of Isaac Newton
- ☐ b. dependent on the force of gravity
- ☐ c. the same as its mass
- ☐ d. the same no matter where the body is located

1-6. Weight and mass are measured with

- ☐ a. a balance
- ☐ b. a spring scale
- ☐ c. different instruments
- ☐ d. the same instrument

1-7. Which of the following is not a unit of weight?

- ☐ a. Dyne
- ☐ b. Kilogram
- ☐ c. Newton
- ☐ d. Pound

1-8. If you multiply the force on an object by the distance the object moves, you get the

- ☐ a. mass of the object
- ☐ b. power used
- ☐ c. weight of the object
- ☐ d. work done

1-9. Power is measured in

- ☐ a. feet
- ☐ b. foot-pounds
- ☐ c. foot-pounds per second
- ☐ d. pounds

1-10. Pressure is measured in

- ☐ a. inches
- ☐ b. inches per pound of force
- ☐ c. pounds
- ☐ d. pounds per square inch

SUMMARY

Every quantity that is measured must be measured in units of standard size. Some units are called base units, and others are called derived units. Derived units are combinations of two or more base units. Base units are defined in terms of measurements made in the laboratory or in terms of standard prototypes of the quantities.

The most common base units are units of length, time, mass, electric current, and temperature. Examples of derived units include area (length squared), speed (length per unit of time), force (mass times length, divided by time squared), and pressure (mass times length, divided by time squared, divided by length squared).

The difference between mass and force is confusing to many people, especially when the force being measured is weight—the force of gravity on an object. Yet, force and mass are entirely different. They are measured by entirely different instruments.

Part of the reason people get confused is that instruments that measure one quantity often are made to give readings as though they measured the other quantity. Force is always measured by an instrument that undergoes deformation, as a spring scale does, during the measurement. Mass is always measured by an instrument that balances when the force of gravity acting on one object counteracts the force of gravity acting on a second object.

Answers to Self-Check Quiz

1-1. a. Electric current. Ref: 1.03, 1.04

1-2. c. The earth's surface. Ref: 1.10

1-3. a. Angles. Ref: 1.19

1-4. c. Speed. Ref: 1.26

1-5. b. Dependent on the force of gravity. Ref: 1.29

1-6. c. Different instruments. Ref: 1.38

1-7. b. Kilogram. Ref: 1.44, 1.45

1-8. d. Work done. Ref: 1.51

1-9. c. Foot-pounds per second. Ref: 1.54

1-10. d. Pounds per square inch. Ref: 1.58

Contributions from the following sources are appreciated:

Figure 1-4. TPC Photo by Brandt & Associates