

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

**MATHEMATICS SKILLS
METRIC MEASUREMENT**

**AN ACADEMIC SKILLS MANUAL
for
The Industrial Maintenance Mechanic Trades**

This trade group includes the following trades:
Boiler Maker,
Facilities Maintenance Mechanic & Technician, and
Industrial Mechanic (Millwright)

*Workplace Support Services Branch
Ontario Ministry of Education and Training*

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.

MATHEMATICS SKILLS

METRIC MEASUREMENT

*An academic skill required for the study of the
Industrial Maintenance Mechanic Trades*

INTRODUCTION

Canada has officially adopted the metric system of measurement. The metric system is designed so that conversions between units follow a simple, consistent pattern based on multiplying or dividing by a multiple of ten. While most North American equipment and parts still come in standard sizes based on the imperial or customary system of measurement, other parts of the world work largely in metric measurements.

You will use both imperial units, such as inches and feet, and metric units, such as centimeters and meters, in many different aspects of your work. You need to be familiar with both the imperial and the metric systems of measurement.

This skills manual looks at the basic metric units and how to convert from one unit to another within the metric system. The following topics are covered:

- ◆ Basic metric units
- ◆ A chart of metric units
- ◆ Converting units
- ◆ Operations with mixed units
- ◆ Other metric units

BASIC METRIC UNITS

The common metric units measure length, weight, volume or capacity and temperature. Measurements for length, weight and capacity all have a **basic unit** of measure. The other units are smaller or larger than the basic unit by a factor of ten.

- ◆ The **meter (m)** is the basic unit of length. In your work, you will also measure using the smaller unit, centimeters.
 - A meter is about the length of an outstretched arm.
 - A centimeter is about as long as the width of your baby finger.
- ◆ The **gram (g)** is the basic unit of weight.
 - It is a small amount; you might buy small screws in a 500 gram package.
 - The weight of a heavy object such as a steel beam is given in kilograms, a larger unit.
- ◆ The **liter (L)** is the basic unit of capacity.
 - Liquid volumes such as water and lubricant are measured in liters.

- ◆ The **degree Celsius** ($^{\circ}\text{C}$) is the basic unit of temperature.
 - 0°C is the freezing point of water,
 - 23°C is about room temperature and
 - 100°C is the boiling point of water.

Prefixes Used in the Metric System

Units that are larger or smaller than the basic units for length, weight and capacity are formed by adding a prefix to the name of the base unit. The prefixes refer to the place value of the unit. The more common prefixes are below:

kilo - means 1000 times bigger than the basic unit, in the thousands place:

examples: kilometer (km), kilogram (kg) and kiloliter (kl)

centi - means 100 times smaller than the basic unit or one-hundredth or .01 of the basic unit:

example: centimeter (cm)

milli - means 1000 times smaller than the basic unit or one-thousandth or .001 of the basic unit:

examples: millimeter (mm), milligram (mg) and milliliter (ml)

Moving the Decimal Point to Multiply or Divide

In order to convert from one metric unit to another, you multiply or divide by 10, 100, or 1000.

To quickly multiply by 10, 100 or 1000:

1. Write the number to be multiplied.
2. Count the zeros in the multiplier.
3. Move the decimal point as many places to the **right** of its original position as there are zeros in the multiplier.
4. Use zeros as place holders between the number and the decimal point if needed.

Example: 346.1×1000

There are three zeros in 1000. Move the decimal point three places to the right. Use two zeros as place holders. (If the decimal point is not shown, it is at the end of the right side of the number.)

$$346.1 \times 1000 = 346100$$

To quickly divide by 10, 100 or 1000:

1. Write the number to be divided.
2. Count the zeros in the divisor.
3. Move the decimal point as many places to the **left** of its original position as there are zeros in the divisor.
4. Use zeros as place holders between the number and the decimal point if needed.

Example: $2.45 \div 100$

There are two zeros, so move the decimal point two places to the left, using one zero as a place holder.

$$2.45 \div 100 = .0245$$

CHART OF METRIC UNITS

Table 1 illustrates how the metric system works. You can see how the different metric units are related to each other. You can also learn how to convert from one unit to another by following the step by step instructions given under Table 1.

First learn the base units: *meter*, *liter* and *gram*. They are found in the shaded middle of the chart.

The next most frequently used units are:

- the large units on the left which start with the prefix *kilo*,
- the units on the far right which start with the prefix *milli*, and
- the units which start with the prefix *centi*.
 - *Please note: the milliliter and cubic centimeter represent the same measure of volume.*

The chart has spaces for the most common place values in the metric system. It only shows the commonly used units. To form a unit not shown, such as decimeter (1/10 of a meter), put the correct prefix (deci) in front of the basic unit.

THE METRIC SYSTEM							
	BIGGER UNITS			→ →	TO BASIC UNIT	→ →	TO SMALLER UNITS
Place Value	1000	100	10	1	1/10 or .1	1/100 or .01	1/1000 or .001
Prefix	Kilo	Hecto	Deca		Deci	Centi	Milli
Length	Kilometer (km)			Meter (m)		Centimeter (cm)	Millimeter (mm)
Weight	Kilogram (kg)			Gram (g)			Milligram (mg)
Volume/ Capacity	Kiloliter (kl)			Liter (l)			Milliliter (ml) or Cubic Centimeter (cc)

TABLE 1: THE METRIC SYSTEM

Converting Units Using the Chart

1. Count the number of spaces from the original unit (but don't count the original unit space) to the new unit, and notice whether you have moved to the left or the right.
2. In the number you are converting move the decimal point the same number of spaces in the same direction.
3. Use zeros as place holders where necessary.
4. Change the name of the unit.

Examples:

From ml to L, it's 3 places to the left; move the decimal 3 places to the left. $39 \text{ ml} = .039 \text{ L}$

From kg to g, it's 3 places to the right; move the decimal 3 places to the right. $12.4 \text{ kg} = 12400 \text{ g}$

From m to cm, it's 2 places to the right; move the decimal 2 places to the right. $4 \text{ m} = 400 \text{ cm}$

CONVERTING FROM ONE UNIT TO ANOTHER

The chart shows graphically how to move the decimal point when converting from one unit to another. To convert without a chart, there are two rules to know.

1. To convert from a larger unit to a smaller unit, the number gets bigger. Move the decimal point to the *right*.

When going to or from a basic unit, the prefix of the other unit can tell you how many places to move the decimal point.

Examples:

From kilo (1000) unit to basic unit → move the decimal point three places to the right.

From basic unit to milli (.001) unit → move the decimal point three places to the right.

From basic unit to centi (.01) unit → move the decimal point two places to the right.

Note: Move the decimal point the same number of places as there are zeros in the prefix kilo or the same number as there are decimal places in the prefixes centi and milli.

2. To convert from a smaller unit to a larger unit, the number gets smaller. Move the decimal point to the *left*.

When going to or from a basic unit, the prefix of the other unit tells how many places to move the decimal point.

Examples:

From basic unit to kilo (1000) unit ← move the decimal point three places to the left.

From milli (.001) unit to basic unit ← move the decimal point three places to the left.

From centi (.01) unit to basic unit ← move the decimal point two places to the left.

Note: Move the decimal point the same number of places as there are zeros in the prefix kilo or the same number as there are decimal places in the prefixes centi and milli.

To convert to or from a basic unit, you need to know two things:

1. Whether you are going from a larger unit to a smaller unit, or from a smaller unit to a larger one.
 - This tells you what direction to move the decimal point.
2. How many zeros or decimal places are in the non-basic unit.
 - This tells you how many places to move the decimal point in the required direction.

Example: Change 450 grams to kilograms.

450 g = .450 kg A smaller unit to larger one, so move the decimal point to the left.
The prefix kilo has three zeros, so move the decimal point three places.

Example: Change .31 kilograms to grams.

.31 kg = 310 g A larger unit to smaller one, move the decimal point to the right.
A prefix kilo has three zeros, move the decimal point three places.
Zero is used as a place holder

Example: Change 1656 milliliters to liters.

1656 ml = 1.656 L Smaller unit to larger one, move decimal point to the left.
Prefix milli has three decimal places move the decimal point three places.

Example: Change 12 liters to milliliters.

12 L = 12000 ml Larger unit to smaller one, move decimal point to the right.
Prefix milli has three decimal places move the decimal point three places.

Example: Change .8 meters to centimeters.

.8 m = 80 cm Larger unit to smaller one, move decimal to the right.
Prefix centi has two decimal places, move decimal point two places.

Example: Change 239 centimeters to meters.

239 cm = 2.39 m Smaller unit to larger one, move decimal to the left.
Prefix centi has two decimal places, move the decimal point two places.

In Brief:

To convert from a larger unit to a smaller unit:

1. The number gets bigger.
2. Move the decimal point to the right:
 - from kilo units to basic units → decimal point moves three places to the right.
 - from basic units to milli units → decimal point moves three places to the right.

To convert from a smaller unit to a larger unit:

1. The number gets smaller
2. Move the decimal point to the left
 - from basic units to kilo units ← decimal point moves three places to the left
 - from basic units to milli units ← decimal point moves three places to the left

Converting Between Two Units, Neither of Which is a Basic Unit

You can convert between two units when neither is a base unit.

If you don't know how many places there are between the two units:

1. First convert the original unit to the base unit.
 - as you convert to and from the base unit use the prefixes to tell you how many places to move.
2. Then convert to the new unit.

Example: to convert kilograms to milligrams, first convert to grams and then to milligrams.

1. *Kilograms to grams:*

- Kilo means 1000. There are three zeros in 1000 and that is the number of places to move the decimal point.
- When converting from a larger unit to a smaller one, you move to the right.
- Move the decimal point three places to the right.

2. *Grams to milligrams:*

- Milli means one thousandth or .001. There are three decimal places in the prefix milli.
- You are still going from a larger to a smaller unit, so continue to move the decimal point to the right.
- Move the decimal point three places to the right.

To convert from kilograms to milligrams, you moved the decimal point a total of six decimal places to the right.

Example: Change .3118 kg to mg.

$$.3118 \text{ kg} = 311.8 \text{ g}$$

Convert kilograms to grams to milligrams.

Kilograms to grams, move decimal three places to the right.

$$311.8 \text{ g} = 311\,800 \text{ mg}$$

Grams to milligrams, move decimal three places to the right.

Example: Change 75 cm to mm.

75 cm = 750 mm Centimeter to millimeters, larger to smaller, move decimal point one place to the right.

75 cm = .75 m If you did not know that there is one place between centimeters and millimeters, convert from centimeters to meters first.

.75 m = 750 mm Now convert from .75 meters to millimeters.

Example: Change 25 milliliters to cubic centimeters.

25ml = 25 cc Millimeters to cubic centimeters (one ml is equal to 1 cc).

OPERATIONS WITH MIXED UNITS

In the metric system, it is easy to convert between units. Therefore, measurements are not usually left in mixed forms.

- A dimension of 3 meters and 12 centimeters is written as 3.12 meters or 312 centimeters.

Example: If you have a piece of metal 3 meters long to which you must add a 12 centimeter piece, the total length will be given in meters or centimeters, either 3.12 m or 312 cm.

You may be asked to give the answer in required units.

- If a certain unit is required, change all the units to that one.
- Otherwise, change everything to the base unit.
- If none of the units is a base unit, choose one of the other units to work in.
- You can now do any mathematical operation required.

To do calculations with mixed units:

1. Change all the different units to one chosen unit.
2. Do the calculation.

Example: Add 1 liter to 750 milliliters.

1. Change all units to liters.
750 milliliters = .750 liters or .75 liters
2. Add the units
1 liter + .75 liters = 1.75 liters

Example: (4 km 149 m) - (8 m 90 cm)

(4000 m + 149 m) - (8 m + .9 m) Change all units to meters.

(4149 m) - (8.9 m) Add the units inside brackets together.

4149 m - 8.9 m = 4140.1 m Remove the brackets and subtract the numbers.

Example: 72 L 45 ml \div 9 L

$$(72 \text{ L} + .045 \text{ L}) \div 9 \text{ L}$$
$$72.045 \text{ L} \div 9 \text{ L}$$

Change all units to liters and add them together.

$$72.045 \text{ L} \div 9 \text{ L} = 8.005$$

Divide: notice the units cancel out

Note:

If you divide a quantity with a unit by another quantity **with the same unit**, the units cancel out.

If you multiply or divide a quantity with a unit by a number **with no unit**, the answer **retains the unit**.

If you multiply a unit **by the same unit**, the unit is **squared**.

To find area, the length and width are multiplied together. Units of area are the units of length squared.

- An area of 15 meters square is written in short form as 15 m^2 .
- Centimeters, millimeters and kilometers can also be squared, giving the square units cm^2 , mm^2 and km^2 .

To find volume, three measurements of length are multiplied together. Units of volume are units of length cubed.

- A volume of 25 cubic centimeters is written in short form as 25 cc or 25 cm^3 .
- Meters, millimeters and kilometers can also be cubed, giving the cubic units m^3 , mm^3 and km^3 .

To find capacity of a container, we again use the units liter and milliliter.

In the metric system, the units of volume, and capacity are related to each other. The volume of water in cubic centimeters is also related to its weight in grams.

- The equivalent units cubic centimeter (cc) and milliliter (ml) are both used as measures of volume or capacity.
 - 1 cubic centimeter (cc) is the same volume as 1 milliliter.
 - 1 gram of water occupies 1 cc of space (gram is a measure of weight, cc is a measure of volume or capacity).

OTHER METRIC UNITS

We will look at a few of the scientific units you will meet in your courses and at work.

The **newton** is the metric unit of force.

- A force of 1 newton on a mass of 1 kilogram will cause an acceleration of 1m per second per second.

The **joule** is the metric unit of work.

- One joule is the work done when a force of 1newton acts through a distance of 1 meter.

Pressure is the measure of a force per unit area.

- If force is in newtons and area is in square meters, the unit is called a **pascal**.
- Since a pascal is very small, the common metric unit of pressure is the **kilopascal (kPa)**.

Torque is the turning force developed by the engine. To calculate torque multiply the force exerted by the engine by the length of the connecting rod that the force acts on. Torque is measured in newtons and the length in meters

- The unit of torque is expressed as newton-meters (N•m).
- This is the same as the unit of work, which is also called the joule (J).

Power is the rate of doing work. The basic unit of power is the **watt**.

- A watt is equal to one joule of work per second.

The metric unit, the watt (or kilowatt), is the basic unit of power for mechanical systems such as engines in the metric system. The watt is most commonly as a unit of electrical use.

TO CONVERT METRIC UNITS

2. When you convert an amount in a **larger unit** to a **smaller one**, the number becomes **larger**. You move the **decimal to the right**.
 3. When you convert an amount in a **smaller unit** to a **larger one**, the number becomes **smaller**. You move the **decimal point to the left**.
 4. If going to or from a basic unit, count the number of zeros in the prefix kilo (3) or the number of decimal places in the prefixes centi (2) or milli (3) to determine how many places to move the decimal point. If neither unit is a basic unit and you do not know the number of places between them, convert first to the basic unit and then to the final unit.
 5. Use Rules 1 & 2 above to determine which direction to move the decimal point.
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Answer these questions on the metric system. **Answers are at the end of this skills manual.**

1. Change each length to meters.

- a) 8.7 cm b) .037 km c) 46 mm d) 85 cm

2. Change the weight to grams.

- a) 34 000 mg b) .09 kg c) 6.7 kg d) 35 mg

3. Change the weight to milligrams.

- a) 56 g b) .0981 kg c) 1.365 g d) .00443 g

4. Change the volume to liters.

- a) 1 760 ml b) 51 ml c) 7 ml

5. Change the volume to ml.

- a) 6.8 L b) .09 L c) 24 L

6. Change the length to cm.

- a) 4.3 m b) 600 mm c) .25 m d) 98 mm

Solve the following questions with mixed measurements so that the answer has one unit.

7. a) $3\text{ m } 45\text{ cm} + 10\text{ m } 125\text{ cm}$
b) $9\text{ km } 1320\text{ m} - 4\text{ km } 534\text{ m}$
c) $454\text{ g} + 18\text{ kg}$
d) $341\text{ ml} - .29\text{ L}$
e) $5\text{ m} - 62\text{ cm}$

Remember:

If you divide a quantity with a unit by another quantity **with the same unit**, the units cancel out.

If you multiply or divide a quantity with a unit by a number **with no unit**, the answer **retains the unit**.

If you multiply a unit **by the same unit**, the unit is **squared**.

8. a) $45\text{ L } 800\text{ ml} \times 3$
b) $12\text{ kg } 220\text{ g} \div 4$
c) $.4\text{ m } 48.8\text{ cm} \div 12\text{ cm}$
d) $12\text{ m} \times 10\text{ cm}$
9. A 12.4 meter steel rod is divided into four equal pieces. How long will each piece measure?
10. A can containing 3.5 liters of lubricant is divided into five equal sized smaller containers. How much lubricant will each of the smaller containers hold?

ANSWER PAGE

1. a) .087 m b) 37 m c) .046 m d) .85 m
2. a) 34 g b) 90 g c) 6 700 g d) .035 g
3. a) 56 000 mg b) 98 100 mg c) 1 365 mg d) 4.43 mg
4. a) 1.76 L b) .051 L c) .007 L
5. a) 6 800 ml b) 90 ml c) 24 000 ml
6. a) 430 cm b) 60 cm c) 25 cm d) 9.8 cm
7. a) $(3 \text{ m} + .45 \text{ m}) + (10 \text{ m} + 1.25 \text{ m}) = 14.70 \text{ m}$ or 1 470 cm
- b) $(9000 \text{ m} + 1320 \text{ m}) - (4000 \text{ m} + 534 \text{ m})$
 $= 10320 \text{ m} - 4534 \text{ m}$
 $= 5786 \text{ m}$
or 5.786 km
- c) $454 \text{ g} + 18\,000 \text{ g} = 18454 \text{ g}$ or 18.454 kg
- d) $.341 \text{ L} - 29 \text{ L} = .051 \text{ L}$ or 51 ml
- e) $5 \text{ m} - 62 \text{ cm}$
 $= 500 \text{ cm} - 62 \text{ cm}$
 $= 438 \text{ cm}$ or 4.38 m
8. a) $(45 \text{ L} + .8 \text{ L}) \times 3$
 $= 45.8 \text{ L} \times 3$
 $= 137.4 \text{ L}$ or 13 400 ml
- b) $(12\,000 \text{ g} + 220 \text{ g}) \div 4$
 $= 12\,220 \text{ g} \div 4$
 $= 3055 \text{ g}$ or 3.055 kg
- c) $(40 \text{ cm} + 48.8 \text{ cm}) \div 12 \text{ cm}$
 $= 88.8 \text{ cm} \div 12 \text{ cm}$
 $= 7.4$
- d) $12 \text{ m} \times .1 \text{ m} = 1.2 \text{ m}^2$ or $12\,000 \text{ cm}^2$
9. $12.4 \text{ m} \div 4 = 3.1 \text{ m}$
10. $3.5 \text{ liters} \div 5 = .7 \text{ liters}$