Chapter

1

Physical Concepts within Systems of Measurement

In this chapter, you will learn the following to World Class standards:

- **Evaluating your Measuring Ability**
- **Understanding Distance**
- **Insert Metric Dimensions on a Drawing using the English System**
- **Speed, Average Speed and Instantaneous Speed**
- **Acceleration and Gravity**

Evaluating your Measuring Ability

What is measuring? The concept of determining a quantity sounds easy to anyone just right up to the point of doing the task or using the information we obtain. Almost everyone has the ability to measure such quantities as distance, weight, the number of units in a container, the volume of sound or the brightness of a computer monitor.

Two common system of measurement are the English and Metric system. Right at the beginning of this text, we would like to make a small evaluation of your knowledge, making the following measurements using the two systems. We made the first measurement of each grouping, first using of a piece of printer paper, then the weight of a grown man, the number of cups or liters in a gallon, and lastly the speed of a car. You need to conduct two more measurements of anything you find around the classroom, work or at home. For this exercise, filling in every field in the table is not necessary.

Measurement	English	Metric
Distance		
1. Printer paper	11 inches	280 mm
2.		
3.		
Weight		
1. Grown man	190 lbs	418 kg
2.		
3.		
Volume		
1. Measuring a gallon of milk	16 cups	3.8 liters
2.		
3.		
Speed		
1. Speed of a car	65 mph	104.6 km/hr
2.		
3.		

Figure 1.1 – Measuring Pretest

If you do not have a device to measure the distance, weight, volume or speed, you can record a value along with the unit of measurement in the English or Metric column and demonstrate your ability to convert the value to another system. Place your answer in the other column. After you complete the table, compare your answers with another individual conducting the exercise and with your instructor. When another person checks your measurement, do they agree with you or are there differences? Just note any dissimilarity and bring them to your instructor's attention when you cover that topic in this textbook.

Understanding Distance

Distance is the length between two points. To discover the distance between two points, we will study how to determine the separation using two systems of measurement, the English and Metric system. In addition to learning discrete units of length, we will have a chance to measure, record and display magnitudes of length on Computer Aided Design (CAD) drawings and in engineering reports. We will also study techniques to obtain distances on parts and assemblies where simple straight line measuring will not function.

In the English measurement system, we gauge distances typically using inches, feet, yards and miles. We select the units of measurement based on the type of number that we would like to see. As the numeric value grows in size, we change to a measuring unit that covers a larger distance, so the number will become smaller. When we measure a computer monitor, our drawing will have distances shown in inches, since many features on the computer display measure between a fraction of an inch to just over one foot. Our measurements can appear like 5.42, 0.875 or 14.5. However, when we determine the length of a hallway in the house, determining the answer in inches would result in a very large number, so we record the numeric value of feet then inches and finally a portion of an inch. Architectural designers will place dimensions that look like 52 ft – 10 ½ inches or 35'-4 ¼ "on their drawing. Aerospace engineers are more likely to use miles in their measurements of flight, rather than the smaller inches, feet or yards, because the planes or jets they design are traveling greater distances between cities. The table shown in Figure 1.2 displays the typical English units for distance.

Name	Description	Abbreviation
Inch	$\frac{1}{12}$ ft	in.
Foot	12 in.	ft
Yard	36 in. or 3 ft	yd
Mile	5280 ft or 1760 yd	mi

Figure 1.2 – Units of Distance in the English System of Measurement

Where in the English system, we have various names of units representing different lengths, in the metric system, we measure using one base unit, the meter. The Metric system is the principal or exclusive system of measurement in every part of the world except the United States of America. However, in the United States, the automotive and electrical industries are manufacturing using the Metric system of measurement. Even if we do not work in the transportation or an electronics business, we may have to send information to a parent or sister company, were they are using the metric system. CAD programs like AutoCAD have features to add metric dimensions to a drawing using the English System of Measurement by just placing a check in a box in the Alternate Units tab when modifying the Dimension Style. Year after year, more organizations and people are working with the metric system and eventually units like the meter will become the exclusive distance measurement.

Where the English System of measurement has irregular steps from one unit of measurement to the next, the metric system defines the distance between two points with only one length, the meter. Then when we want to control the size of the number, we place a prefix in front of the word, "meter" to create a new unit and each prefix separates the metric unit by a factor of 10. In a factory, we measure parts using millimeters, in the building industry, we utilize meters and in the transportation industry, we use kilometers. In the chart in Figure 1.3, we see the prefixes underlined in front of the word, meter. The prefixes will remain standard throughout the Metric system of measurement, so we will see measurements like kilometers, kilograms and kiloliters, which all have a meaning of 1000 of the base unit.

Name	**Description**	**Abbreviation**
Millimeter	$\frac{1}{1000}$ of a meter	mm
Centimeter	$\frac{1}{100}$ of a meter	cm
Decimeter	$\frac{1}{10}$ of a meter	dm
Decameter	10 meters	dam
Hectometer	100 meters	hm
Kilometers	1000 meters	km

Figure 1.3 – Metric Distance Measurements

Insert Metric Dimensions on a Drawing using the English System

When learning to draw in CAD with the World Class CAD Fundamentals of 2D Drawing textbook, our first drawing was the Rectangular problem using the English system of measurement. In this exercise, we will add the metric dimensions in millimeters below the dimension value that is shown in inches.

Open the Rectangular drawing in AutoCAD as shown in Figure 1.4. Next, open the Dimension Style dialog box and select the Alternate Units tab as shown in Figure 1.5. Check the display alternate units' box in the upper left hand corner of the window. Change the precision value to 0.0 and select the "Below primary value" radio button in the Placement section of the window.

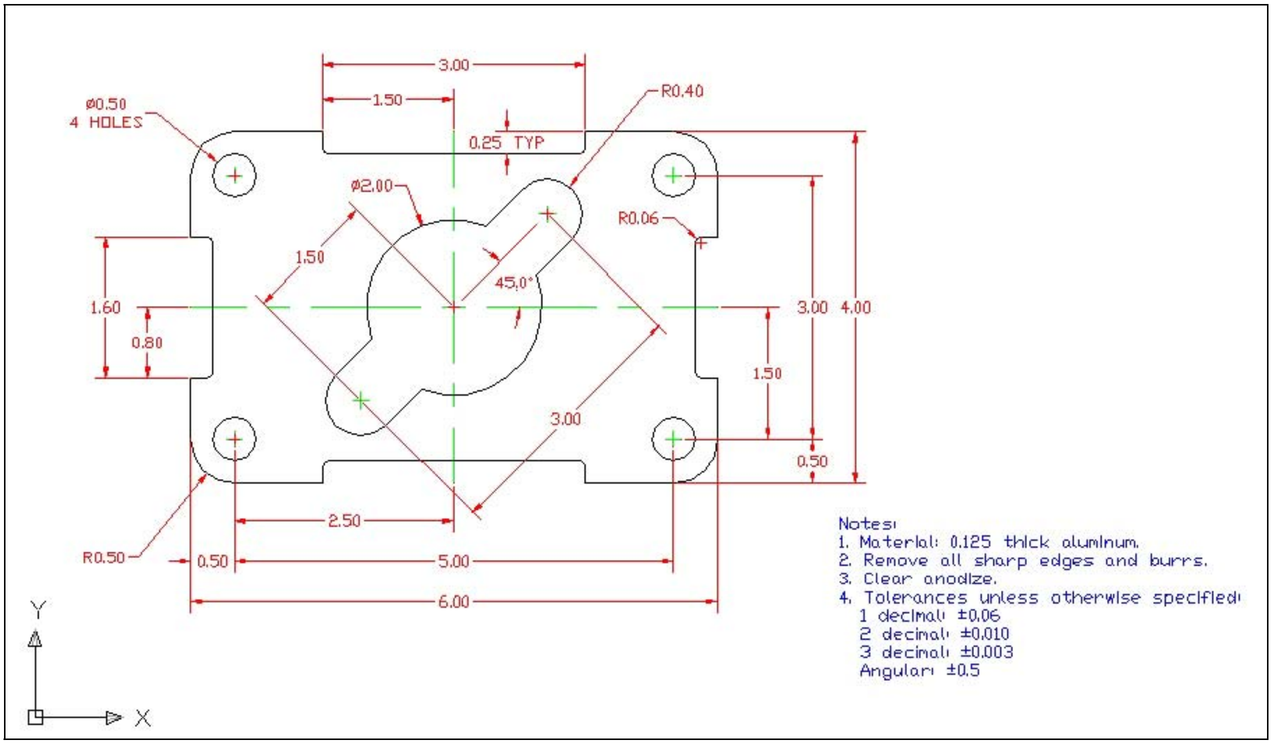

Figure 1.4 – Rectangle Drawing in Fundamentals of 2D Drawing

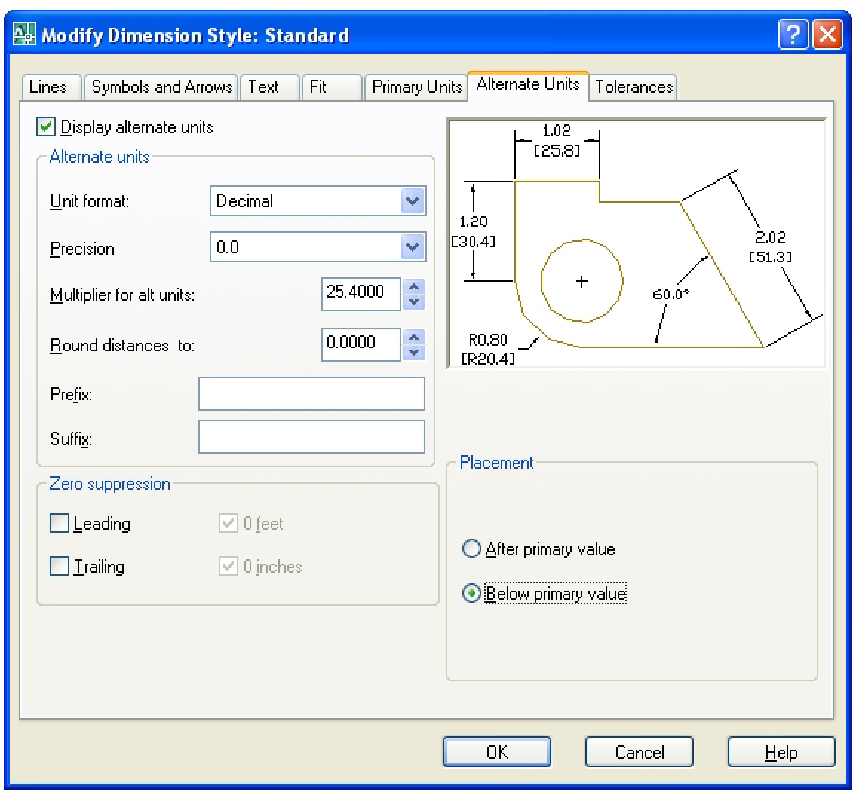

Figure 1.5 – The Alternate Unit tab in the Modify Dimension Style Window

After picking the OK button and closing the Dimensions Style window, we see the metric values in brackets below the English dimensions. When adding the metric values to the automatic dimensions, some dimension arrows, dimension lines and dimension extension lines may overlap, so we may need to move a dimension that is now hard to read or overlapping.

The notes on the drawing have not been changed, so we will manually change each one. First we need to know that 1.0 inch equals 25.4 millimeters. To convert 0.125 inches to millimeters, multiply 0.125 times 25.4 as shown in the formula.

Millimeters = Inches 3 25.4

Millimeters = 0.1253 25.4 = 3.175

Now, that we have the metal thickness in millimeters, select the Edit Text button on the Text toolbar and pick the notes on the rectangle drawing. After the 0.125 material thickness, type an open bracket, followed by 3.2 and then a closed bracket as shown in Figure 1.6. Compute the millimeters for 1, 2 and 3 decimal tolerances and place their metric value in brackets after the English quantity.

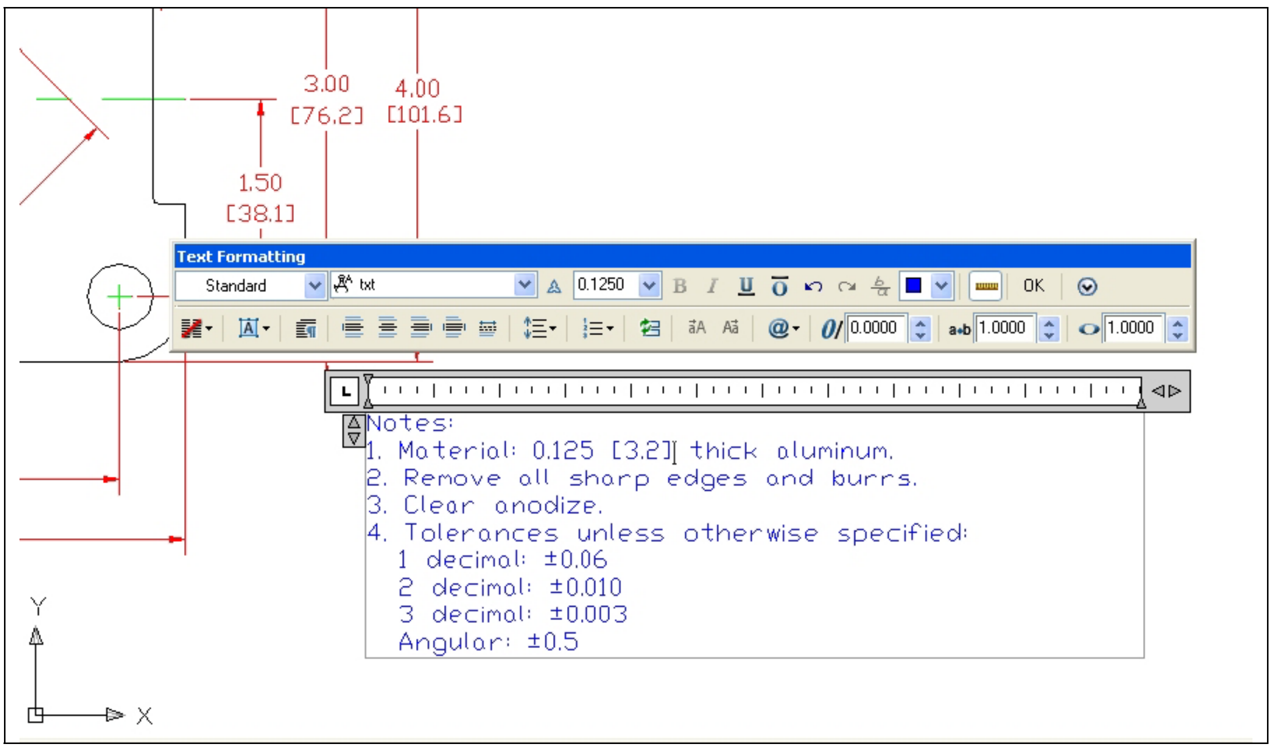

Figure 1.6 – The Alternate Unit tab in the Modify Dimension Style Window

When the changes are complete, place the Rectangular drawing in a drawing border with title block. Save the drawing file and process the finished print for approval.

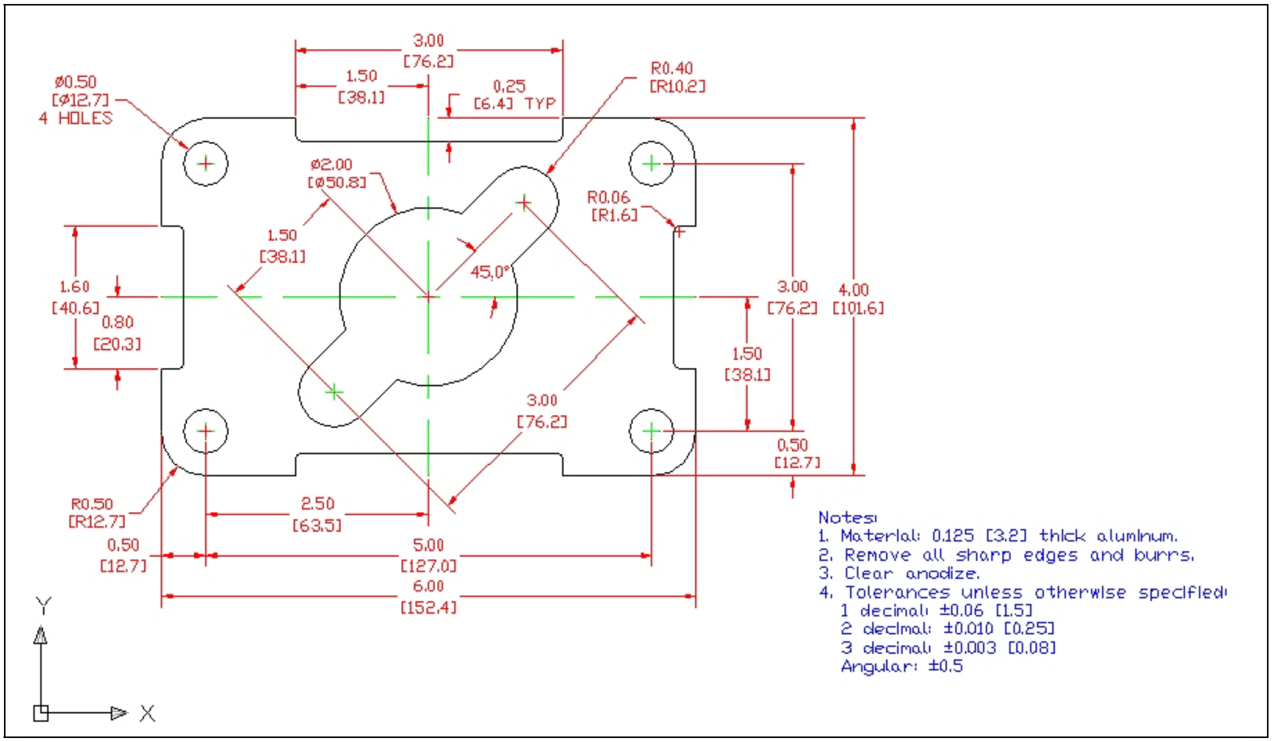

Figure 1.7 – The Finished Rectangular Drawing

Repeat the process on the Circular Drawing, adding the metric values below the English dimensions. If English measurements exist in the notes in the circular drawing, make the manual changes as we did in the Rectangular problem.

For our third drawing, the Bracket problem, which we accomplished using the Metric measurement system in the World Class CAD Fundamentals of 2D Drawing textbook, the alternate dimensions will be an English value. Each millimeter is equal to 0.03937 inches, so in the Alternate Units tab for that drawing, change the Multiplier for all units from 25.4 to 0.03937 and the Precision value to 0.00 as shown in Figure 1.8.

*** World Class CAD Challenge 10-1 * - Open the Rectangular Drawing from the World Class CAD – Fundamentals of 2D Drawing textbook. Add metric dimensions to all English measurements; place the drawing in a border with title block and save the file as Rectangular.dwg in 15 minutes.**

*** World Class CAD Challenge 10-2 * - Open the Circular Drawing from the World Class CAD – Fundamentals of 2D Drawing textbook. Add metric dimensions to all English measurements; place the drawing in a border with title block and save the file as Rectangular.dwg in 15 minutes.**

*** World Class CAD Challenge 10-3 * - Open the Bracket Problem from the World Class CAD – Fundamentals of 2D Drawing textbook. Add English dimensions to all metric measurements, update the title block and save the file as Bracket.dwg in 15 minutes.**

Continue this drill multiple times using the steps we have learned, each time completing the drawing under 15 minutes to maintain your World Class ranking

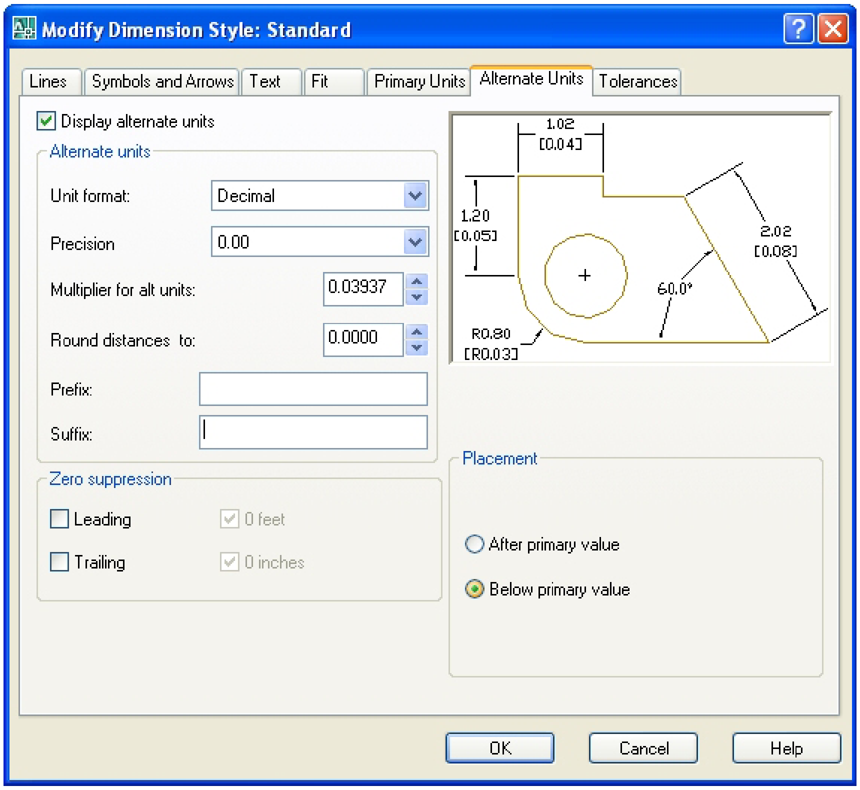

Figure 1.8 – The Finished Rectangular Drawing

Speed, Average Speed and Instantaneous Speed

Next, we will study the speed of an object, and we will observe two modes of measuring speed, instantaneous speed and average speed. Instantaneous speed is distance divided by the time when the time measurement is very small. In an automobile, the speedometer is displaying the current speed of the car with as much accuracy as the engineers can build into the system. We compute average speed by taking the distance and dividing by the time as shown in the formula below.

$$\bar{v} = \frac{x_f - x_0}{t_f - t_0}$$

We can compute average speed when we take the distance we travel from the odometer of the car and divide by the time of the trip. In the example shown below, the final measurement on the scale can be 1100 miles. The odometer reading at the beginning of the journey could be 875 miles. The start time was 2:05 pm and the finished time is 4:32 pm. In the formula for average speed,

Insert the numbers into the formula for average speed.

$$\bar{v} = \frac{1100mi. - 875mi.}{5:32 - 2:05} = \frac{225mi.}{3hr \,\&\, 27mi.} = \frac{225mi.}{3.45hr.} = 65.22\text{mph}$$

Subtract the starting miles from the finished miles was relatively easy, but the time calculation involved a little work. First we subtract the start time from the finish time, and then we convert the remaining minutes back to a fraction of an hour by dividing the 27 minutes by 60 minutes which is 0.45 hours. Add 0.45 hours to the three hours and the trip took 3.45 hours. To determine the average speed, divide the distance traveled by time and we have 65.22 miles per hour.

When we use a mechanism to measure instantaneous speed, the actual time can be a fraction of a second. We are trapped by the accuracy of our measuring device, but when observing the speed of an object like car, a second can be precise enough to develop the value. When we measure objects like spacecraft that travel into Earth's atmosphere from space at thousands of miles an hour, a determination of instantaneous speed may need to be more accurate. Some digital devices input values very quickly like 200,000 hertz. That means that our measurement device receives data every one two hundred thousandths of a second, so the time variable t would be every 0.000005 seconds for each reading.

$$v = \lim_{\Delta t \to 0} \bar{v} = \frac{dx}{dt}$$

In the English System of Measurement, speed is typically recorded as feet per second and miles per hour. In the Metric System, we compute speed in meters per second and kilometers per hour as shown in Figure 1.9.

Name	Abbreviation
Feet per Second	**fps, f/s**
Miles Per Hour	**mph**
Meters per Second	**m/s**
Kilometer per hour	**Km/hr**

Figure 1.9 – Measurements of Speed

Velocity is also measured by dividing distance by time, but where speed is just the magnitude; velocity is measured as magnitude and direction. In this textbook, we will study vectors in two dimensions and 3D space, so we will be able to compute the resultant velocity of an object when other forces act on it.

Periodically, information will be given in an engineering department in miles per hour and we need to compute the number in feet per second or in meters per second. If we need to compute the average speed of 65.22 mph in feet per second, we will use the factor-label method to move from one type of unit to another.

Using the factor-label method, we write the speed as a fraction with the 65.22 miles as the numerator and the 1-hour as the denominator. Every following fraction multiplied in this formula has equivalent values such as 5680 feet equals one mile or 3600 seconds equals one hour. Now to start to the process and to convert miles to feet, place the one mile into the denominator position in the second fraction. Above the one mile in the numerator place, write the equivalent distance of 5280 feet. When we multiply the conversion formula, the mile units will cross out. In the third fraction, we write one hour in the numerator, which is opposite the hour in the first fraction. As we stated before, 3600 seconds equals one hour, so the value is written in the denominator position as shown in the calculation. Now, we multiply the numerator across the top and divide by the denominators at the bottom. The answer is 65.22 miles per hour is the same speed as 102.903 feet per second.

$$\frac{65.22mi}{hr} \times \frac{5680ft}{1mi.} \times \frac{1hr}{3600s} = 102.903\text{ft/s}$$

For another opportunity to work with the factor-label method to convert from one system or unit of measurement to another, we use the same first three fractions as in the previous conversion. The fourth fraction has us converting the formula using the fraction 1 foot equals 12 inches. The fifth fraction converts inches to meters and there are 39.37 inches in a meter, which we compute as 1000 mm (1 meter) divided by 25.4 mm per inch. Now we multiply the numerator across the top and divide by the denominators at the bottom. 65.22 miles per hour is the same speed as convert the following problems per second.

$$\frac{65.22mi}{hr} \times \frac{5680ft}{1mi.} \times \frac{12in}{ft} \times \frac{m}{39.37in} \times \frac{1hr}{3600s} = 31.365\text{m/s}$$

Convert the following problems:

No.	Measurement		Solution
	from	to	
1	9.5 ft	in	
2	12 m	in	
3	48 in	m	
4	32 ft	in	
5	62 ft	m	

6	100 mph	fps	
7	35 mph	m/s	
8	10 m/s	fps	
9	121 fps	m/s	
10	400 km/hr	mph	

Acceleration and Gravity

Average acceleration is the measurement of speed divided by time.

$$\bar{a} = \frac{v_f - v_0}{t_f - t_0}$$

If the final speed of the car is 65 mph and the initial speed is 0 mph, and the car accelerated to the 65 mph in 6.5 seconds, we would like to compute the average acceleration in meters per second per second.

$$\frac{65.mi}{hr} \times \frac{5680\,ft}{1mi.} \times \frac{12in}{ft} \times \frac{m}{39.37in} \times \frac{1hr}{3600s} = 31.26\text{m/s}$$

$$\bar{a} = \frac{31.26m/s - 0m/s}{6.5s - 0s} = \frac{31.26m/s}{6.5s} = 4.81m/s^2$$

As we have been in vehicles that accelerate on an expressway, we can recognize the force from acceleration nearing 5 meters per second squared. However, the Metric system value for gravity is 9.8 meters per second per second, and the English unit for the acceleration of an object falling due to gravity is 32.2 feet per second per second. Over twice the acceleration of our automobile going from zero to 65 mph in a few seconds.

As with Galileo dropping objects from heights, we can examine the distance covered by an object that falls due to Earth's gravity in a few seconds.

$$v = at$$

Or in the case when gravity is equal to the acceleration.

$$v = gt$$

Using Calculus we can derive the formula for the distance of the fall as

$$y = \frac{1}{2} g t^2$$

where y is vertical distance traveled, g is gravity at 9.8 m/s^2 (32.2 ft/s^2) and t is the time traveled.

So we will compute the distance traveled for an object that falls in the Earth's gravity in a vacuum.

$$y = \frac{1}{2}\left(\frac{9.8m}{s^2}\right)(1s)^2 = 4.9 \text{ meters in the first second}$$

$$y = \frac{1}{2}\left(\frac{9.8m}{s^2}\right)(2s)^2 = 19.6 \text{ meters in the next second}$$

And we continue on with the calculation, the chart appears as shown in Figure 1.10.

Time	**Distance Traveled**	
(seconds)	**(at 9.8 m/s^2)**	**(at 32.2 ft/s^2)**
1	4.9 m	16.1 ft
2	19.6 m	64.4 ft
3	44.1 m	144 ft
4	78.1 m	256.6 ft

Figure 1.10 – Distance Traveled in Four Seconds

With the Earth's gravity, an object can travel almost the distance of a football field in 4 seconds. In this textbook, we will use the acceleration of gravity to help compute the forces on objects that we will design for our environment.

In the next chapter, we will learn about values in magnitude and direction when we study vectors.