Scale and Dimensioning

Description
In this activity, the teacher will first select an object that is larger than the page and scale it to fit in the drawing area to explain metric scale. Second, the teacher will then dimension the scaled object using standard conventions. Students will use paper with a title block to complete this activity. Students will also continue to improve their skills with lettering techniques and lineweights.

Lesson Objectives
The student will be able to:
• Complete a board set-up
• Identify and appropriately use drafting tools
• Differentiate lineweights by varying pencil pressure while creating scale drawings of objects
• Determine the appropriate scale to ensure an object is proportionally drawn
• Incorporate dimensioning standards
• Refine lettering techniques

Assumptions
The student will:
• Have a basic knowledge of drafting tools and equipment
• Understand the basics of appropriate use of drafting equipment
• Have previously drawn a title block for use in completing this activity

Terminology
Aligned dimensions: numerical dimension values that are aligned with the direction of the dimension line. The drawing therefore has to be turned to correctly read the dimensions.

Border lines: thick, dark lines used to create a solid border around a blank page.

Dimensions: a measurement of something in a specific linear direction. Most often this includes the length, width, and height of an object.

Dimension lines: lines spanning the distance between extension lines; they have arrowheads and include a numerical dimension measurement.

Drafting board: a flat, smooth surface usually covered in vinyl, which helps to hold paper affixed to it. It has square, parallel edges that allow a T-square to slide easily.
Drafting brush: used to sweep away debris from a drawing so it does not smear the full drawing.

Eraser shield: a micro-thin piece of metal with cut-outs that allow the user to erase detailed sections of a drawing without erasing the rest of the drawing.

Extension line: small lines that extend outward from an object or feature to indicate a dimension point.

Guide lines: thin, light lines drawn using the lettering guide for evenly spaced letters.

Layout lines: very light lines used to lay out measurements before those measurements are drawn in heavy dark lines.

Lettering guide: used to assist in the drawing of uniform lines to draw consistent, evenly-spaced lettering.

Lineweight: the thickness and darkness of drawn lines.

Masking tape (drafting dots): holds drawing paper/vellum to the drafting board so the paper does not shift while drawing.

Pencil: a drawing utensil with a mechanical or solid core (lead). Leads range from hard to soft: 6H, 4H, 2H, H, HB, 2B, 4B, 6B. H is very hard with a fine point and B is extremely soft with a blunt point. A hardness of 2H will be used for these activities.

Precision drawing: creating drawings with specialized tools and equipment.

Scale: ratio of length of a drawn object relative to its length in “real space.” A proportional representation of an object either reduced or enlarged.

Steel rule: straightedge made of rigid material, divided into specific increments, found both in metric and imperial units.

Title block: comprised of the information boxes found on the bottom right-hand corner of a drawing, the title block indicates drawing details such as the title, author name, scale, and date a drawing was created.

Triangles (right angle and isosceles): made of hard, clear plastic, they are used to draw lines at vertical and set angles: 45°–90°–45°, 30°–60°–90°

T-square: a precision drawing instrument, used as a guide for other drafting equipment. Has a 90° angle where the head and blade attach.

Unidirectional dimensions: show the numerical values in a normal reading position (horizontally); no rotation of the drawing is required.

**Estimated Time**

30–60 minutes

**Recommended Number of Students**

20, based on *BC Technology Educators’ Best Practice Guide*
Facilities

- Regular classroom space with desks/chairs for all students
- Drafting boards would be ideal; however, smooth, clean, and flat surfaces will also suffice

Tools

- T-square
- Steel rule
- Triangles (right angle and isosceles)
- Eraser shield
- Drafting brush
- Masking tape (drafting dots)
- Drafting board
- Lettering guide
- 2H mechanical pencil
- Architectural scale
- Sample blocks for drawing (should be 50 mm wide x 100 mm high x 150 mm long)

Materials

- Handout for students with instructions (suggestion: develop a handout from the instructions for the teacher-led activity)
- Title block drawing page (created in the Introduction to Title Blocks activity)
- Practice worksheet for reading metric scales
- Practice worksheets for dimensioning
Teacher-led Activity

Part 1: Scale an object to fit title block

1. Gather all materials listed above.

2. Using the T-square and masking tape and/or drafting dots, align title-blocked paper to your drafting board and securely tape down (Figure 1).

3. Have students take measurements of the object block using the steel rule. This should include at a minimum length, width, and height (thickness) of the object (Figure 2). Have students make notes on a scrap piece of paper for future reference in the activity.

If students need further practice with the scale before drawing, have them complete the student activities on pages 7 and 22.
4. Using the metric scale, explain how to choose the best scale for this assignment.

Explain that the chosen scale must allow for all object details while still drawing the object proportionally onto the page.

The metric scale uses ratios of the same units in both ratio terms, resulting in an expression of how many times smaller the object is compared with the drawing. For example, if the ratio is 1:20, the object is 20 times larger than the object drawn.

On a metric scale there are only six scale ratios: 1:10, 1:5, 1:20, 1:2, 1:50, and 1:1. The units on the scale are represented as 1 m.

![Figure 3—Metric Scale](image)

5. Have the students draw the object using the measurements they took with the steel rule in Step 3.

**Note:** Students should draw the object in the centre near the bottom of the drawing space (Figure 4). They should use appropriate tools and equipment to ensure their drawing is square and is a detailed representation of the three-dimensional object.
6. Once students have completed the drawing of their scaled object, have them label the drawing and locate the title underneath the object.

7. Students can also fill in the title block information (see below). The scale box will be specific to the scale chosen. Responses will vary. Scale is represented as a ratio in the title block space. For example, if the drawing was completed using the 1:2 measurements on a metric scale, then the ratio would be 1:2 on the title block.

<table>
<thead>
<tr>
<th>ACTIVITY # 4</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DATE</td>
</tr>
<tr>
<td>SCALE AND DIMENSIONING</td>
<td>SCALE</td>
</tr>
<tr>
<td></td>
<td>PAGE 1 OF 1</td>
</tr>
</tbody>
</table>

**Part 2: Dimensioning the object**

**Dimensioning notes:**

1. When dimensioning objects, remember three key points:
   - Never leave any size, shape, or object in doubt.
   - Do not repeat the same dimension. Doing so could lead to confusion in reading the drawing measurements.
   - All dimensions should be located on the drawing in a clear, concise, and easy-to-follow manner.

2. There are two styles of dimensioning (Figure 5). For this lesson use the *unidirectional dimension* style.
   - *Aligned dimensions* show the numerical values aligned with the direction of the dimension lines. This results in having to turn the drawing to correctly read the dimensions.
   - *Unidirectional dimensions* show the numerical values in a normal reading position (horizontally); no rotation of the drawing is required.

![Aligned dimensions](image1) ![Unidirectional dimensions](image2)

*Figure 5—Dimensioning systems*
Student Activity

1. Using the scale-drawn object (and/or drawing) from the previous section, identify the areas that will require dimensions. Remember not to leave any areas in doubt.

2. Dimension and extension lines should be light in weight, clean, and a consistent thickness. Extension lines are drawn out from the object and act as a border edge for the dimension lines.

3. The dimension line should be drawn between the extension lines with arrows indicating where the measurement falls between the extension lines. A space must be left in the centre of each dimension line where the numerical value is placed. Be sure to include units of measurement with each dimension.
4. Complete each area of the drawing to ensure that no area is left out. A good rule of thumb is to ask yourself the question: “Could I build the object with the dimensions currently on the drawing?” If not, review the drawing and add the missing dimensions.

**Extension Activity**

- Further practice drawing, scaling objects, and dimensioning.
- Worksheets to practise reading dimensions from drawings.

**Assessment**

- Student participation in discussion/demonstration
- Drawing completed with the following:
  - Lines are drawn correctly.
  - Corners of border lines are closed (horizontal and vertical lines cross).
  - Dimensions meet standard convention styles.
  - Dimensions are neat and tidy.
  - Scale is appropriate to the size of the object and space available for drawing.
  - Lettering is neat, clean, and uppercase.
  - Title block is filled out correctly with appropriate information.

**Appendix Acknowledgment**

© Camosun College. Trades Access Common Core: *Competency D-3: Read Drawings and Specifications* (pp. 34-40). The Trades Access Common Core resources are licensed under the Creative Commons Attribution 4.0 Unported Licence (http://creativecommons.org/licenses/by/4.0/), except where otherwise noted.
Appendix

Figure 13 shows a simple drawing. Notice that the dimensions are given between arrows that point to extension lines. By using this method, the dimensions do not get in the way of the drawing. One extension line can be used for several dimensions. Notice also that the titles require larger letter sizes than those used for dimensions and notations. It is important that the title and sketch number stand out, as shown in Figure 13. When you begin lettering, you may wish to use very light lettering guide lines to ensure uniformity in lettering size and alignment.

![Figure 13 — Standard lettering sizes](image)

Principles of dimensioning
A good sketch of an object is one that you can use as a blueprint to manufacture the object. Your sketch must show all the necessary dimensions of the part, locate any features it may have (such as holes and slots), give information on the material it is to be made from, and if necessary, stipulate the processes to be used in the manufacture of the object.
Three principles of dimensioning must be followed:

1. Do not leave any size, shape, or material in doubt.

2. To avoid confusion and the possibility of error, no dimension should be repeated twice on any sketch or drawing.

3. Dimensions and notations must be placed on the sketch where they can be clearly and easily read.

Consider Figure 14 and note whether these three dimensioning principles have been followed.

Although the dimensions and notations are clear and easy to read in Figure 14, the following points should be made:

- Leg and rail sizes have not been shown.
- The thickness of the top has not been given.
- The material has not been given as a notation.
- The 600 dimension has been repeated.
- The type of finish to be used has not been given.
- Note 2 is redundant.
The sketch of the shop table is far from complete, and the table could not be made without a lot of guesswork. Figure 15, on the other hand, shows a completed sketch that, along with the necessary notes and dimension information, can be readily used for construction purposes.

**Figure 15 — Dimensioning**

**Rules of dimensioning**

For most objects, there are three types of dimensions:

- size dimensions
- location dimensions
- notation dimensions

Figure 16 illustrates the difference between size and location dimensions. (S = size dimension and L = location dimension).
Size dimensions are necessary so that the material size of the object can be determined. Location dimensions are necessary so that parts, holes, or other features can be positioned in or on the object. Notation dimensions describe the part, hole, or other feature with a short note such as the “Ø20 2 holes” notation (see Figure 16). Keep these points in mind:

- Keep all dimension lines at least 10 mm (3/8”) clear of object lines wherever possible.
- Try to group related dimensions rather than scattering them.
- Try to keep dimensions off the views themselves.
- Separate one line of dimensions from another line of dimensions or from a notation by a space of at least 10 mm (3/8”).
- Leave a space of approximately 3 mm (1/8”) between the object outline and the beginning of any extension line.
- Keep arrowheads slim and neat.
- Never dimension to a hidden line.
- Draw leader lines at an angle when intersecting object lines to avoid confusing them with extension lines.

Figure 17 illustrates good placement of dimensions and notations. Note the placement of extension lines and the use of centre lines to locate features such as holes. Also, note the shape and size of arrowheads.
**Dimensioning systems**

Two systems are used for dimensioning drawings. They are the aligned and the *unidirectional* systems. Figure 18 shows examples of both systems. As you can see, the aligned system requires that you turn the drawing on its side, whereas the unidirectional system may be read from the normal reading position. For most drawings, the unidirectional system is preferred, as it is easier to read; however, architectural drawings still use the aligned system.

![Figure 17 — Extension line usage](image)

**Figure 18 — Dimensioning systems**

![Aligned dimensions](image) ![Unidirectional dimensions](image)
Systems of measurement
You may be required to sketch or read drawings constructed with either metric (SI) or imperial dimensions. You may also encounter drawings that are dual dimensioned and contain both systems of measurement on the same drawing.

SI system of measurement
The SI system of measurement has become the official standard in Canada. It is common practice on shop drawings to express all metric dimensions in millimetres. Figure 19 shows a detail drawing for a connector arm using metric measurements. All metric drawings should contain a note specifying that all dimensions are in millimetres.

Imperial system of measurement
An imperial drawing may use the decimal-inch system, the fractional-inch system, or feet and inches.

- In the decimal-inch system, very accurate dimensions for items such as machine parts are expressed as decimals of an inch, such as 0.005". In words this reads as five one-thousandths of an inch.

- In the fraction-inch system, dimensions for things such as steel and lumber sizes are expressed as inches and fractions of an inch from as small as 1/64" (Figure 20). Most drawings that are dimensioned in the imperial system will use the fraction-inch system.
Notes:
1. All dimensions are in inches
2. Materials - 5/16 × 3 mild steel plate

Figure 20 — Connector arm – imperial measurement

In the feet-inch system (Figure 21), the dimensions of large structures such as machine frames and buildings are expressed in feet and inches, such as 2'-6" (two feet, six inches).

Figure 21 — Fuel storage shed
Use scale rulers to determine actual dimensions from drawings

Scale drawings are accurate and convenient visual representations made and used by engineers, architects, and people in the construction trades. The accuracy is achieved because the drawing is proportional to the real thing. The convenience comes from the size of the drawing. It is large enough to provide the desired detail but small enough to be handy.

The flexibility to draw proportionally in different sizes is provided by scales. For the purposes of representation, we will only be concerned with reduction scales. Reduction scales make the drawing smaller than the object. The kinds of rulers we will be discussing for making scaled drawings are the architect’s scale and the metric scale, both shown in Figure 1.

The scale of the drawing is always written on the drawing, unless the drawing is not drawn to scale. In the latter case, this will be indicated by the “not to scale” abbreviation (NTS). The scale is the ratio of the size of the drawing to the object. For drawings smaller than the object, the ratio is that of a smaller distance to a larger one.

The architect’s scales use ratios of inches to a foot. The most common architect’s scale used is ¼ inch to the foot, written on drawings as:

Scale ¼” = 1’-0”

This means that a line ¼” long on the drawing represents an object that is one foot long. At the same scale, a line 1½" long represents an object 6’ long, because 1½" contains 6 quarter-inches.

Metric scale ratios use the same units in both ratio terms, resulting in an expression of how many times smaller than the object the drawing is. For example, the standard metric scale ratio that corresponds approximately to ¼” = 1’-0” is written on drawings as "Scale 1:50."
This means that the object is 50 times as large as the drawing, so that 50 mm on the object is represented by 1 mm on the drawing. For another example, 30 mm on the drawing represents $50 \times 30 \text{ mm} = 1500 \text{ mm}$ (or 1.5 metres) on the object.

Figure 2 lists the scale ratios used for building plans and construction drawings in both metric and the approximate equivalent architectural scale ratios.

<table>
<thead>
<tr>
<th>Type of Drawing</th>
<th>Common Metric Ratios</th>
<th>Imperial Equivalents and Ratios</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site plan</td>
<td>1:500</td>
<td>$1'' = 40'\cdot 0''$</td>
<td>1:480 • To locate the building, services and reference points on the site</td>
</tr>
<tr>
<td></td>
<td>1:200</td>
<td>$\frac{3}{16}'' = 1'\cdot 0''$</td>
<td>1:192 • To show the overall design of the building</td>
</tr>
<tr>
<td>Sketch plans</td>
<td>1:200</td>
<td>$\frac{3}{16}'' = 1'\cdot 0''$</td>
<td>1:192 • To indicate the juxtaposition of the rooms and locate the positions of piping systems and components</td>
</tr>
<tr>
<td>General locations</td>
<td>1:100</td>
<td>$\frac{1}{8}'' = 1'\cdot 0''$</td>
<td>1:96 • To show the overall design of the building</td>
</tr>
<tr>
<td>Drawings</td>
<td>1:50</td>
<td>$\frac{1}{4}'' = 1'\cdot 0''$</td>
<td>1:48 • To indicate the juxtaposition of the rooms and locate the positions of piping systems and components</td>
</tr>
<tr>
<td>Construction details</td>
<td>1:20</td>
<td>$\frac{1}{2}'' = 1'\cdot 0''$</td>
<td>1:24 • To show the detail of system components and assemblies</td>
</tr>
<tr>
<td></td>
<td>1:10</td>
<td>$1'' = 1'\cdot 0''$</td>
<td>1:12 • To show the detail of system components and assemblies</td>
</tr>
<tr>
<td></td>
<td>1:5</td>
<td>$3'' = 1'\cdot 0''$</td>
<td>1:4 • To show the detail of system components and assemblies</td>
</tr>
<tr>
<td></td>
<td>1:1</td>
<td>Full size</td>
<td>1:1 • To show the detail of system components and assemblies</td>
</tr>
<tr>
<td></td>
<td>1:24</td>
<td>$\frac{1}{2}'' = 1'\cdot 0''$</td>
<td>• To show the detail of system components and assemblies</td>
</tr>
<tr>
<td></td>
<td>1:12</td>
<td>$1'' = 1'\cdot 0''$</td>
<td>• To show the detail of system components and assemblies</td>
</tr>
<tr>
<td></td>
<td>1:4</td>
<td>$3'' = 1'\cdot 0''$</td>
<td>• To show the detail of system components and assemblies</td>
</tr>
<tr>
<td></td>
<td>1:1</td>
<td>Full size</td>
<td>• To show the detail of system components and assemblies</td>
</tr>
</tbody>
</table>

Figure 2 — Preferred scales for building drawings

**Architect’s (imperial) scales**

Traditional architectural measurements of length are written very precisely in feet and inches using the appropriate symbols for feet and inches separated by a dash (e.g., 4'-3 $\frac{1}{2}''$ and 7'-0''). This is the way that all imperial measurements are written on construction drawings.

Listed below are the scales found on the architect’s triangular scale ruler.

1. $\frac{3}{32}'' = 1'\cdot 0''$
2. $\frac{3}{16}'' = 1'\cdot 0''$
3. $\frac{1}{8}'' = 1'\cdot 0''$
4. $\frac{1}{4}'' = 1'\cdot 0''$
5. $\frac{3}{8}'' = 1'\cdot 0''$
6. $\frac{1}{2}'' = 1'\cdot 0''$
7. $1'' = 1'\cdot 0''$
8. $\frac{1}{2}'' = 1'\cdot 0''$
9. $1\frac{1}{2}'' = 1'\cdot 0''$
10. $3'' = 1'\cdot 0''$
11. $1'' = 1''$ (full size—use the scale labelled 16)
Figure 3 shows one face of an architect’s imperial triangular scale ruler. There are two edges on each face and each edge contains two scales that run in opposite directions. At each end of an edge, a number or fraction indicates the distance in inches that represents one foot. The top edge is in eighths of an inch from left to right, and in quarters of an inch from right to left. Note that the ¼” scale from 0 to the right end represents 95 feet, and the ¼” scale from 0 to the left end represents 47 feet.

At each end, between the zero and the number indicating scale, the length representing one foot is subdivided into 6, 12, 24, or more parts to indicate inches and, in some scales, fractions of an inch. For example, each of the six marks on the ¼” scale represents two inches, while each mark equals a quarter of an inch on the 1” reduction scale and one inch on the ¼” scale.

Now look at the 1½” scale in Figure 4. The subdivided unit is divided into inches and fractions of an inch. Reading left from the zero, notice the figures 3, 6, and 9, which represent measurements of 3”, 6”, and 9”. From the zero to the first long mark represents 1”. Between the zero and the one-inch mark there are four spaces, each of which represent one-quarter of an inch.

Piping drawings usually use a ⅛” scale for larger buildings, a ¼” scale for smaller buildings and houses, and a ½” scale for details. Each drawing will state in the title block the scale that is used. Sometimes when special details are given, the scale is placed directly under the detail.

To draw or measure a length to scale, first find the edge of the ruler containing the scale. One end of the length will rest exactly on one of the foot marks of the scale, and the other end should rest either on the zero marker or somewhere on the inch subdivision of the scale. The length can then be marked and drawn or read off from a drawing.
Figures 5 and 6 demonstrate this manner of reading dimensions from four of the ratios on the architect’s scale.

![Figure 5 — Reading dimensions using an architect’s ruler (NTS)](image)

Architectural units have feet divided into inches, whereas engineering units divide feet into tenths and hundredths. Engineers’ scales are not used to make piping drawings.

**Metric scales**

A triangular metric scale is similar to the architectural scale in that it has six edges, but it has only one scale ratio per edge. The ratio is marked at the left end of the scale. For example, the scale of 1:50 means that 1 mm on the drawing represents 50 mm on the object. This means that the object is 50 times larger than the drawing of it. An object 450 mm long would be represented by a line 9 mm long (450 mm/50).

Figure 7 shows one of the three sides of a metric scale. The scale labelled 1:50 is read from left to right, from 0 to 15 m. The 1:5 scale (on the bottom) can also be read from left to right (0 to 600 mm) by turning the scale around.
1. Write the correct measurement of the dimensions shown below in the box at the right.

Sample  
1:100  
0  1m  2  3  4  5  6  7  8  9  10  11  12  13  14  

a.  
1:100  
0  1m  2  3  4  5  6  7  8  9  10  11  12  13  14  

b.  
1:50  
0  1m  2  3  4  5  6  7  

c.  
1:5  
0  0.1m  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  1  1.1  1.2  1.3  1.4  

d.  
1:10  
0  0.1m  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  1.0  1.1  1.2  1.3  1.4  

e.  
1:20  
0  0.5m  1m  1.5  2  2.5  

11.5 m
Answer Key

1. a. 6'-5"
   b. 12'-10"
   c. 1'-6"
   d. 4'-9"
   e. 0'-6"
   f. 0'-11"
   g. 2'-0"
   h. 0'-3"
   i. 1'-9"
   j. 2'-11"