EVALUATING
ACADEMIC READINESS
FOR APPRENTICESHIP TRAINING
Revised for
ACCESS TO APPRENTICESHIP

SCIENCE SKILLS
MEASUREMENT TOOLS

AN ACADEMIC SKILLS MANUAL
for
The Precision Machining And Tooling Trades

This trade group includes the following trades:
General Machinist, Tool & Die Maker,
Mould Maker, Pattern Maker, and
Machine-Tool Builder Integrator

Workplace Support Services Branch
Ontario Ministry of Training, Colleges and Universities

Revised 2011

In preparing these Academic Skills Manuals we have used passages, diagrams and questions similar to those an apprentice might find in a text, guide or trade manual.

This trade related material is not intended to instruct you in your trade. It is used only to demonstrate how understanding an academic skill will help you find and use the information you need.

SCIENCE SKILLS
MEASUREMENT TOOLS

An academic skill required for the study of the Precision Machining and Tooling Trades

INTRODUCTION

Measuring accurately is an essential skill in any manufacturing process. Tools have been developed that assist in the precise measuring and laying out of pieces of work. Some of these tools can be read to an extremely high degree of accuracy. No tool is useful, however, if you cannot read its scale effectively. This skills manual looks at some basic measuring tools. It covers the following topics:

- Preliminary math for measuring
- The steel ruler
- The micrometer
- Calipers
- Dividers

PRELIMINARY MATH FOR MEASURING

A preliminary step in reading scales on a precision measuring tool is knowing how to work with decimal numbers and fractions. Workers have to change fractions to decimal numbers and decimals to fractions in making measurements and reading layout instructions.

Fractions and Decimals

A fraction is written with one part, called the *numerator,* on top and another part, called the *denominator,* on the bottom. They are separated by a line called a *fraction bar or line*.

A decimal is a fraction which has as its denominator a power of ten. It is written by using a digit placed to the left of a point called the *decimal point.* Money is written in the decimal system

To change a fraction to a decimal number, divide the numerator of the fraction by the denominator.

> **Example:** To change 8/25 to a decimal, divide 8 by 25, which equals 0.32. If the number is a mixed number (a whole number with a fraction part such as 4 3/5) the whole number is written before the decimal point. 4 3/5 is written as the decimal number 4.6.

To change a decimal to a fraction, remove the decimal point, then write the decimal part of the number as the numerator. The denominator is a power of ten written with as many zeros as there are digits in the decimal part of the number (including zeros). The fraction formed in this way is then reduced to lowest terms.

> **Example:** To convert .275 to a fraction, the decimal is written as the numerator. The denominator is a power of ten having three zeros as there are three digits in the decimal. Thus .275 written as a fraction is 275/1000. Reduced to lowest terms, it becomes 11/40 .

If the number being converted includes a whole number, it is written separately, before the fractional part. 8.045 written as a mixed fraction is 8 45/100 reduced to 8 9/20 .

It is also helpful to be familiar with place value in reading decimals and fractions.

- The basic unit is called the ones place.

- If you move from the right hand side to the left in a number, the place value increases to the tens place, the hundreds, the thousands, ten-thousands, hundred-thousands, millions and so on. 9 648 345 represents a number containing nine millions, six hundred forty-eight thousands, three hundred forty five.

- To the right of the ones place is the decimal point.

- After the decimal point are the fractional place values. The first place after the decimal point is the tenths place, the next is the hundredths place, then the thousandths place, the ten-thousands place, the hundred-thousandths place, the millionths place and so on. Notice that the names of the place values after the decimal point are written with the letters "*th*" after the same names that are used to indicate whole number place values.
    - .9 represents 9 tenths. We say this decimal as, "decimal nine."

Imperial and Metric Measurement

Another helpful skill is converting from standard or imperial measurement to metric and back again. Sometimes the blueprints have metric measurements while the handiest measuring tool has an imperial scale.

To convert from the imperial system to metric, multiply the number of inches, feet or yards by the appropriate metric equivalent or conversion factor.

To convert from metric to imperial, multiply the number of millimeters, centimeters or meters by the appropriate imperial conversion factor. You will need to know the conversion factors or have a conversion table nearby.

Some useful imperial to metric equivalencies:

1 in = 25.4 mm
1 in = 2.54 cm
1 ft = .305 m
1 yd = .914 m
1 mi = 1.6 km

Example: Convert 15 inches to mm.

The conversion factor is 25.4
Multiply 15 x 25.4
15 in x 25.4 = 381 mm

Some useful metric to imperial equivalencies:

1 mm = .039 in
1 cm = .394 in
1 m = 39.4 in
1 m = 3.28 ft
1 m = 1.09 yd
1 km = .625 mi

Example: Convert 8 m to yards.

The equivalency factor is 1.09
Multiply 8 x 1.09
8 m x 1.09 = 8.72 yd

THE STEEL RULER

The steel ruler is used for linear or straight line measurement. Rulers come in inch, decimal and metric graduations. One end of the ruler is placed even with one end of the work. The ruler should be placed parallel to the edge of the piece of work. Read the line on the ruler which is directly over the other end of the work.

Imperial rulers: The scale of a fractional ruler is divided into full inches and fractions of inches. The fractional scale can be in eighths, sixteenths, thirty-seconds or sixty-fourths. If the scale is in eighths, each smaller mark within every inch line represents one-eighth of an inch. To read a fractional ruler:

1. Note the number of full inches.
2. Add to this the fraction past the last full inch mark.

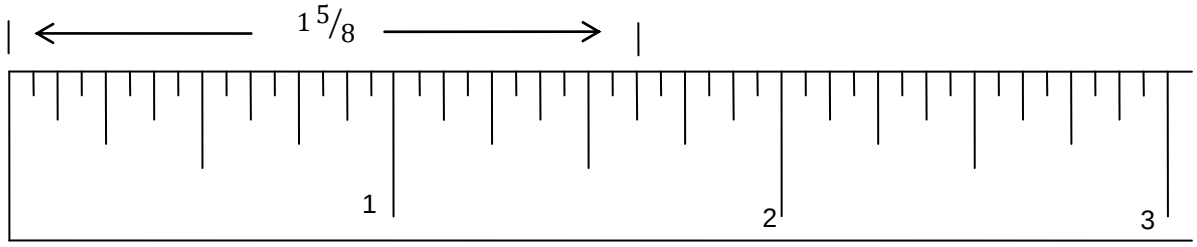


Figure 1: Imperial Ruler

To read the measurement above:

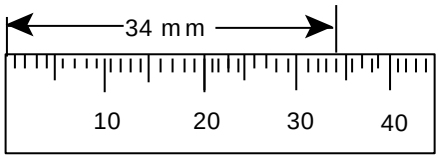
Note the number of full inches: 1 inch
1. Note the number of eighths past the last full inch mark: 5/8 inch
2. Add the whole number and the fraction to get the complete reading: 1 5/8 inches

Metric rulers: Metric rulers are graduated in millimeters. A larger marking is placed every 10 millimeters. Remember that 10 millimeters equals 1 centimeter, so each 10 millimeter line also represents 1 centimeter. To read a metric ruler:

1. Note the number of main divisions showing. Each main division has a value of 10 mm and the scale usually has the divisions increasing by tens numbered (10, 20, 30, 40 etc).
2. Count the number of smaller markings past the last main division line.
3. Add this value to the number found in the first step.

To read the measurement here:

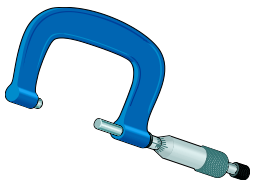
1. Note the number of main divisions of ten: 30 mm
2. Each small line marks 1 mm.
3. Count the number of small lines past the 30 mm line: 4 mm
4. Reading is: 30 mm + 4 mm = 34mm



A reading of 34 mm on the millimeter scale

If the end of a steel ruler is worn, a more accurate measurement can be obtained by starting at some major division such as 1 inch or 10 mm. After making the reading, subtract either the 1 inch or the 10 mm that isn't included in the measurement.

THE MICROMETER



The Micrometer

Outside micrometers are used when a higher degree of accuracy is required than a steel ruler can provide. The main parts of the micrometer are the frame, the anvil, the spindle, the sleeve and the thimble.

The micrometer is tightened by turning the thimble until the anvil and spindle fit snugly on each end of the object that is being measured.

- As the thimble turns, it moves along the sleeve one graduation mark each time it makes one revolution.
- When the thimble can no longer turn, a reading is taken of the graduation marks where the thimble stopped moving.
- This reading gives the length of the piece being measured.

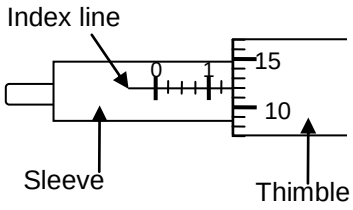
The standard inch micrometer measures accurately to one-thousandths of an inch. The standard metric micrometer measures in hundredths of a millimeter. For greater accuracy, the Vernier scale on a micrometer allows standard measurements up to one ten-thousandths of an inch or up to two-thousandths of a millimeter.

The easiest micrometer to use has a digital readout built into the frame that automatically gives an exact reading. But you will need to know how to read a micrometer in case you are making a measurement with a micrometer that doesn't have a digital readout.

Standard inch micrometer: To measure a piece of work using a standard inch micrometer, tighten the micrometer and then take the reading. The reading is not as straightforward as reading a ruler. There are a number of steps to follow:

1. Note the last number showing on the sleeve and multiply it by .100.
2. Multiply any small lines visible past that number by .025.
3. Note the number of the division line on the thimble that coincides with the center or index line on the sleeve and multiply that number by .001.
4. Add all the resulting numbers to get the total reading.

To read the measurement shown:



A micrometer showing a reading of .162"

1. Note the last number showing on the sleeve and multiply it by .100:

   1 x .100 = .100

2. Count the number of small lines visible past that number and multiply by .025:

   2 x .025 = .050

3. Note the number of the division line on the thimble that coincides with the center line on the sleeve and multiply it by .001:
   12 x .001 = .012

4. Add all the resulting numbers to get the total reading

   .100
   .050
   .012
   .162 inch

Metric micrometer: A metric micrometer has graduations of .5 or ½ of a millimeter on the scale on the sleeve, so every two lines represent 1 mm. Every tenth line, representing a division of 5 mm (10 x ½ = 5), is numbered, starting at 5 mm, then 10 mm, 15 mm, 20 mm etc. To read a metric micrometer, follow these steps:

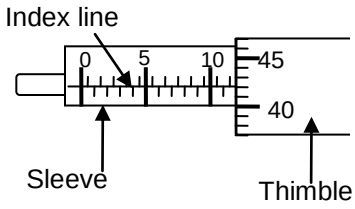
1. Note the last division number showing on the sleeve and multiply it by 1 mm.
2. Note the number of lines showing past the last numbered division line.
3. Note the number of the division line on the thimble that coincides with the index line and multiply it by .01.
4. Add the resulting numbers to get the total reading.

To read the measurement shown here:

1. Note the last number showing on the sleeve and multiply it by 1 like this:
   10 x 1 = 10 mm

2. Count the number of division lines past the number 10 and multiply by .50:
   3 x .50 = 1.5 mm

3. Note the number on the thimble that coincides with the index line and multiply it by .01:
   42 x .01 = .42



A micrometer showing a reading of 11.92 mm

4. Add the resulting number to get the total reading:

   10.0
    1.5
    .42
   11.92 mm

Vernier micrometer: The vernier micrometer has one more scale, called the vernier scale, on the sleeve that allows a measurement to one ten-thousandths of an inch. The vernier scale consists of ten divisions that run parallel to and above the index line. A line extends from each of these divisions to the scale on the thimble. The division line on the vernier scale that lines up with or coincides with a line on the thimble scale is the one noted.

To read a vernier micrometer:

1. Follow the steps to read a standard inch micrometer.
2. Continue by noting the number on the vernier scale that coincides with a number on the scale on the thimble.

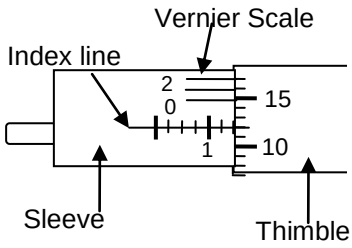
3. This number is multiplied by .0001.
4. All the resulting numbers are added to get the total reading.

To read the measurement shown on the right:

1. Note the last number showing on the sleeve and multiply it by .100:
   1 x .100 = .100

2. Count the number of small lines visible past that number and multiply by .025:
   2 x .025 = .050

3. Note the number of the division line on the thimble that coincides with the center line on the sleeve and multiply it by .001:
   12 x .001 = .012



A micrometer showing a reading of .1622"

4. Note the number on the vernier scale that coincides with the thimble scale and multiply it by .0001:
   2 x .0001 = .0002

5. Add all the resulting numbers to get the total reading:

   .100
   .050
   .012
   .0002
   .1622 inch

CALIPERS

Calipers are used to measure a space when a direct measurement cannot be made directly. The legs of the caliper are adjusted to cover the space to be measured, then the distance between the legs is read from a steel ruler or a gage. The most common types of calipers used in a shop are the outside calipers and the inside calipers.

Calipers can also be used to scribe lines on a piece of metal. Use a hermaphrodite caliper, which has a curved point at the end of one leg and a straight point at the end of the other, in this case. The points at the ends of the legs are set to the needed distance using a steel rule. The curved point runs along the edge of the piece of work while the straight point marks a line on the surface of the metal at the correct distance from the edge.

If you place the first leg of the calipers at the 1 inch or 10 mm mark because the end of the ruler is worn, you add that amount to the distance needed to calculate where the other leg of the caliper should be placed on the ruler.

For example, if you needed to set a caliper to 45 mm and you set the first leg at the 10 mm division, you would set the other leg at the 55 mm mark.

Outside calipers measure the outside diameter of a round piece of work or the length of a flat piece of work. Inside calipers fit inside a hole to measure the diameter.

DIVIDERS

The divider is a tool with two legs that end in sharp points. It is used for transferring measurements, comparing distances and scribing circles and arcs. To set a divider to a size, place one point on the 1 inch or 10 mm line of a steel ruler and the other point on the graduation line the correct distance from the first line. Remember to add 1 inch or 10 mm to the measurement required when placing the second leg on the second division mark.

If the division lines are etched into the steel ruler, feel until the point is set exactly in the line. The divider can now be used to transfer this measurement onto a piece of work.

Answer the following questions on measurement tools by filling in the blank space with the correct word. Answers are on the last page.

1. To change a fraction to a decimal, divide the numerator of the fraction by the _____ .

2. 5 3/4 written as a decimal number is _____ .

3. When changing a decimal number to a fraction, the decimal part of the number becomes the _____ of the fraction. It is written over a denominator that is a power of ten.

4. .25 written as a fraction is 25/100. Reduced to lowest terms, this becomes _____ .

5. 6.15 written as a fraction in lowest terms is _____ .

6. 16 inches converted to millimeters is _____ .

7. 10 centimeters converted to inches is _____ .

8. 3 yards converted to meters is _____ .

9. 5 meters converted to feet is _____ .

10. The most common tool used for straight line measurement is the _____ _____.

11. If the scale on a fractional ruler is in eighths, each smaller mark or graduation within every inch marker represents _____ of an inch.

12. Metric rules are graduated in _____ .

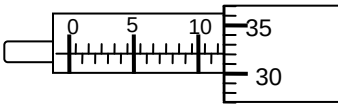
13. In a metric ruler, each main division represents _____ millimeters.

14. To read a metric ruler, note the number of main divisions and then count the number of millimeters past the last main division line. Add these values to get the _____ reading.

15. If you are using dividers to mark a distance of 11 centimeters and you place the first leg of the dividers at the 1 cm or 10 mm division mark (they are the same place), where should the point of the second leg be placed? _____

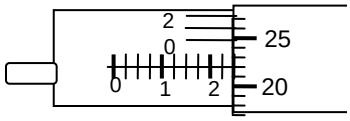
16. If you need to measure a piece of work and your measurement requires a higher degree of precision than a steel ruler provides, you could use a _____ .

17. Read the metric micrometer below:



Number of main divisions: _____ x _____ = _____
Number of division lines past the 10: _____ x _____ = _____
Number on thimble that coincides with index line: _____ x _____ = _____
Total reading in mm: _____

18. Read the standard inch fractional micrometer:



Last number on sleeve: _____ x _____ = _____
Number of small lines past the 2: _____ x _____ = _____
Number on thimble that coincides with index line: _____ x _____ = _____
Number on vernier scale that coincides with the scale on thimble: _____ x _____ = _____
Total reading in inches: _____

ANSWER PAGE

1. denominator
2. 5.75
3. numerator
4. 1/4
5. 6 3/20
6. 406.4 mm
7. 3.94 inch
8. 2.74 m
9. 16.4 ft
10. steel ruler
11. 1/8 or one-eighth
12. millimeters
13. 10
14. total
15. At 12 cm or 120 mm (they are the same place)
16. micrometer
17. Number of main divisions: 10 x 1 = 10
    Number of division lines past the 10: 2 x .50 = 1.0
    Number on thimble that coincides with index line: 32 x .01 = .32
    Total reading in mm: 10 + 1.0 + .32 = 11.32 mm
18. Last number on sleeve: 2 x .100 = .200
    Number of small lines past the 2: 2 x .025 = .050
    Number on thimble that coincides with index line: 22 x .001 = .022
    Number on vernier scale that coincides with the scale on thimble: 1 x .0001 = .0001
    Total reading in inches: .200 + .050 + .022 + .0001 = .2721 inch