USING SCALES

INTRODUCTION

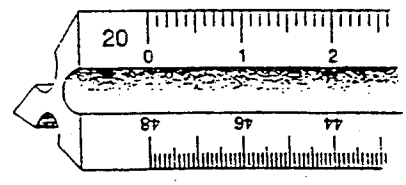
Scales are used by engineers, architects, machinists, and other professionals as a way to quickly relate the *true* dimensions of an object to how that object is *shown* in a drawing.

DEFINITIONS

The term "scale" can mean two things:

(1) A scale is the plastic (or wood) **object**, with, normally, three sides, which you will use to measure lengths of lines and dimensions of certain objects.

Typical 3-sided Scale:



(2) the numerical **ratio** between a dimension on your drawing and its *true* physical dimension. An example of number (2) is 1" = 40 feet; This numerical ratio means that every inch on your drawing (or map) represents 40 feet of *true* measurement.

Ratio Scales:

1" = 50'

$\frac{3"}{4}$ = 1'

READING SCALES:

Engineer's Scale:

The engineer's scale is used by engineers as well as other professionals who read and rely on engineering drawings. If you look at the three sides of the engineer's scale, you will see, on the left side of each face, the numbers 10, 20, 30, 40, 50 and 60. These numbers are used to distinguish the different types of "ratio" scales available on the engineer's (object) scale. The numbers 10 through 60 refer to the number of divisions into which an inch is divided.

Engineer's Scale (continued):

Note the following about the engineer's scale:

1. Engineers always deal in *decimals*, never in fractions. For instance, to an engineer, 5' 6" is **always** expressed as 5.5 feet; be careful in noting this distinction.

   This aspect can be confusing because engineer's scales combine a a traditionally metric concept, the decimal system, with units which are not traditionally divided into 10 parts, e.g., feet, miles, inches. An engineer will typically refer to distances as decimal portions of feet; an example of this is that 9 inches is more normally designated as 0.75 feet.

   Note that all units on the engineer's scale are divided into 10 equal parts, a requirement for any decimal-based system.

2. The engineer's scale is always used as a ratio scale of **1 inch = some value.** Some typical engineer's ratio scales include:

   1" = 20"

   1"= 5 feet

   1" = 30 miles

   1" = 600,000 feet

   One inch on the drawing (or map) is always the standard for engineers scales. Note also that all engineer's scales refer to some power of the numbers 1 through 6; in other words, an engineer's drawing will be limited to having scales such as 1" = 5', 1" = 50', 1" = 500', but rarely will an engineer's drawing have a scale of, say, 1" = 55 ', 1" = 75", or 1"=25 miles.

In using an engineer's scale, you will always need to determine what one inch on the scale represents. When using the engineer's scale marked "60", you could potentially measure a line at 1"= 6', 1"= 60', 1"= 600', 1" = 6", or many other "ratio" scales where the second number begins with a 6.

Example Problem:

The line above is measured with an engineer's scale.

(A) If the line is drawn at a scale of 1"= 6', what is the line's length? *(answer: 22.5 feet)*

(B) If the line is drawn at a scale of 1"= 400", what is the line's length? *(answer: 1,500 inches)*

(C) If the line is drawn at a scale of 1"= 3000', what is the line's length? *(answer: 11,300 feet)*

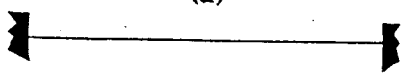
Engineer's Scale (continued):

Note the different ways in which **one face** of the engineer's scale can be used to measure lines with many different ratio scales. Be careful to **not** resort to using a calculator when using a scale. If you focus on what one inch represents, and count up to the line's length, you will not need to use a calculator. A scale is created so that measurements can be made quickly and accurately.

SELF-QUIZ—ENGINEER'S SCALE:

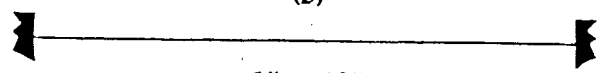
Measure the following lines using the engineer's scale: (answers on last page)

(a)



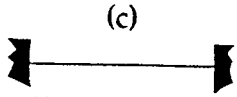
1" = 10 feet

(b)



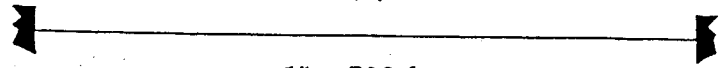
1" = 40"

(c)



1" = 30 miles

(d)

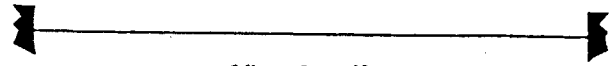


1" = 500 feet

(e)

1" = 6"

(f)



1" = 2 miles

Architect's Scale:

The architect's scale is used by architects, engineers, landscape architects, and any profession which uses architects' drawings. An architect's scale is considerably different than an engineer's scale, so be careful to make a clear distinction between these two types of scales. If you look at the three sides of the architect's scale, you will see, on both the right and left sides of each face, the numbers 16, 3/16, 3/32, 1, 1/2, 1/4, 1/8, 1-1/2, 3, 3/8, and 3/4. These numbers are used to distinguish the different types of scales available on the architect's scale.

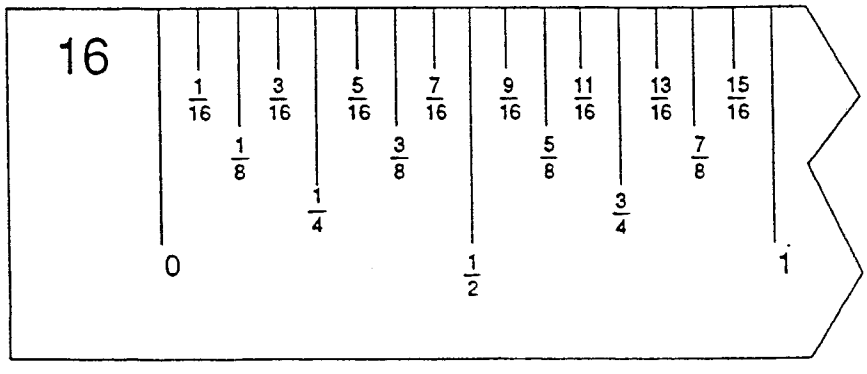
Note the following about the architect's scale:

1. Architects always deal in *fractions*, never in decimals. Note this important difference between the architect's and engineer's scales. For instance, to an architect, 3.5" is *always* expressed as $3\frac{1}{2}"$. Note that a distance of 5.3125 feet (an engineer's scale designation) is expressed by an architect as $5'–3\frac{3}{4}"$. Architects never refer to fractions of feet, however, and a distance of 40.5 feet to an engineer would be expressed by an architect as 40'–6", not $40\frac{1}{2}'$. The pattern is to express distances as feet, inches, and fractions of inches, if applicable. This is identical to how the construction industry in the U.S.

Architect's Scale (continued):

expresses lengths and distances. On the Architect's Scale full scale face (labeled 16), inches are divided into 16 equal parts, with each line identified as shown in the diagram below:

Architect's Scale full scale face
(DIAGRAM NOT TO SCALE):



"Fool! This is an eleven-sixteenths... I asked for a five-eighths!"

2. All of the scales available on the architect's scale, with **one** exception (the full scale shown before), refer to the fraction of an inch that is equal to one **foot**. For example, the 3/16 printed on the right end of one face of the architect's scale refers to a scale which is 3/16" = 1 foot. Likewise, the 1/8 printed on the left end of another face on the architect's scale refers to a scale which is 1/8" = 1 foot.

Each of the remaining rules applies to all architect's scale faces **except** for the scale face marked "16":

3. All of the marks in the middle of the architect's scale refer to **feet**.

4. At the end of each architect's scale face, all of the closely packed lines, **as a group**, represent one foot. Individual lines are used to measure **inches** and, where possible, fractions of inches (remember that all of the numbers in the middle of the scale face represent **feet**). In the case of the scale 1/4" = 1 foot, each of the individual closely packed lines on the right end of the scale represent **1 inch**. This is true because all of the lines together represent 1 foot; since that foot is divided into 12 equal parts, each individual line is equal to 1 inch (since 12 inches = 1 foot). Note that for the scale 3" = 1 foot, each of the smallest lines at the right end of the scale represent **1/8"**; this is true because each individual inch increment is further divided into 8 equal parts, or 1/8".

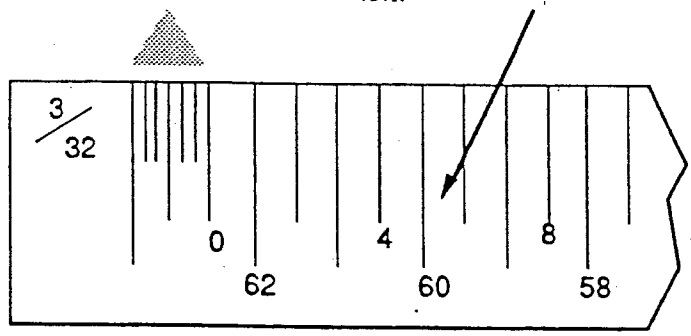
5. Each face on an architect's scale has *four* scales: two on the top and two on the bottom. The scale designation on the **left** end of the architect's scale refers to a scale which will measure distances working from **left to right**, and hence,

Architect's Scale (continued):

will only read those values which *increase* from left to right; likewise, the scale designation on the **right** end of the architect's scale refers to a scale which will measure distances working from **right to left**, and will only read those values which on the scale increase from **right to left**.

Closely packed lines,as a group, add up to one foot. On this scale, the 'incremented' foot is divided into 6 equal spaces. For an architect, each space equals 2 inches.

Marks in the middle of the scale represent feet. In this example, the 0, 4 and 8 represent feet for the 3/32 scale, which increases from left to right. The 62, 60 and 58 represent feet for the scale (3/16) which begins at the right end and increases right to left.



6. To measure a line using the architect's scale, line up one end of the line with a full foot designation, *so that the other end of the line falls somewhere in the increment foot at the end of the scale.* This will be demonstrated in class.

7. An architect's scale has less versatility than the engineer's scale. This is true because an engineer may use a scale to measure everything from a map of an entire country down to a drawing of integrated circuits. Conversely, an architect is usually restricted to drawings depicting buildings or structures. Since most structures or buildings fall within a specific size range, an architect's scale represents specific scales which allow for a convenient size in a drawing.

Example Problem:

The line above is measured with an architect's scale.

(A) If the line is drawn at a scale of $\frac{3"}{16}$ = 1', what is the line's length? *(answer: 18'-9")*

(B) If the line is drawn at a scale of $\frac{3"}{4}$ = 1', what is the line's length? *(answer: 4'-8")*

(C) If the line is drawn at a scale of 3"= 1', what is the line's length? *(answer: 1'- $2\frac{1"}{8}$)*

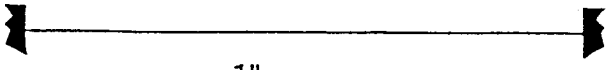
(D) If the line is drawn full scale, what is the line's length? *(answer: $3\frac{1"}{2}$)*

Architect's Scale (continued):

SELF-QUIZ—ARCHITECT'S SCALE:

Measure the following lines using the architect's scale: (answers on last page)

(a)

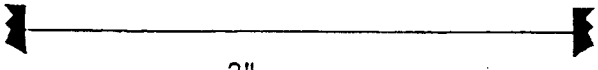


$\frac{1"}{2}$ = 1 foot

(b)

$\frac{3"}{32}$ = 1 foot

(c)

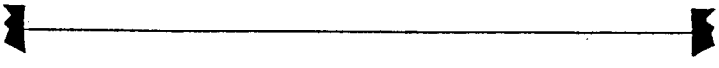


$\frac{3"}{4}$ = 1 foot

(d)

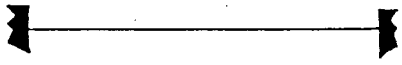
$\frac{1"}{2}$ = 1 foot

(e)



$1\frac{1"}{2}$ = 1 foot

(f)



1/4 size (be careful)
read the next section for help
indetermining which architect's scale
face to use

RATIO-TYPE SCALES:

Absolute Scale vs. Relative Scale

This class will define two types of "ratio" scales: absolute scale and relative scale. In the case of both types of "ratio" scales, the first number represents the dimension on the drawing (or map), and the second number (after the equals sign) represents the true dimension (or "reality"). Ratio scales can be expressed with (1) an equals sign [=], (2) a colon [:], (3) a fraction bar [/], or occasionally (4) the term "size".

Absolute Scale:

An absolute scale gives an absolute ratio between a dimension on your drawing and its true dimension. Some books refer to an absolute scale as a *representative fraction*. The most important item to remember concerning absolute scales is that they are unitless; as a result, an absolute scale does not usually include any units. An absolute scale is used in

Absolute Scale (continued):

many applications (particularly maps) because it represents a scale without the need for using a unit system. Examples of absolute scales include:

1/30	1/3.8
1:50 000	1/1 (also known as full scale)
1/256	1:80
1:4	1:2 (also known as half scale)
1"= 3"	1" = 20"

Although the last two scales listed contain units (unlike the others), these types of scales are still considered to be absolute scales, because, in the example of 1" = 3", all dimensions on your drawing will still be 1/3 true size– the absolute ratio between drawing and reality is 1 to 3. If any units are specified on a scale, they must be the ***same*** units if they are to represent an ***absolute*** scale. Metric scales (if used) are normally expressed as absolute scales. In this course, we will use metric dimensions but will not construct any *scaled* drawings using the metric system.

Relative Scales:

In contrast to an absolute scale, a relative scale relates one unit of measure on your drawing with a ***different*** unit of measure for reality. An example of this is 1 inch = 40 feet; this is a relative scale because the unit used on your drawing— inches— is different than the unit it is representing, in this case, feet. Examples of relative scales include the following:

1" = 10 feet	1' = 30 miles
1 mm = 100 m	1 mm = 1 km
3/4" = 1'	1" = 1'
1" = 70'	1" = 5280 feet

Note that all architect's ratio scales are relative scales– **no** architect scale, in its ordinary notation, accurately reflects the absolute amount that a particular object or feature is scaled down onto a drawing. For example, an architect's scale of 3/32" = 1' is **not** 3/32 size.

Converting Relative Scales To Absolute Scales:

To convert a relative scale to an absolute scale, you must first convert both sides of your equation to equivalent units. Once a scale is represented using the same units on both sides of the equal sign, it then represents the absolute ratio between drawing ("scaled-down") dimension and true dimension. In some instances, a final step is necessary to convert the first number in an absolute scale to a "1".

Example 1: **If a map has a scale of 1 inch = 600 feet, what is the absolute scale of the map (expressed as a fraction)?**

1 inch = 600 feet

STEP 1: Convert the feet units into inch units

1 inch = 600 feet x (12 inches/ 1 foot)

If we multiply the right side of the equation by a factor equaling 1 (in this example, 12 inches/ 1 foot) we will not change the "validity" of the equation.

Simplifying, 1 inch = 7200 inches.

STEP 2: Since both sides of the equation now have *identical* units, we can easily express this scale as an absolute scale, by merely dropping the units:

1/ 7200 ← **Answer**

This scale states, simply, that every dimension on the map is 1/7200 true size. Note that for a drawing representing a large area, a scale of 1/7200 may be necessary if the entire area is to fit, scaled down, onto the drawing.

Example 2: **If an architect's floorplan has a scale of $\frac{1}{8}$ inch = 1 foot, what is the absolute scale of the map (expressed as a fraction)?** Note: It is not 1/8.

STEP 1: Convert the feet units into inch units

$\frac{1}{8}$ inch = 1 foot x (12 inches/ 1 foot)

Simplifying, $\frac{1}{8}$ inch = 12 inches

STEP 2: Since both sides of the equation now have *identical* units, we can easily express this scale as an absolute scale, by merely dropping the units:

$\frac{1}{8}$: 12

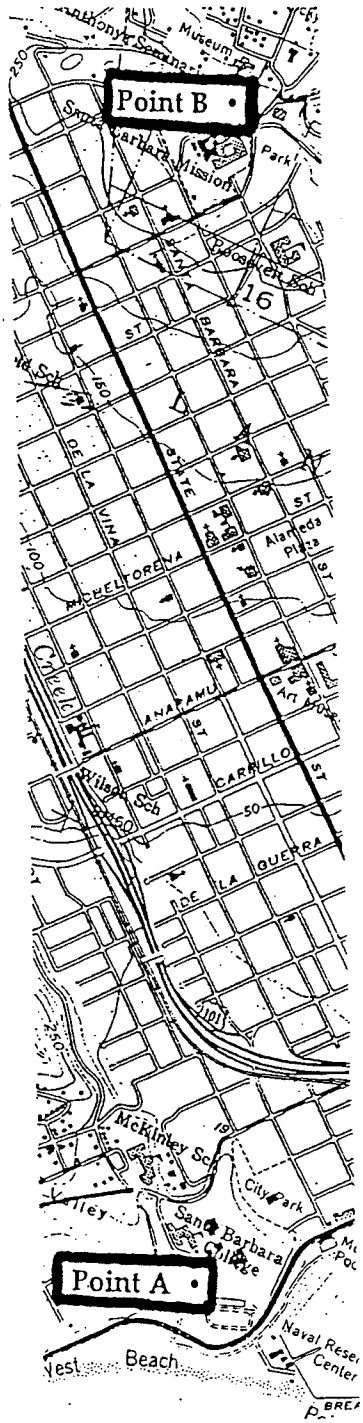
STEP 3: If the first number is not equal to 1, we multiply both sides of the equation by the reciprocal of the first number:

$\frac{1}{8}$ (x 8) : 12 (x 8) **1/ 96** ← **Answer**

Converting Absolute Scales To Relative Scales:

On some occasions, it will be necessary to convert an absolute scale to a relative scale. The following example shows how to work "backwards" from a drawing with an absolute scale, to determine which scale, engineer's or architect's, can be used to measure distance directly from that drawing .

Example: United States Geological Survey (USGS) maps are available in $7\frac{1'}{2}$ (of longitude) size, often used by campers and backpackers. The piece of such a map shown below shows Santa Barbara, and has an absolute scale of 1:24,000. In this map, what is the straight-line distance from SBCC (point A) to the Santa Barbara Mission (point B)?



Solution:

Step 1: Add units to both numbers

1:24,000 ➡ 1" = 24,000"

Step 2: Convert second number into different units, readable by engineer's scale:

$$1" = 24{,}000" \times \frac{1\text{foot}}{12\text{ inches}} = 2{,}000'$$

This scale, 1" = 2000', is identical to 1:24,000, and can be directly measured by using the engineer's scale (20 face).

Step 3: Measure distance using appropriate scale. Recall that the '2' represents 2000 feet. Count up to the distance that you're measuring. In this instance, the distance from point A (SBCC) to point B (SB Mission) is 13,600 feet.

13,600 feet ⬅ answer

Engineer's Scale Self-Quiz solutions:

(a) 19' (b) 114' (c) 29 mi
(d) 1740' (e) 9.4" (f) 5.8 mi

Architect's Scale Self-Quiz solutions:

(a) 5'-10" (b) 10'-4" (c) $3'\text{-}9\frac{1"}{2}$
(d) $3'\text{-}1\frac{1"}{2}$ (e) $2'\text{-}2\frac{3"}{4}$ (f) $\frac{3"}{8}$