

**EVALUATING
ACADEMIC READINESS
FOR APPRENTICESHIP TRAINING**
Revised for
ACCESS TO APPRENTICESHIP

**MATHEMATICS SKILL
ACCURACY, TOLERANCE AND PRECISION**

**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*

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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.

MATHEMATICS SKILL ACCURACY, TOLERANCE AND PRECISION

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

INTRODUCTION

The saying, “measure twice and cut once”, expresses the importance of accurate measurement. The more careful you are when measuring and cutting, the more accurate or precise your work will be.

Example: To cut a 4' x 4' sheet of metal into a smaller piece that is 3' 6 1/2" by 2', you would measure first and then cut. The piece you cut will never be *exactly* 3' 6 1/2" by 2'. There will always be some small error due to the width of a blade or a mark, or the angle of vision you have when you make the cut. However, if you measure carefully with a tape that has 1/16 inch divisions, you can be pretty sure that the piece will measure as close as possible to 3' 6 1/2" by 2'.

Careful measurement and accurate cutting will be the key to having a product as close as possible to the required one.

In this skills manual we will cover the following topics:

- ◆ Measurement
- ◆ Precision
- ◆ Accuracy
- ◆ Tolerance

MEASUREMENT

Linear Measure

To measure the length of something, we use a measuring tape. The divisions on a measuring tape are called the scale. If the smallest division on an imperial tape is 1/16 inch, then the tape has a scale of 1/16 inch. If the smallest division on a metric tape is one millimeter, it's scale is 1mm, or, .001m (meter).

An imperial tape measure: The largest division on the Imperial tape is most likely the one foot division. If the tape is 12 feet long, there are twelve one foot divisions.

- Between each foot division, there are twelve 1 inch divisions.
- Between each of the inch divisions, there are sixteen smaller divisions that are each 1/16th of an inch long.

- If an inch is divided into 16 equal parts, the first part is $1/16$, the second is $2/16$, the third is $3/16$, etc all the way to $16/16$ ths.
 - Some of the fractions can be reduced to lowest terms. For example, $4/16$ can be reduced to $1/4$.

Remember: Fractions representing the same amount, such $4/16$ and $1/4$, are called equivalent fractions. Other equivalent fractions marked on the tape are $1/2$ and $8/16$, $3/4$ and $12/16$, $1/8$ and $2/16$, and $5/8$ and $10/16$. Equivalent fractions are just different ways of writing or naming the same fractional amount.

On the measuring tape, $1/4$ and $4/16$ are equivalent.

- There are three $1/4$ inch divisions – $1/4$ "", $2/4$ " (or $1/2$ ""), and $3/4$ ".
 - The quarter inch divisions are slightly larger marks than the $1/16$ inch divisions.
- Another series of equivalent fractions is $8/16$ ", $2/4$ " and $1/2$ ".
 - To find $1/2$ inch on the tape, you can count eight $1/16$ inch division marks, or you can locate the larger $1/2$ inch division mark directly.

Example: You need to measure **3' 6 1/2"** on a piece of metal using a tape with $1/16$ inch divisions.

1. You first find **3 feet** on the tape.
2. Then you find the **6 inch** division that comes after the 3 foot division.
3. After the 6 inch mark, you find the division mark showing $1/2$ **inch**.
4. You mark the metal right beside the mark at 3 ft 6 $1/2$ in.

Recall that the $1/2$ inch division mark on the tape is also the $8/16$ th division mark.

- The division in front of $1/2$ or $8/16$ is $7/16$.
- The division after it is $9/16$.
- Even though you know your mark will not be *precisely* at the $1/2$ mark, you can be reasonably sure that it is between $7/16$ and $9/16$.

A metric tape measure: The largest division on a metric tape is usually a meter. If the tape is 10 meters long there will be ten, one meter divisions. The tape will have 100 centimeter divisions between each meter division and, possibly, 10 millimeter divisions between each centimeter division.

Example: You are cutting a 3.60 meter length of material. The tape you are using has centimeter divisions as the smallest division.

1. You would first find the 3 meter division on the tape.
2. Then you would count the centimeter divisions by ten until you got to 60.
3. You mark the material at the 3 meter, 60 centimeter division mark and then cut.
 - a. The division in front of the 60 cm mark is 59.9 cm.
 - b. The division after it is 60.1 cm.
 - c. Even though you know your cut will not be *precisely* at the 60 centimeter mark, you can be reasonably sure that it is between 59.9 and 60.1 cm.

Measuring weight

If you need to measure something by weight you will use either an Imperial or metric weigh scale following a similar procedure.

Measuring capacity

To measure the liquid capacity of a container you will use either metric or Imperial measuring containers and follow a similar procedure.

PRECISION

Precision is the indication of how close you are to the true measurement. It is determined by the smallest division of the scale on the measuring device.

- ◆ The smaller the scale, the more precise the measurement. We say that the measurement is precise to the nearest smallest division on the scale.
 - Our measurement of 3' 6 1/2" is precise to the nearest 1/16 inch if the tape we used has 1/16 inch divisions.
 - The measurement of 3.60 meters is precise to the nearest .001 m (or .1 cm)

You may be given a measurement but not the scale. If you are asked what the precision of that measurement is, you go by the smallest division indicated by that measurement. When there are fractions of a measurement the denominator of the smallest division indicates the precision.

Example: The imperial measurement 3' 6 1/2" has 1/2 inch as its smallest division. If you did not know what scale the tape had, you would say that the measurement was precise to 1/2 inch.

Example: If the measurement given is 10 feet 2 inches, the smallest division is inches. There are no fractions of an inch. So the measurement is precise to the nearest inch.

Example: To make a measurement such as 5 feet 7 1/4 inches precise to 1/16 inch, you change the 1/4 inch into an equivalent fraction with a denominator 16.

You write 1/4 inch as 4/16 inch to indicate that the measurement is precise to 1/16 inch.

Example: What is the precision of 6 11/32 inches?

The smallest division in the measurement is 32nds of an inch. The measurement is precise to 1/32 in.

Example: Find the precision of 10 m 3 cm.

The smallest division is centimeters so the measurement is precise to the nearest centimeter.

Example: What is the precision of 10.75 inches?

This measurement is given as a decimal , 10.75 inches, instead of as a fraction. The precision is determined by converting the decimal to a fraction.

.75 as a fraction is 75/100

The level of precision of 75/100 is to the nearest 1/100 inch.

Example: What is the precision of 3.250 liters?

3.250 liters is the same as 3 liters 250 milliliters. The measurement is precise to the nearest milliliter.

Example: What is the precision of 16.400 kilograms?

16.400 kilograms is the same as 16 kilograms 400 grams. The measurement is precise to the nearest gram.

ACCURACY

Accuracy means careful exactness, and is related to the amount of error made in a measurement. The closer to the correct division mark on the scale you are, the less error you have in your measurement and the more accurate it is.

TOLERANCE

Sometimes when you are making a measurement, you are given an amount of tolerance that is acceptable. **Tolerance** is an allowance for error. You may be given a measurement of 4.5 centimeters with a tolerance of $\pm .2$ centimeters. The $\pm .2$ centimeters is read as *plus or minus .2 centimeters*. The measurement you make will be acceptable if it is anything from .2 cm less than 4.5 cm to .2 cm more than 4.5 cm. If the accepted tolerance is $\pm .2$ cm, this measurement would be considered good enough if it were between 4.3 cm and 4.7 cm.

Example: Within what range of measurement should you be if you are given a measurement of 46.4 centimeters with a tolerance of $\pm .05$?

$$46.4 \text{ cm} - .05 = 46.35 \text{ cm}$$
$$46.4 \text{ cm} + .05 = 46.45 \text{ cm}$$

The range of measurement should be within 46.35 cm and 46.45 cm.

Answer the following questions. The answers are on the last page.

1. Find the precision of each measurement.

- | | | |
|----------------|--------------------|---------------|
| a) $5/12$ inch | b) 3 ft 9 $1/4$ in | c) 12 meters |
| d) 40 m 10 cm | e) 15 $10/16$ in | f) 6 $2/5$ in |
| g) 7.25 in | h) 12.5 in | i) 4.54 in |

2. Give the range of measurement for the following.

- a) 3.5 in with a tolerance of $\pm .1$ in
- b) 26.5 mm with a tolerance of $\pm .5$ mm
- c) 8.4 in with a tolerance of $\pm .03$ in

ANSWER PAGE

1. a) $1/12$ in
b) $1/4$ in
c) 1 meter
d) 1 cm
e) $1/16$ in
f) $1/5$ in
g) fraction = $25/100$ in, precision is $1/100$ in
h) fraction = $5/10$ in, precision is $1/10$ in
i) fraction = $54/100$ in, precision is $1/100$ in

2. a) 3.4 in to 3.6 in
b) 26 mm to 27 mm
c) 8.37 in to 8.43 in