Introduction

In this topic you will learn about the order of operations, and how to apply this mathematical rule when solving number problems. For the purposes of talking about mathematical concepts, it is important to first define some different types of numbers and mathematical operations that will be discussed throughout this unit.

Types of Numbers

The following table outlines three main types of numbers.

Basic Types of Numbers		
Type	**Description**	**Examples**
Whole numbers	Any number that does not need to be expressed as a fraction or with a decimal point.	0 1 2 3
Decimals	Any number that is expressed with a decimal point.	10.2 3.14 1.486 0.009
Fractions	A number that is expressed as a part of a whole. A fraction is expressed as one number (the number of parts) shown on top of another number (the total number of parts in the whole).	3/4 1/2 7/8 5/3

Mathematical Operations

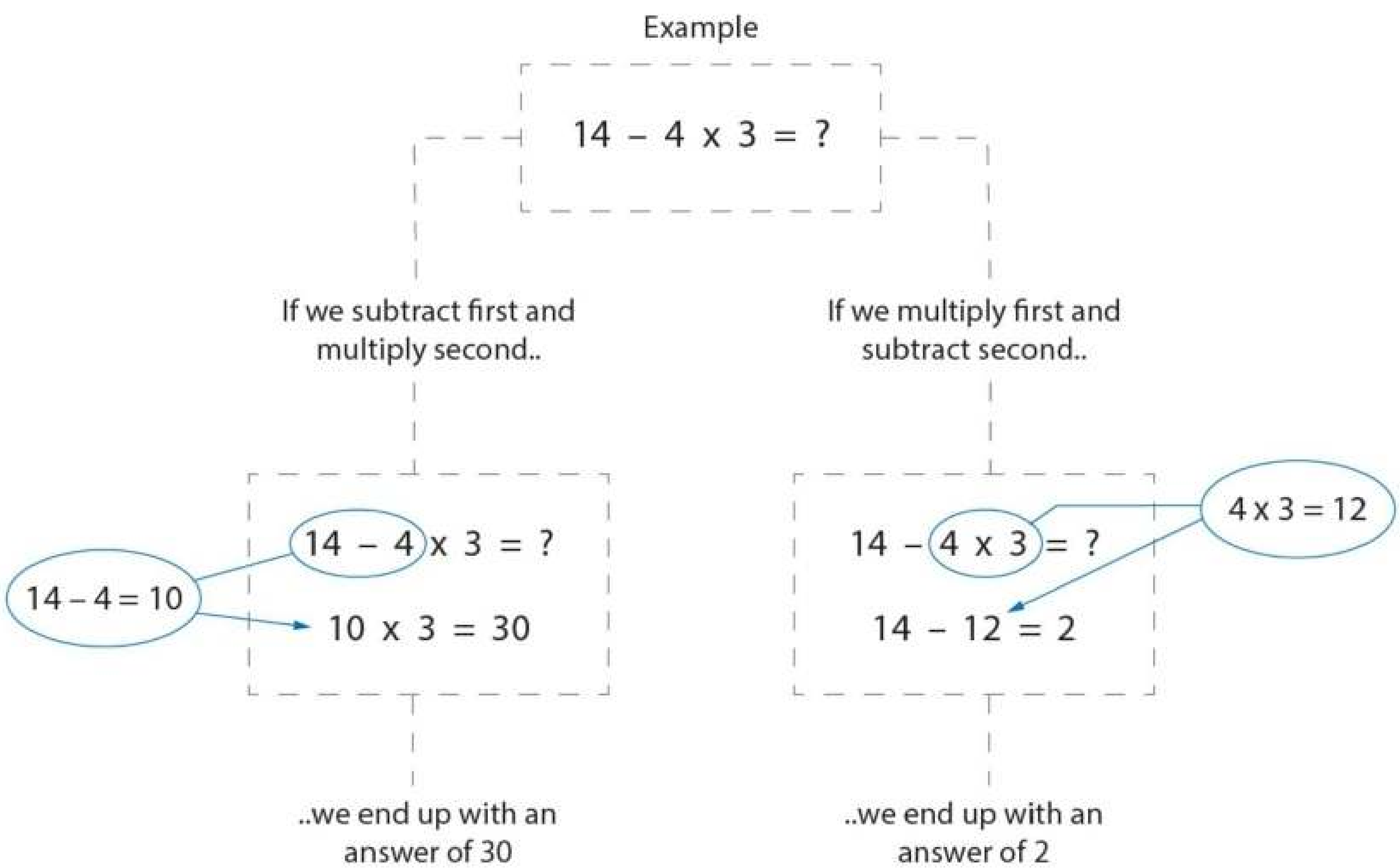
When we're dealing with mathematics, the term 'operation' refers to a calculation of some kind, for example, addition is a mathematical operation. There are many types of mathematical operations. The following table describes six of the most fundamental operations:

?

Basic Mathematical Operations		
Operation	**Symbol**	**Example**
Add	+	6 + 2 = 8
Subtract	–	6 – 2 = 4
Multiply	x	6 x 2 = 12
Divide	÷	6 ÷ 2 = 3
Square	^{2}	$6^2 = 36$
Square Root	√	√36 = 6

Order of Operations

When more than one operation appears in a mathematical problem, changing the order in which you perform each operation can change the answer, as shown in the following example:



The two answers to the simple mathematical problem above are very different! The correct answer for this example is 2. This shows that if a standard order of operations is not used, then calculated answers may end up being wrong.

Check your understanding of the content by clicking on the link below then undertaking the activity.

Load the Activity

BODMAS

The order of operations can be remembered using the 'BODMAS' rule, that is:

- **B**rackets
- **O**rders
- **D**ivision and **M**ultiplication
- **A**ddition and **S**ubtraction

BODMAS

Order	Operations
1^{st}	First perform any calculations inside brackets.
2^{nd}	Then perform squares (^{2}) and square roots (√) – and/or cubes and cube roots etc.
3^{rd}	Then perform division (÷) and multiplication (x).
4^{th}	Then perform addition (+) and subtraction (–).

Calculations should be performed left to right, and note that the order of operations within a set of brackets must also follow the BODMAS rule, i.e. squares and square roots first, then multiplications and divisions, followed by additions and subtractions.

Check your understanding of the content by clicking on the link below then undertaking the activity.

Load the Activity

Significant Figures

The 'significant figures' of a number, are the digits (i.e. figures) that are meaningful (i.e. significant) for the application of that number. Whenever we express a number, we express it to a certain amount of 'significant figures'. In the context of electrotechnology work, we usually express all values to **three significant figures**.

For example, consider that the value of voltage at a socket outlet is 230.675 volts. If we want to test the socket outlet to make sure it's working correctly, then only the first three figures are really meaningful for this purpose, i.e. 230 volts.

It doesn't matter if it's 230.1 volts or 230.9 volts, if we get a reading of 230 volts then this tells us all we need to know.

Rounding Off

When expressing a number to a given amount of significant figures, the correct rounding technique must be used. When rounding off a number, remember the following rule:

- For 0 to 4 – round down.
- For 5 to 9 – round up.

Expressing Significant Figures

The following table explains how to express a whole number, correctly rounded to different significant figures. Note how the rounding rule applies in each case.

Whole Number	
2,285,427	
Significant Figures	**Expression**
7	2,285,427
6	2,285,430
5	2,285,400

?

4	2,285,000
3	2,290,000
2	2,300,000
1	2,000,000

The following table explains how to express a decimal, correctly rounded to different significant figures.

Decimal	
0.2735946	
Significant Figures	**Expression**
7	0.2735946
6	0.273595
5	0.27359
4	0.2736
3	0.274
2	0.27
1	0.3

Calculations on Energy Space

Whenever a calculation is required as part of an activity, quiz, or test on the Energy Space platform, you will be asked to give the answer *correctly rounded to three significant figures*.

Take this quick course on significant figures.

This learning activity consists of 4 parts designed to develop your understanding of how to express values to a stated number of significant figures.

Topic 1.2 Learning Activity

Solving Whole Number Problems

The following worked examples demonstrate how to apply the BODMAS rule when solving problems involving whole numbers. In each example, the answers are given to three significant figures.

Worked Example 1

Consider the following problem:

$$13 + 7 - 8 \div 2 = ?$$

1. There are no brackets, so the first step is to solve the division:

$$13 + 7 - 4 = ?$$

2. The next step is to solve the addition and the subtraction, left to right:

$$20 - 4 = 16$$

Worked Example 2

Consider the following problem:

$$(3 + 4) \times 5 + (42 - 15) = ?$$

1. The first step is to solve the brackets, starting with the brackets on the left:

$$7 \times 5 + (42 - 15) = ?$$

$$7 \times 5 + 27 = ?$$

2. The next step is to solve the multiplication:

$$35 + 27 = ?$$

3. The final step is to solve the addition:

$$35 + 27 = 62$$

?

Worked Example 3

Consider the following problem:

$$10 - 4 + 7 \times (22 \div 2 + 1) = ?$$

1. The first step is to solve the brackets – first the division, and then the addition:

$$10 - 4 + 7 \times (11 + 1) = ?$$

$$10 - 4 + 7 \times 12 = ?$$

2. The next step is to solve the multiplication:

$$10 - 4 + 84 = ?$$

3. The final step is to solve the subtraction and the addition, left to right:

$$6 + 84 = 90$$

This learning activity consists of 3 parts designed to develop your understanding of how to apply the order of operations when solving whole number problems. This activity involves calculations, so you may wish to have a calculator available to assist you.

Solving Problems involving Decimals

The following worked examples demonstrate how to apply the BODMAS rule when solving problems involving decimals. In each example, the answers are rounded to three significant figures.

Worked Example 1

Consider the following problem:

32.7 + 0.875 – 8.6 x 2 = ?

1. There are no brackets, so the first step is to solve the multiplication:

   32.7 + 0.875 – 17.2 = ?

2. The next step is to solve the addition and the subtraction, left to right:

   33.575 – 17.2 = 16.375

3. The final step is to correctly round the answer to three significant figures:

   16.375 = 16.4

Worked Example 2

Consider the following problem:

(27.5 – 14.8) x (2.22 + 7.35) + 4.12 = ?

1. The first step is to solve the brackets, starting with the brackets on the left:

   12.7 x (2.22 + 7.35) + 4.12 = ?

   12.7 x 9.57 + 4.12 = ?

2. The next step is to solve the multiplication, followed by the addition:

   121.539 + 4.12 = 125.659

3. The final step is to correctly round the answer to three significant figures:

   125.659 = 126

?

Worked Example 3

Consider the following problem:

$$(30.6 \div 2 + 1.18) \times (10 - 4.44) + 2 \times 3.14 = ?$$

1. The first step is to solve the brackets on the left – first the division, and then the addition:

$$(15.3 + 1.18) \times (10 - 4.44) + 2 \times 3.14 = ?$$

$$16.48 \times (10 - 4.44) + 2 \times 3.14 = ?$$

2. The next step is to solve the brackets on the right:

$$16.48 \times 5.56 + 2 \times 3.14 = ?$$

3. The next step is to solve the two multiplications, left to right:

$$91.6288 + 2 \times 3.14 = ?$$

$$91.6288 + 6.28 = ?$$

4. The final steps are to perform the addition and then correctly round the answer to three significant figures:

$$91.6288 + 6.28 = 97.9088$$

$$97.9088 = 97.9$$

This learning activity consists of 3 parts designed to develop your understanding of how to apply the order of operations when solving problems with decimals. This activity involves calculations, so you may wish to have a calculator available to assist you.

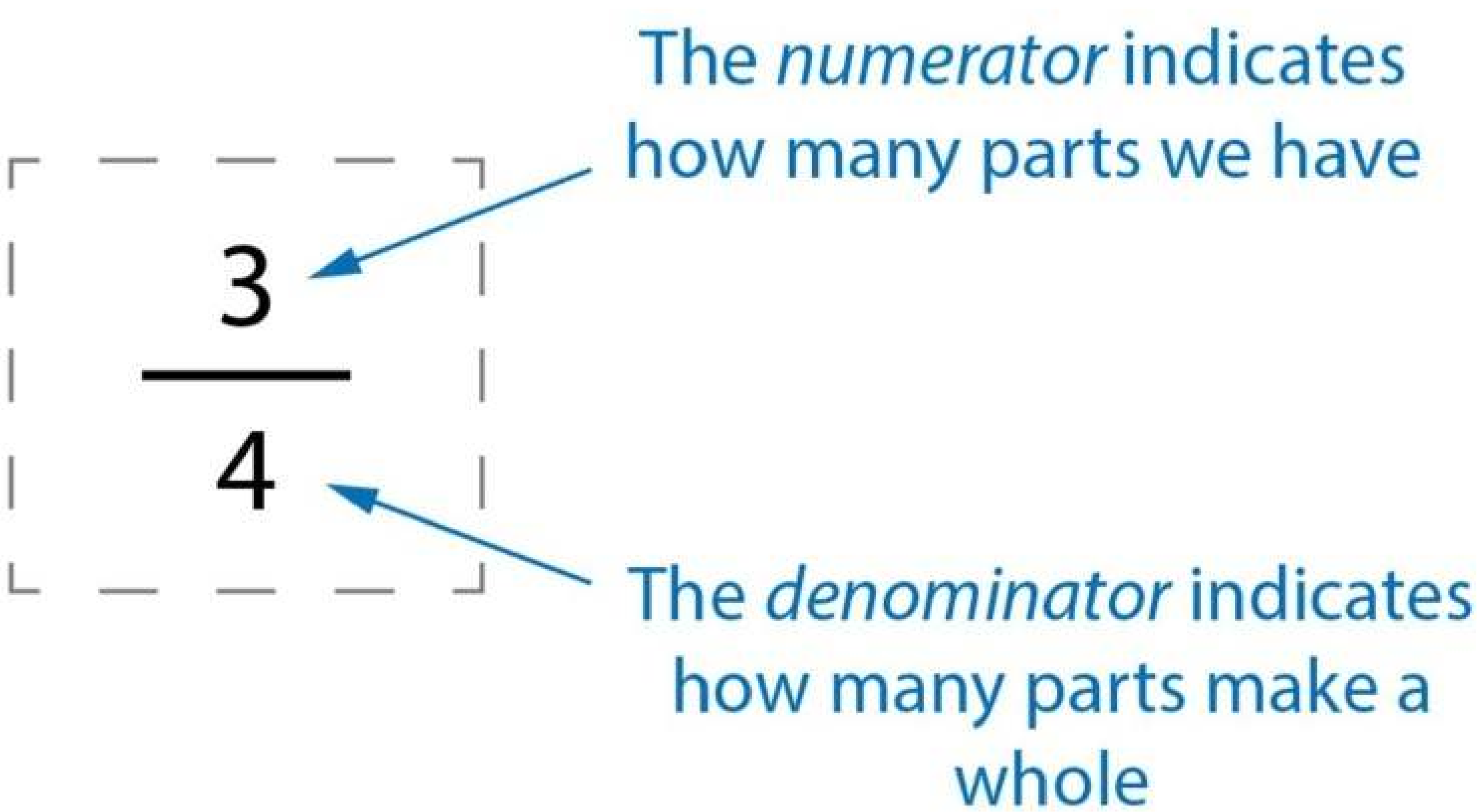
In this skills practice, you are required to correctly apply the order of operations to solve given problems. Upon completion, you will be given the chance to reflect on your ability, and discuss with your teacher/trainer as to whether you will require further support in this area. You will be able to carry out this skills practice at your desk.

Introduction

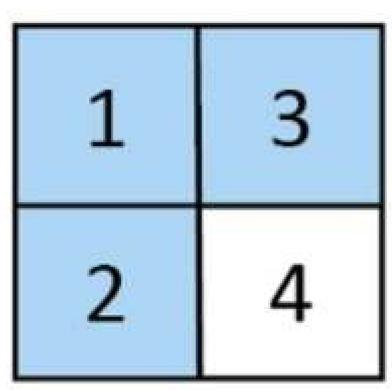
Many trade calculations used in electrotechnology work require a good understanding of fractions. In this topic you will learn about the different types of fractions and the principles and methods for solving problems that include fractions.

What is a Fraction?

A fraction is a number that is expressed as a part of a whole. Fractions consist of one number (the number of parts) shown on top of another number (the total number of parts in the whole):



The fraction expressed above states that there are four equal parts in a whole, and we have 3 of those parts. This could be visually represented in a number of ways, for example:



or

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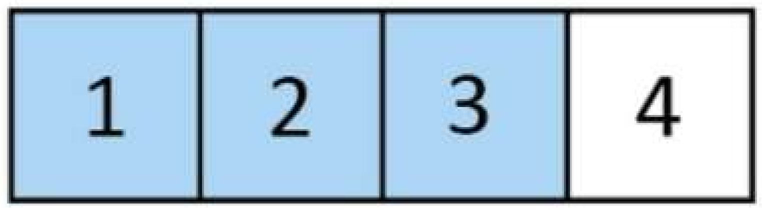


A fraction is simply one way of expressing a number, for example, here are three ways we can express the same number:

$$\frac{3}{4} = 3 \div 4 = 0.75$$

Note how the line separating the two numbers in a fraction can essentially be substituted for a division symbol (÷). Also note how the division symbol itself looks just like a fraction, with dots instead of numbers! This is not an accident – a fraction is a way of expressing division.

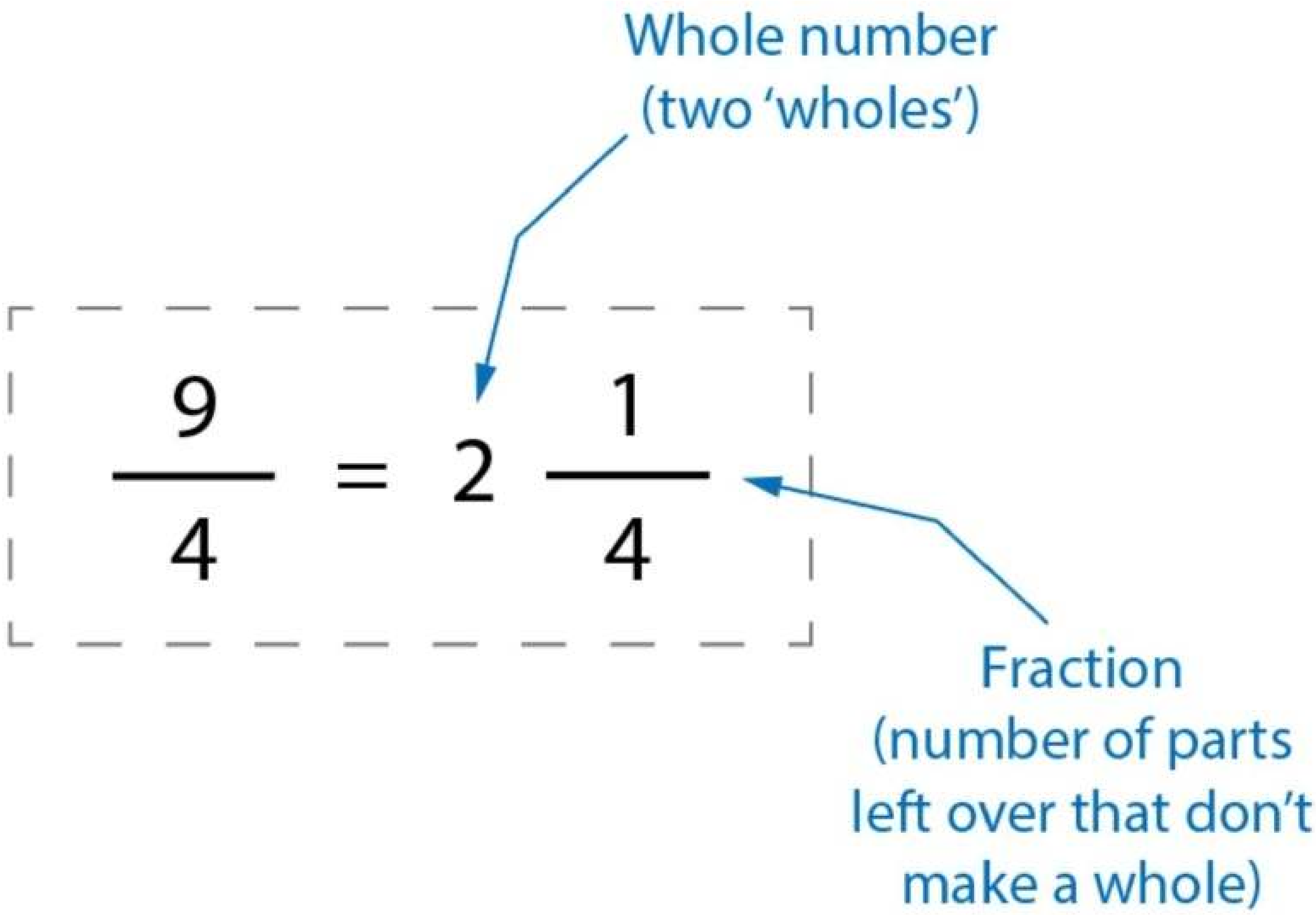
Proper and Improper Fractions

There are two different categories of fractions; these are 'proper fractions' and 'improper fractions'. The following table highlights the differences between them:

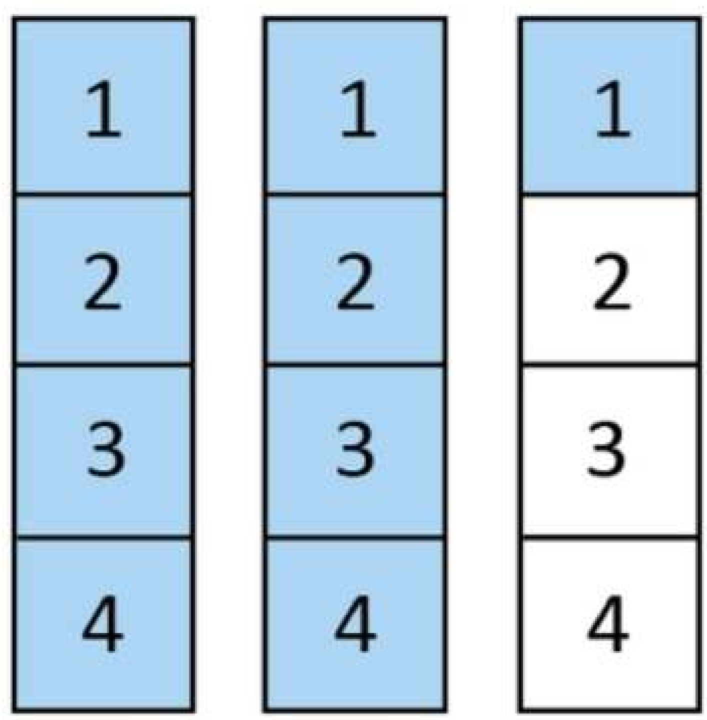
Proper and Improper Fractions	
$\frac{3}{5}$ Proper Fraction	$\frac{9}{4}$ Improper Fraction
Represents a number that is greater than 0 but less than 1. The numerator is always less than the denominator.	Represents a number that is equal to or greater than 1. The numerator is always greater than the denominator.

Mixed Numbers

An improper fraction can also be expressed as a 'mixed number'. This consists of a whole number and a fraction, as shown below:



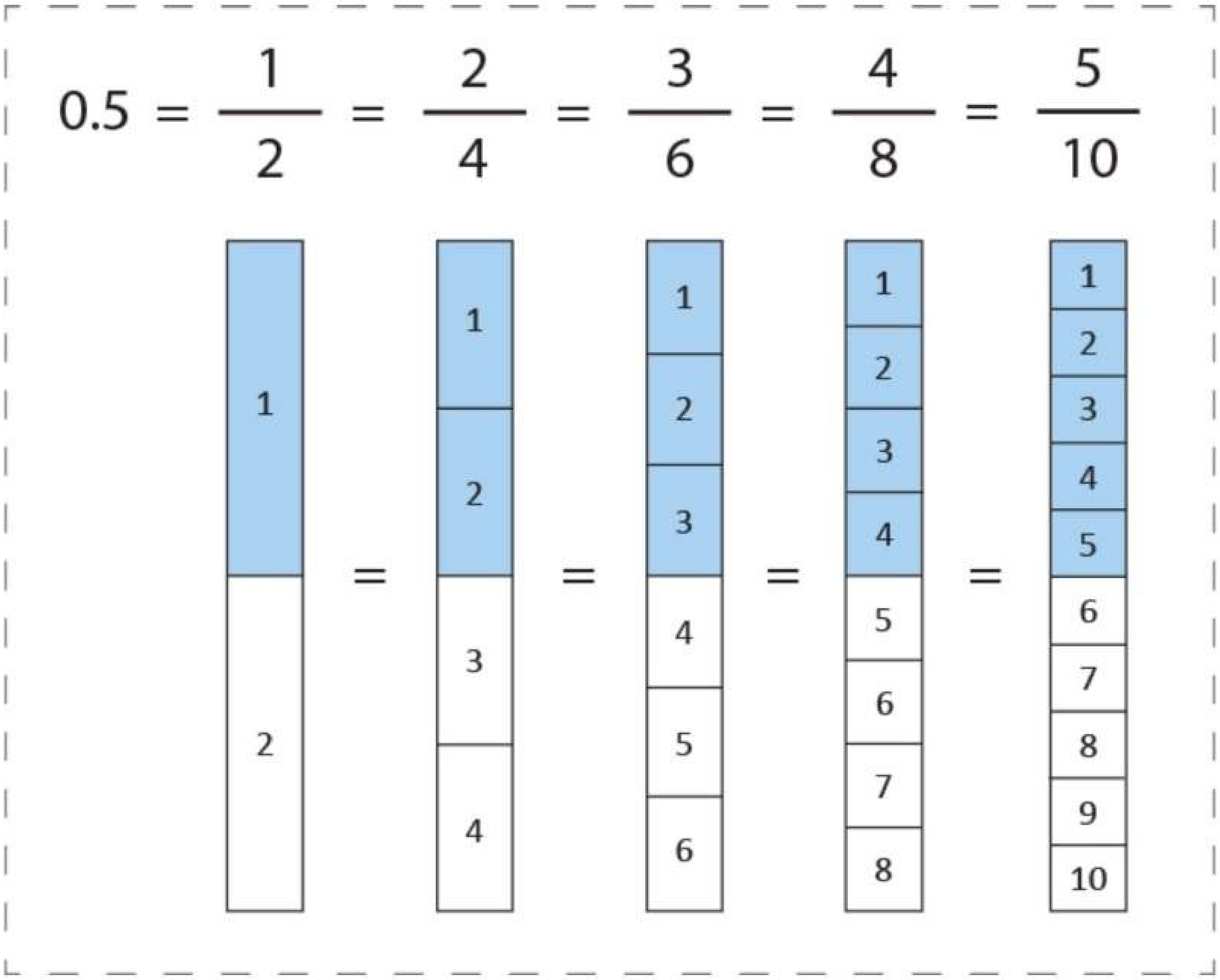
This number could be visually represented as follows:



Check your understanding of the content by matching fractions and mixed numbers in the following interactions.

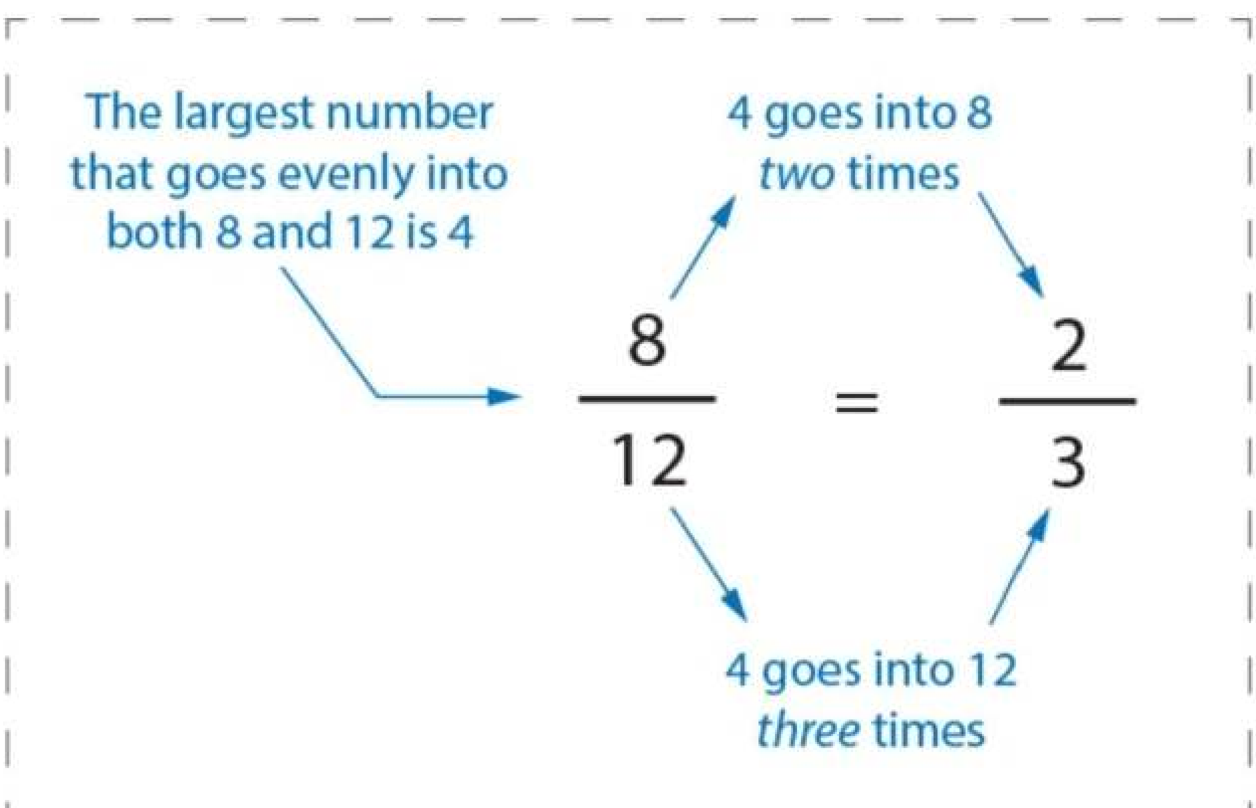
Simplifying Fractions

The same number can be expressed using several different fractions that all equal the same number:



Expressing a fraction is its simplest form, means expressing it using the smallest numbers possible, in the case above, that's ½.

To simplify a fraction, you need to divide the numerator and the denominator by the largest common factor – that is the largest number that will divide evenly into the numerator and the denominator:



Fractions in Electrotechnology Work

Many electrotechnology equations include fractions, which help to show the relationships between the different variables, such as the parameters of a circuit. Fractions are also closely related to percentages and ratios, which are also widely used to evaluate and describe the operation and performance of electrotechnology circuits and equipment.

Adding and Subtracting Fractions

Fractions can only be added or subtracted if they have the *same denominator*. Where this is the case, you simply add or subtract the numerators, whilst the denominator remains the same.

The following shows an example of addition:

$$\frac{4}{7} + \frac{2}{7} = \frac{?}{?}$$

$$\frac{4+2}{7} = \frac{6}{7}$$

The following shows an example of subtraction:

$$\frac{4}{7} - \frac{2}{7} = \frac{?}{?}$$

$$\frac{4-2}{7} = \frac{2}{7}$$

Lowest Common Denominator

If you need to add or subtract two fractions that have different denominators, then you must first adjust the fractions so that they do have the same denominator – you may have heard this referred to as "*finding the lowest common denominator*".

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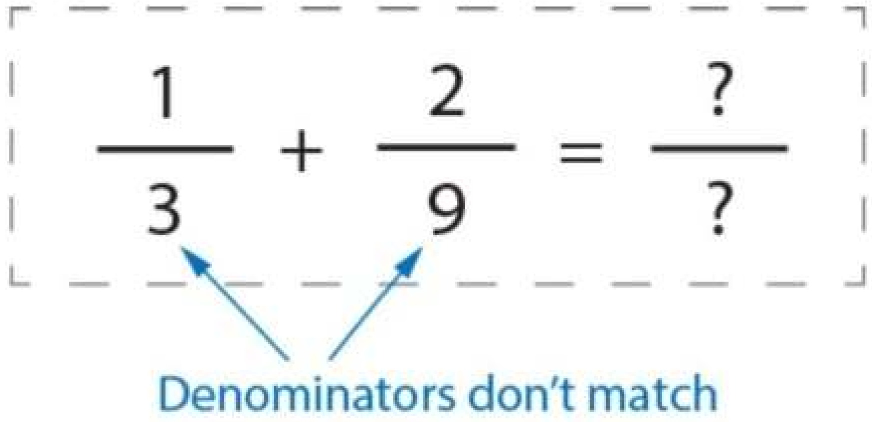
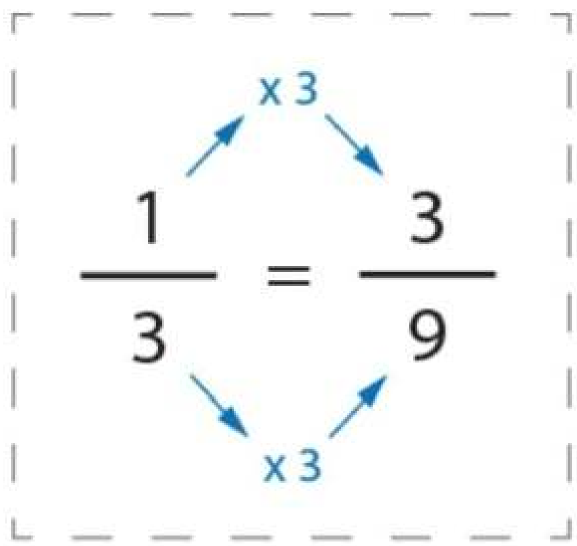


The lowest common denominator will be the smallest common multiple of each denominator – for the example above:

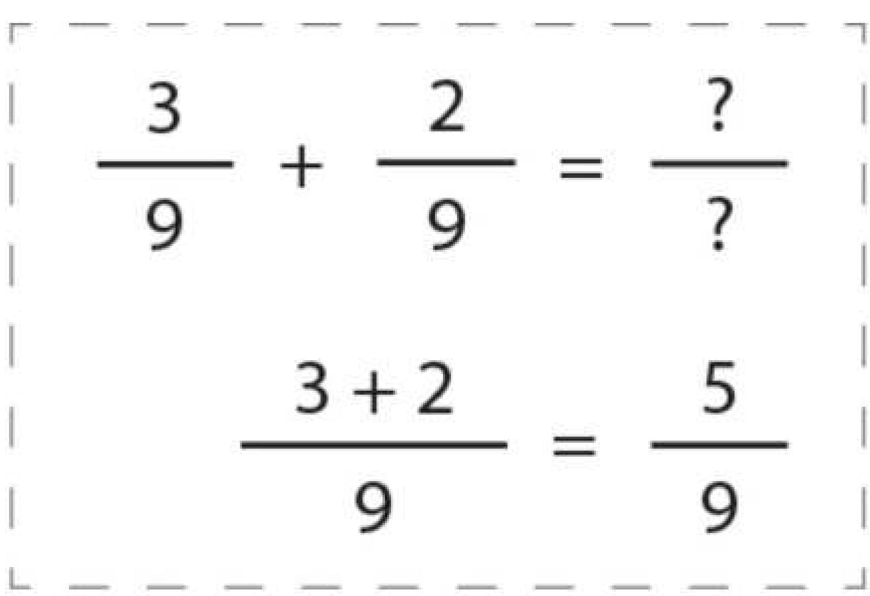
- The multiples of 3 are: 3, 6, **9**, 12, 15, etc.
- The multiples of 9 are: **9**, 18, 27, 36, etc.

So the lowest common denominator is 9. This means if we adjust the first fraction to have a denominator of 9, then both denominators will be the same, and we'll be able to complete the addition.

We change the denominator to 9 by multiplying it by 3, as 3 x 3 = 9. However, we must also multiply the numerator by 3 – otherwise the *value* of the fraction will change:



We can now go back to our original problem, and complete the addition, as both fractions now have a common denominator:



Worked Example 1 – Adding Fractions

Consider the following problem:

$$\frac{1}{6}+\frac{3}{8}+\frac{5}{12}=?$$

1. The first step is to find the lowest common denominator for all three fractions:

- Multiples of 6 are: 6, 12, 18, **24**, 30, etc.
- Multiples of 8 are: 8, 16, **24**, 32, 40, etc.
- Multiples of 12 are: 12, **24**, 36, 48, etc.

2. The lowest common denominator is 24, so we now need to change each fraction to have a denominator of 24:

$$\frac{1\times 4}{6\times 4}+\frac{3\times 3}{8\times 3}+\frac{5\times 2}{12\times 2}=?$$

$$\frac{4}{24}+\frac{9}{24}+\frac{10}{24}=?$$

3. The next step is to solve the addition:

$$\frac{4+9+10}{24}=\frac{23}{24}$$

4. The final step is to express the answer in its simplest form. In this case, the answer above can't be simplified any further.

Worked Example 2 – Subtracting Fractions

Consider the following problem:

$$\frac{7}{10} - \frac{1}{5} - \frac{6}{15} = ?$$

1. The first step is to find the lowest common denominator for all three fractions:

   - Multiples of 10 are: 10, 20, **30**, 40, 50, etc.
   - Multiples of 5 are: 5, 10, 15, 20, 25, **30**, etc.
   - Multiples of 15 are: 15, **30**, 45, 60, 75, etc.

2. The lowest common denominator is 30, so we now need to change each fraction to have a denominator of 30:

$$\frac{7 \times 3}{10 \times 3} - \frac{1 \times 6}{5 \times 6} - \frac{6 \times 2}{15 \times 2} = ?$$

$$\frac{21}{30} - \frac{6}{30} - \frac{12}{30} = ?$$

3. The next step is to solve the subtraction:

$$\frac{21 - 6 - 12}{30} = \frac{3}{30}$$

4. The final step is to express the answer in its simplest form:

$$\frac{3}{30} = \frac{1}{10}$$

Check your understanding of the content by clicking on the link below then undertaking the activity.

Multiplying Fractions

When multiplying or dividing fractions, the denominators *don't need to be the same.*

To multiply two fractions together:

- Multiply the numerators together, and the answer becomes the new numerator.
- Multiply the denominators together, and the answer becomes the new denominator.
- Express the answer in its simplest form.

$$\frac{4}{7} \text{ x } \frac{2}{7} = \frac{?}{?}$$

$$\frac{4 \text{ x } 2}{7 \text{ x } 7} = \frac{8}{49}$$

Worked Example 3 – Multiplying Fractions

Consider the following problem:

$$\frac{1}{2} \times \frac{2}{3} \times \frac{5}{6} = ?$$

1. The first step is to multiply the three numerators, and then multiply the three denominators:

$$\frac{1 \times 2 \times 5}{2 \times 3 \times 6} = \frac{10}{36}$$

2. The next step is to express the answer in its simplest form:

$$\frac{10}{36} = \frac{5}{18}$$

Dividing Fractions

There's a trick to make dividing fractions simple – to divide one fraction into another:

- Change the division sign to a multiplication sign and flip the fraction to the right of the (now multiplication) sign, so that the numerator becomes the denominator and vice versa.
- Solve the multiplication.
- Express the answer in its simplest form.

Worked Example 4 – Dividing Fractions

Consider the following problem:

$$\frac{3}{8} \div \frac{2}{5} \div \frac{1}{2} = ?$$

1. The first step is to swap the division signs for multiplication signs and flip the associated fractions, as shown below:

2. The next step is to solve the multiplication:

$$\frac{3 \times 5 \times 2}{8 \times 2 \times 1} = \frac{30}{16}$$

3. The final step is to express the answer in its simplest form:

$$\frac{30}{16} = \frac{15}{8}$$

Note – This answer is an improper fraction. This answer could also be expressed as a mixed number, as follows:

$$\frac{15}{8} = 1\,\frac{7}{8}$$

Order of Operations with Fractions

The order of operations when working with fractions is the same as that for whole numbers and decimals. Something to note however, is that any mathematical operation shown on the top or bottom of a fraction is considered to be in brackets, even if no brackets are shown:

Worked Example 5 – Order of Operations with Fractions

Consider the following problem:

$$\frac{(3+1)\times 6}{8\times 7} \div \left(\frac{13}{5} - \frac{1}{2}\right) - \frac{1}{2} \times \frac{5-3}{(21\div 3)} = ?$$

This problem may appear complex and 'difficult', but it doesn't need to be viewed this way. All that's required is to follow the order of operations and the rules for working with fractions, and to approach the problem one step at a time.

1. The first step is to solve the brackets (including operations grouped on the top or bottom of a fraction), working left to right:

$$\frac{(3+1)\times 6}{8\times 7} \div \left(\frac{13}{5} - \frac{1}{2}\right) - \frac{1}{2} \times \frac{5-3}{(21\div 3)} = ?$$

$$\frac{4\times 6}{8\times 7} \div \left(\frac{13}{5} - \frac{1}{2}\right) - \frac{1}{2} \times \frac{5-3}{(21\div 3)} = ?$$

$$\frac{24}{8\times 7} \div \left(\frac{13}{5} - \frac{1}{2}\right) - \frac{1}{2} \times \frac{5-3}{(21\div 3)} = ?$$

$$\frac{24}{56} \div \left(\frac{13}{5} - \frac{1}{2}\right) - \frac{1}{2} \times \frac{5-3}{(21\div 3)} = ?$$

$$\frac{3}{7} \div \left(\frac{13}{5} - \frac{1}{2}\right) - \frac{1}{2} \times \frac{5-3}{(21\div 3)} = ?$$

$$\frac{3}{7} \div \left(\frac{13\times 2}{5\times 2} - \frac{1\times 5}{2\times 5}\right) - \frac{1}{2} \times \frac{5-3}{(21\div 3)} = ?$$

$$\frac{3}{7} \div \left(\frac{26}{10} - \frac{5}{10}\right) - \frac{1}{2} \times \frac{5-3}{(21\div 3)} = ?$$

$$\frac{3}{7} \div \frac{21}{10} - \frac{1}{2} \times \frac{5-3}{(21\div 3)} = ?$$

$$\frac{3}{7} \div \frac{21}{10} - \frac{1}{2} \times \frac{2}{(21\div 3)} = ?$$

$$\frac{3}{7} \div \frac{21}{10} - \frac{1}{2} \times \frac{2}{7} = ?$$

2. The next step is to solve the division and multiplication, starting on the left:

$$\frac{3}{7} \times \frac{10}{21} - \frac{1}{2} \times \frac{2}{7} = ?$$

$$\frac{30}{147} - \frac{1}{2} \times \frac{2}{7} = ?$$

$$\frac{10}{49} - \frac{1}{2} \times \frac{2}{7} = ?$$

$$\frac{10}{49} - \frac{2}{14} = ?$$

3. The final step is to solve the subtraction and express the answer in its simplest form:

$$\frac{10 \times 2}{49 \times 2} - \frac{2 \times 7}{14 \times 7} = ?$$

$$\frac{20}{98} - \frac{14}{98} = \frac{6}{98}$$

$$\frac{6}{98} = \frac{3}{49}$$

Simple as that!

Introduction

Percentages are used widely in the electrotechnology industry for the specification and evaluation of electrical systems and equipment. In this topic you will learn about interpreting and working with percentages in ways that are typically required in the workplace.

Percentages in Electrotechnology Work

The following table describes some typical examples of where percentages are used in electrotechnology work.

<table>
<tr><th colspan="2">Percentages in Electrotechnology Work</th></tr>
<tr><td>Electrical Installation Requirements</td><td>Various requirements in AS/NZS 3000 (Wiring Rules) and other Australian Standards state percentages that must be complied with when:
Selecting cables and protection devices to prevent fire and electric shock.
Arranging cables and circuits to prevent fires and ensure equipment operates correctly.
Installing cables and equipment in buildings, e.g. in relation to penetrating fire rated walls.
Being able to apply the percentages in these standards is critical to producing safe and compliant electrical work.</td></tr>
<tr><td>Electrical Operating Parameters</td><td>Electrical circuits and equipment are designed to operate within various electrical parameters (e.g. voltage, current and power). Some parameters are defined as a percentages, such as:
Efficiency.
Regulation.
Various operating tolerances.
Being able to understand these parameters is important to all areas of electrical work, including equipment selection, installation, maintenance, testing and fault finding.</td></tr>
</table>

What is a Percentage?

As mentioned in the previous topic, percentages are closely related to fractions. "Per-cent" means "out of one hundred", so a percentage is essentially the numerator in a fraction with a denominator of 100.

?

$$\frac{5}{100} = 5\ \%$$

Notice how, in the example above, the numerator becomes the percentage value (this only works for fractions where the denominator is 100). Essentially, 5 % means "5 out of 100".**Expressing Decimals as Percentages**

It is also relatively simple to express a decimal as a percentage, simply:

- Multiply the decimal by 100 (move the decimal point two places to the right).
- Add the percentage symbol (%).

$$0.78 \times 100 = 78\ \%$$

The following worded examples show how various decimals can be converted to percentages.

Worked Examples 1 – Expressing Decimals as Percentages

1. Express 0.03 as a percentage:

$$0.03 \times 100 = 3\ \%$$

2. Express 0.62 as a percentage:

$$0.62 \times 100 = 62\ \%$$

3. Express 0.872 as a percentage:

$$0.872 \times 100 = 87.2\ \%$$

4. Express 1.25 as a percentage:

$$1.25 \times 100 = 125\ \%$$

Expressing Percentages as Decimals

To express a percentage as a decimal, the reverse process must be done:

- Divide the percentage by 100 (move the decimal point two places to the left).
- Remove the percentage symbol (%).

$$78\ \% \div 100 = 0.78$$

The following worded examples show how various percentages can be converted to decimals.

Worked Examples 2 – Expressing Percentages as Decimals

1. Express 8 % as a decimal:

$$8 \div 100 = 0.08$$

2. Express 25 % as a decimal:

$$25 \div 100 = 0.25$$

3. Express 94.5 % as a decimal:

$$94.5 \div 100 = 0.945$$

4. Express 130 % as a decimal:

$$130 \div 100 = 1.3$$

$$\frac{1}{10} = \frac{10}{100} = 10\ \%$$

$$\frac{1}{25} = \frac{4}{100} = 4\ \%$$

$$\frac{2}{5} = \frac{40}{100} = 40\ \%$$

$$\frac{16}{25} = \frac{64}{100} = 64\ \%$$

However it will not always be easily done – to express *any* fraction as a percentage:

- Divide the numerator by the denominator (i.e. convert the fraction to a decimal).
- Multiply the result by 100 (move the decimal point two places to the right).
- Add a percentage symbol (%).

Worked Examples 3 – Expressing Fractions as Percentages

1. Express $\frac{1}{2}$ as a percentage:

$$1 \div 2 = 0.5$$
$$0.5 \times 100 = 50\ \%$$

2. Express $\frac{13}{20}$ as a percentage:

$$13 \div 20 = 0.65$$
$$0.65 \times 100 = 65\ \%$$

3. Express $\frac{3}{8}$ as a percentage:

$$3 \div 8 = 0.375$$
$$0.375 \times 100 = 37.5\ \%$$

Expressing Percentages as Fractions

To express a percentage as a fraction:

- Use the number of percent as the numerator of the fraction.

- Insert 100 as the denominator of the fraction.
- Reduce the fraction to simplest form.

Worked Examples 4 – Expressing Percentages as Fractions

1. Express 25 % as a fraction:

$$25\ \% \ = \frac{25}{100}$$

$$\frac{25}{100} = \frac{1}{4}$$

2. Express 18 % as a fraction:

$$18\ \% \ = \frac{18}{100}$$

$$\frac{18}{100} = \frac{9}{50}$$

3. Express 80 % as a fraction:

$$80\ \% \ = \frac{80}{100}$$

$$\frac{80}{100} = \frac{4}{5}$$

Application of Percentage Calculations

There are a number of reasons it can be useful to calculate percentages from decimals or fractions and vice versa. The following table explains some of these reasons.

Application of Percentages		
Purpose	**Example**	**Calculation**
To calculate the percentage of a value	If the "full-load current" of an electric heater is 40 amperes, then how much current is the heater drawing at 25 % of full load?	25 % ÷ 100 = 0.25 0.25 x 40 = **10 amperes** So the heater will draw 10 amperes at 25 % of full load.

To express one quantity as a percentage of another	The allowable tolerance for a 230 volts supply is +10 % and -6 %. Is a supply voltage of 245 V within the acceptable tolerance?	245 – 230 = 15 volts 15 ÷ 230 = 0.0652 0.0652 x 100 = **+6.52 %** **+6.52 % < +10 %** So yes, 245 volts is within tolerance.
To calculate the percentage of increase or decrease	If the current in a circuit increases from 5 amperes to 7.5 amperes, what is the percentage increase?	7.5 – 5 = 2.5 amperes 2.5 ÷ 5 = 0.5 0.5 x 100 = **50 %** So the current has increased by 50 %.

Efficiency

The efficiency of a system can be determined from the following equation:

$$\eta = \frac{P_{OUT}}{P_{IN}} \text{ x } 100$$

Where:

- η = efficiency expressed as a percentage (%)
- P_{OUT} = output power measured in watts (W)
- P_{IN} = input power measured in watts (W)

Worked Example – Calculating Efficiency

Calculate the efficiency of an electric motor that draws 5 kW of power from the supply and outputs 4.5 kW of useable power to drive a mechanical load.

$$\eta = \frac{P_{OUT}}{P_{IN}} \text{ x } 100$$

$$\eta = \left(\frac{4500}{5000}\right) \text{ x } 100$$

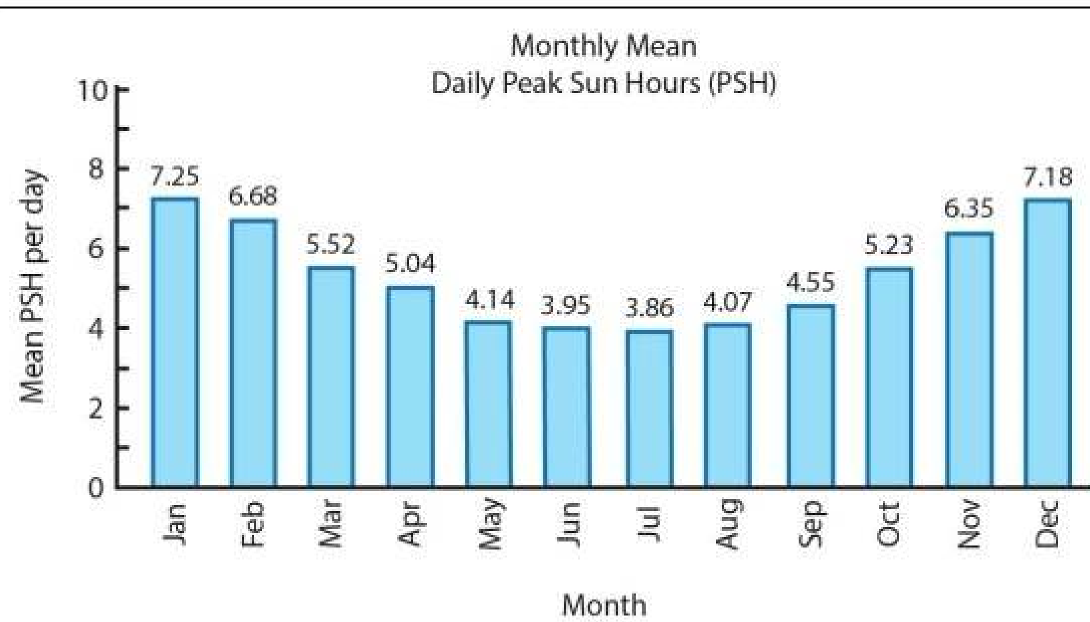
$$\eta = 90\ \%$$

Introduction

The performance and characteristics of electrical appliances are often represented graphically, so it's important for electrotechnology workers to be able to interpret and develop graphs. In this topic you will learn about the features and application of graphs in electrotechnology work, as well as how to draw and interpret various types of graphs.

Types of Graphs

Graphs are used to visually represent data, as this is often much easier to interpret than just looking at a list of numbers. There are three main types of graphs that you are likely to encounter in the Electrotechnology Industry, these are:

Common Types of Graphs		
Type	**Example**	**Description**
Bar Graph		• Represents values using bars of different heights (vertical graphs) or lengths (horizontal graphs). • The example shows how the average sunlight varies month by month at a given location. • It can be seen that there is more average sunlight during the summer months (Dec to Feb), than in the winter months (Jun to Jul).

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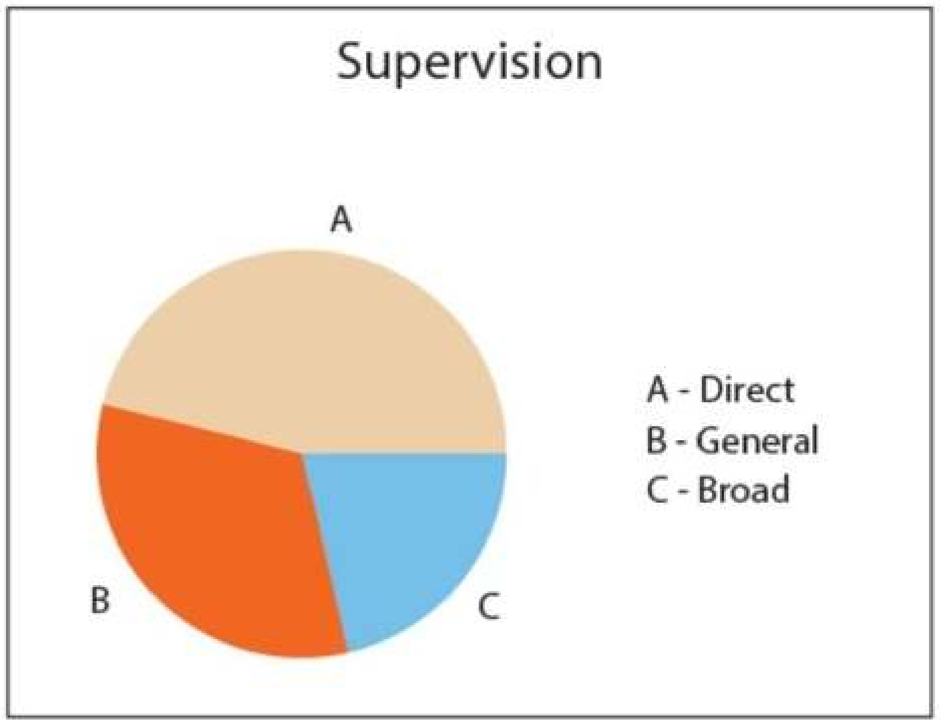
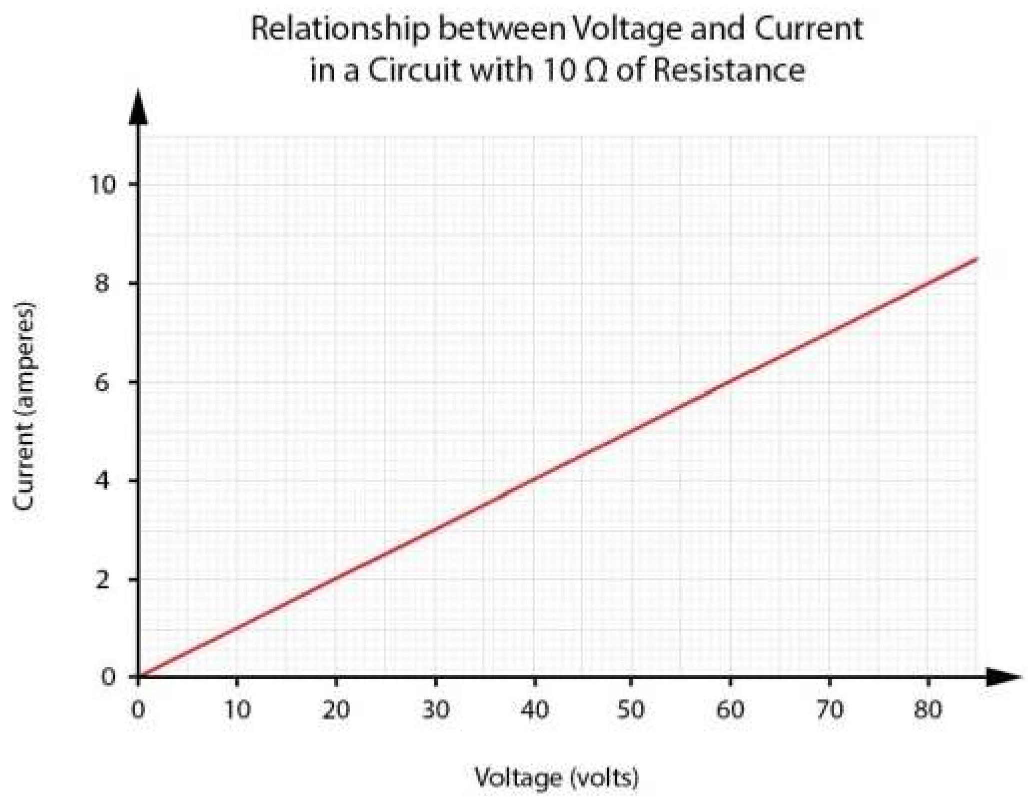
Pie Chart		• Represents data as different sized slices of a pie (i.e. proportions of a whole). • The example shows the different types of supervision the apprentice has worked under. • It can be seen that the apprentice has been mostly working under direct supervision.
Line Graphs		• Represents the relationship between two or more variables. • The example shows the relationship between voltage and current in an electrical circuit. • It can be seen that if the voltage is increased, then the current will also increase.

Application of Graphs

Graphs are useful because they are a visual way of recording and reading information:

- A graph shows high and low points.
- A graph shows where changes occur and what type of changes are taking place, for example:

    - Are parameters steady or fluctuating?

    - Will parameters change slowly or quickly?

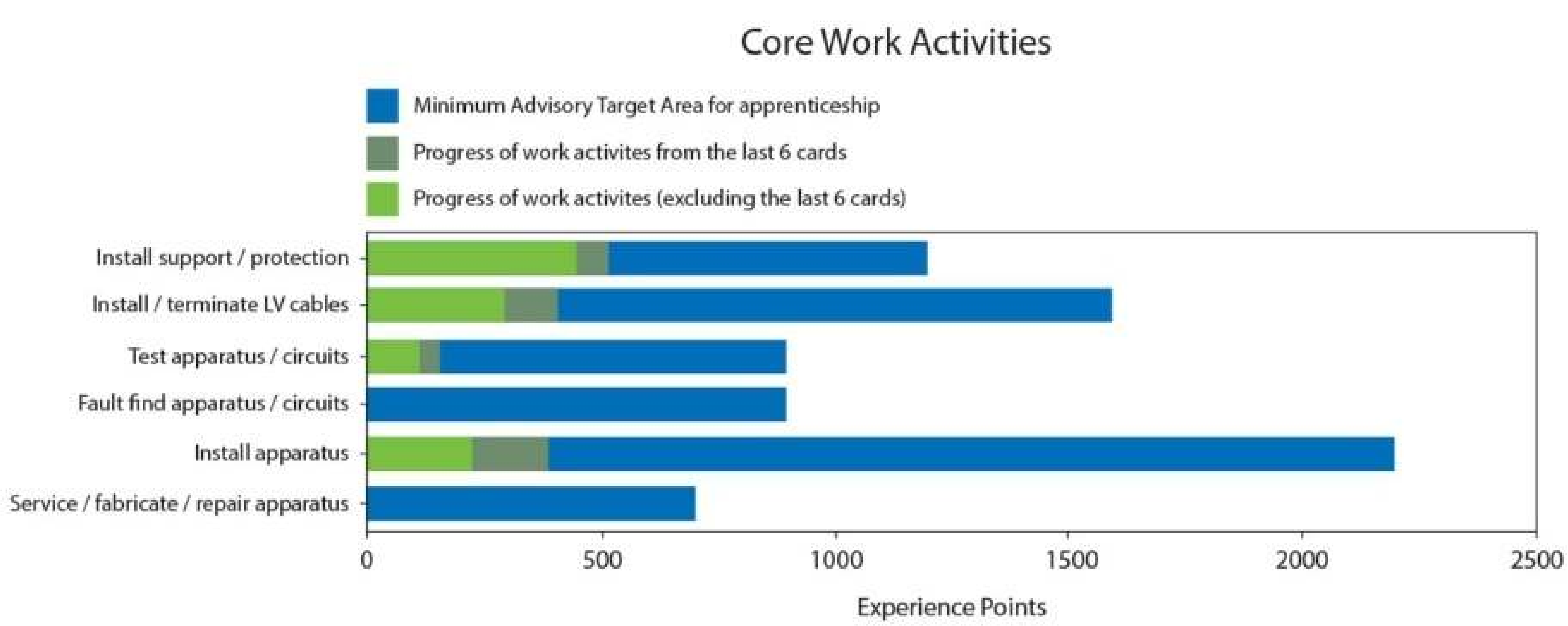
- A graph makes comparisons easy, and can show large amounts of information.

The operational characteristics of electrical equipment are often represented in graphs to make this information easier to interpret and understand. In electrotechnology work, we often need to evaluate these characteristics when:

- Selecting equipment, e.g. selecting circuit breakers to protect different types of circuits with different operating requirements.
- Arranging equipment, e.g. installing solar panels in a position where they will receive the most sunlight.
- Servicing, fault finding and repairing equipment, e.g. testing a motor and comparing the measured results to the manufacturer's data.

Bar Graphs

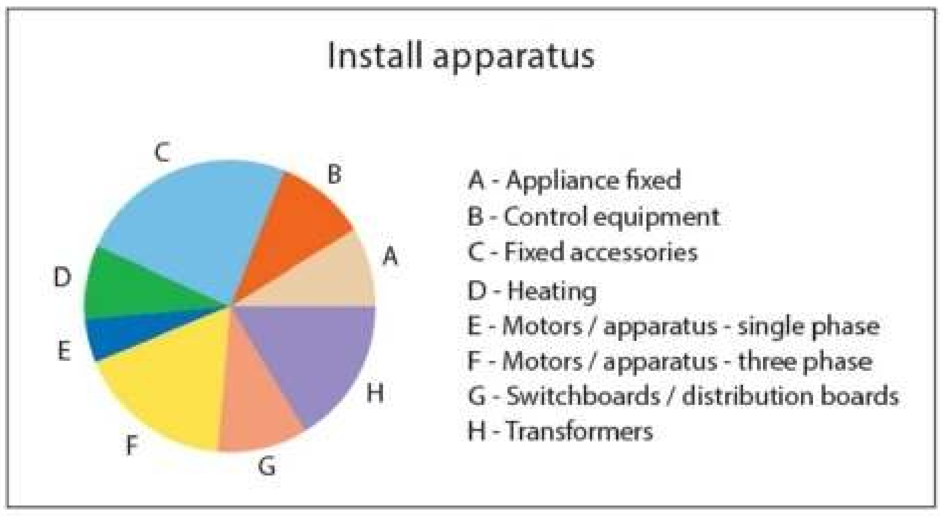
Bar graphs are typically used to compare sets of data, for example the weather conditions in different months. The following horizontal bar graph shows the "work performance" of an apprentice – that is, the experience the apprentice has gained in different work areas (typically recorded by completing an electronic logbook such as eProfiling):



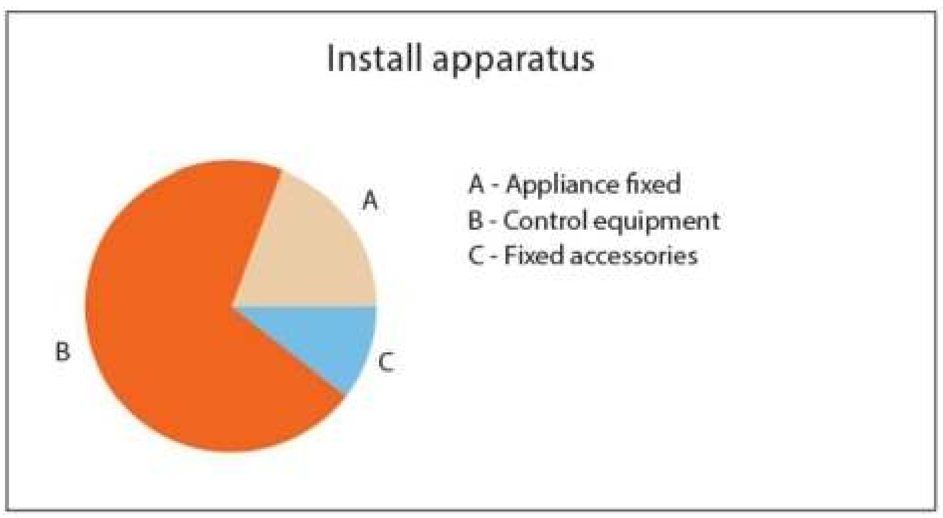
This chart is useful for checking that the apprentice has spent an appropriate amount of time performing different types of work tasks.

Pie Charts

Pie charts are used to show proportions within a set of data. The following pie chart follows on from the bar graph, focusing in on the work area of "Install apparatus". The chart indicates the proportions of different apparatus the apprentice has installed.

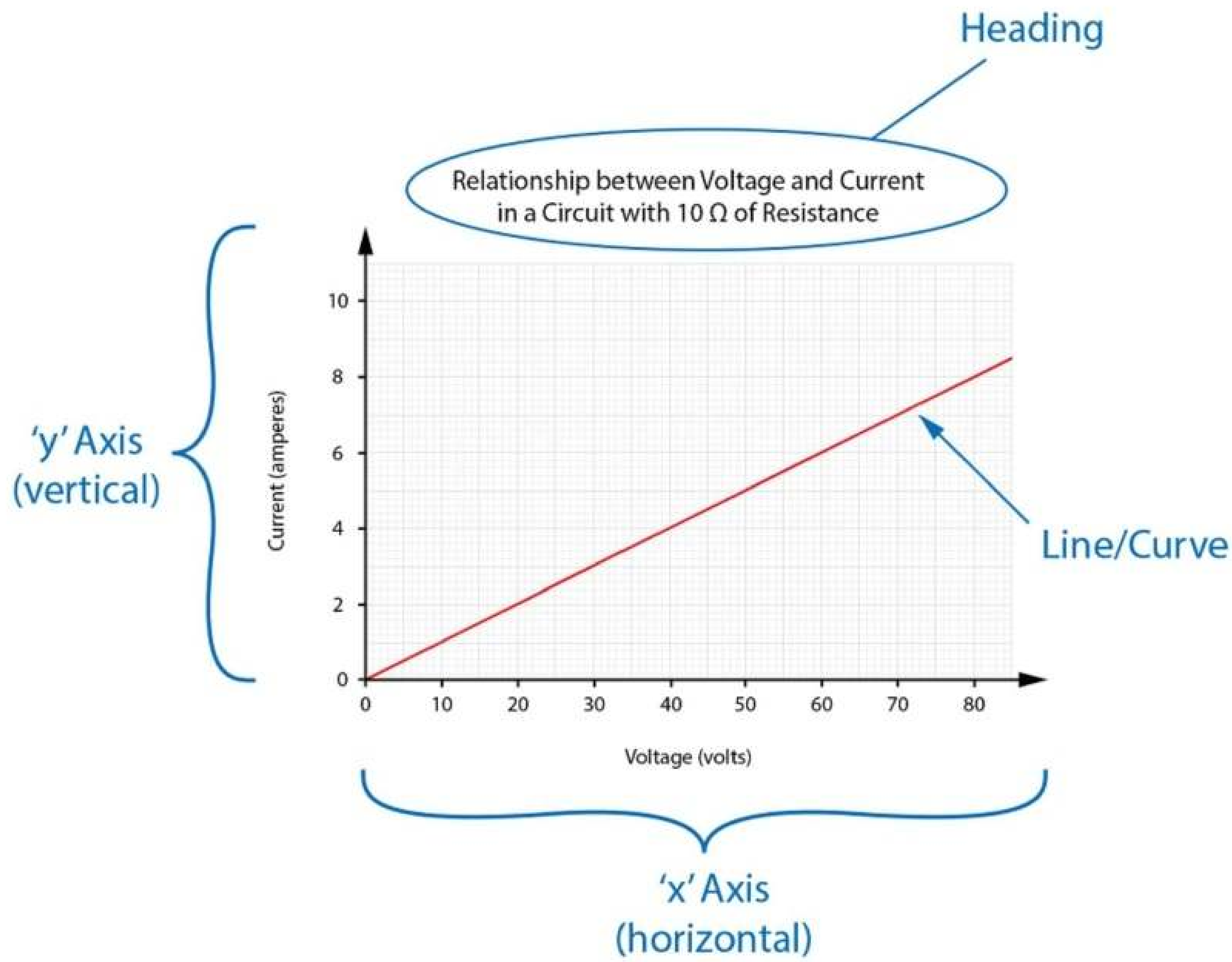


This type of chart would be useful for checking that the apprentice has experience installing enough different types of equipment. For example, even if an apprentice had the same hours of experience, the chart below indicates a much more limited *range* of experience than the chart above:



Line Graphs

Electrical characteristics are most commonly represented in line graphs. The following diagram shows the basic parts of a line graph:

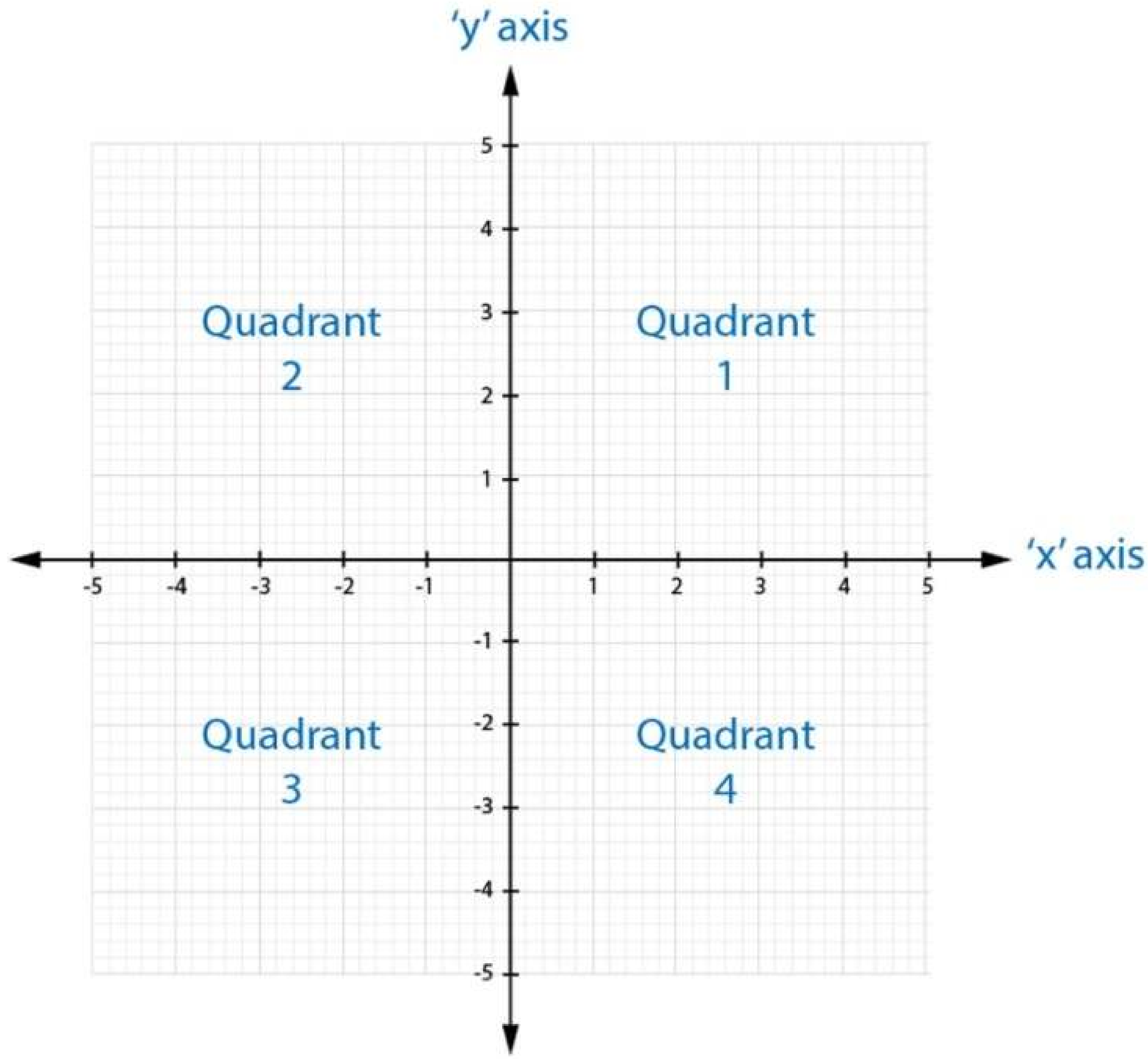


Line graphs should follow these conventions:

- The heading or title indicates what relationship is being represented.
- The 'x' axis is drawn horizontally, and typically represents the 'controlled' variable (in this case, that's the voltage).
- The 'y' axis is drawn vertically, and typically represents the 'un-controlled' variable (in this case, that's the current).
- Each axis includes a scale that is appropriate for the quantity being represented.
- Each axis is labelled with the quantity (e.g. current) and the units of measure (e.g. amperes) for the given scale.
- The line (or curve) is drawn to represent the relationship between the two variables.

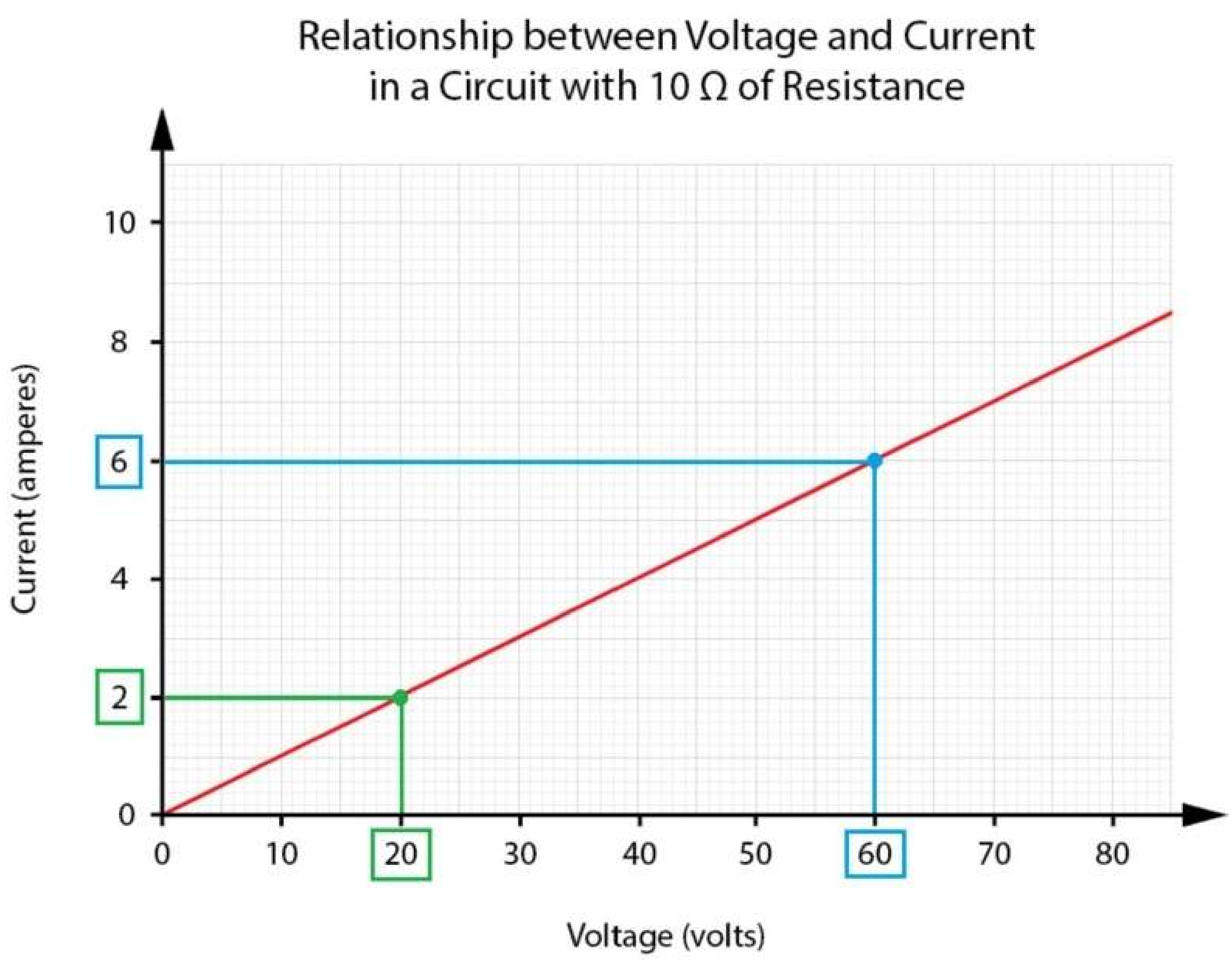
Graph Quadrants

In some cases, the scale of a graph may need to extend beyond zero and into negative units. Where this is the case, the x and/or y axes are extended, so that the graph ends up being split into multiple 'quadrants', as shown below:


'y' axis
5
4
3
2
1
-1
-2
-3
-4
-5
Quadrant
2
Quadrant
1
Quadrant
3
Quadrant
4
'x' axis
-5
-4
-3
-2
-1
1
2
3
4
5

Interpreting Graphs

To interpret the line graph below, we follow a point on the x axis up to where it intersects with the line/curve, and then we follow across to see what that point lines up with on the y axis.



Using this method, we can see that for the 10 Ω circuit represented above:

- Applying a voltage of 20 volts will cause a current of 2 amperes to flow (shown in green).
- Applying a voltage of 60 volts will cause a current of 6 amperes to flow (shown in blue).

?

Check your understanding of the content by answering the following questions.

1. How much current would flow in the 10 Ω circuit if a voltage of 50 volts is applied?

2. What voltage would cause a current of 7 amperes to flow in the 10 Ω circuit?

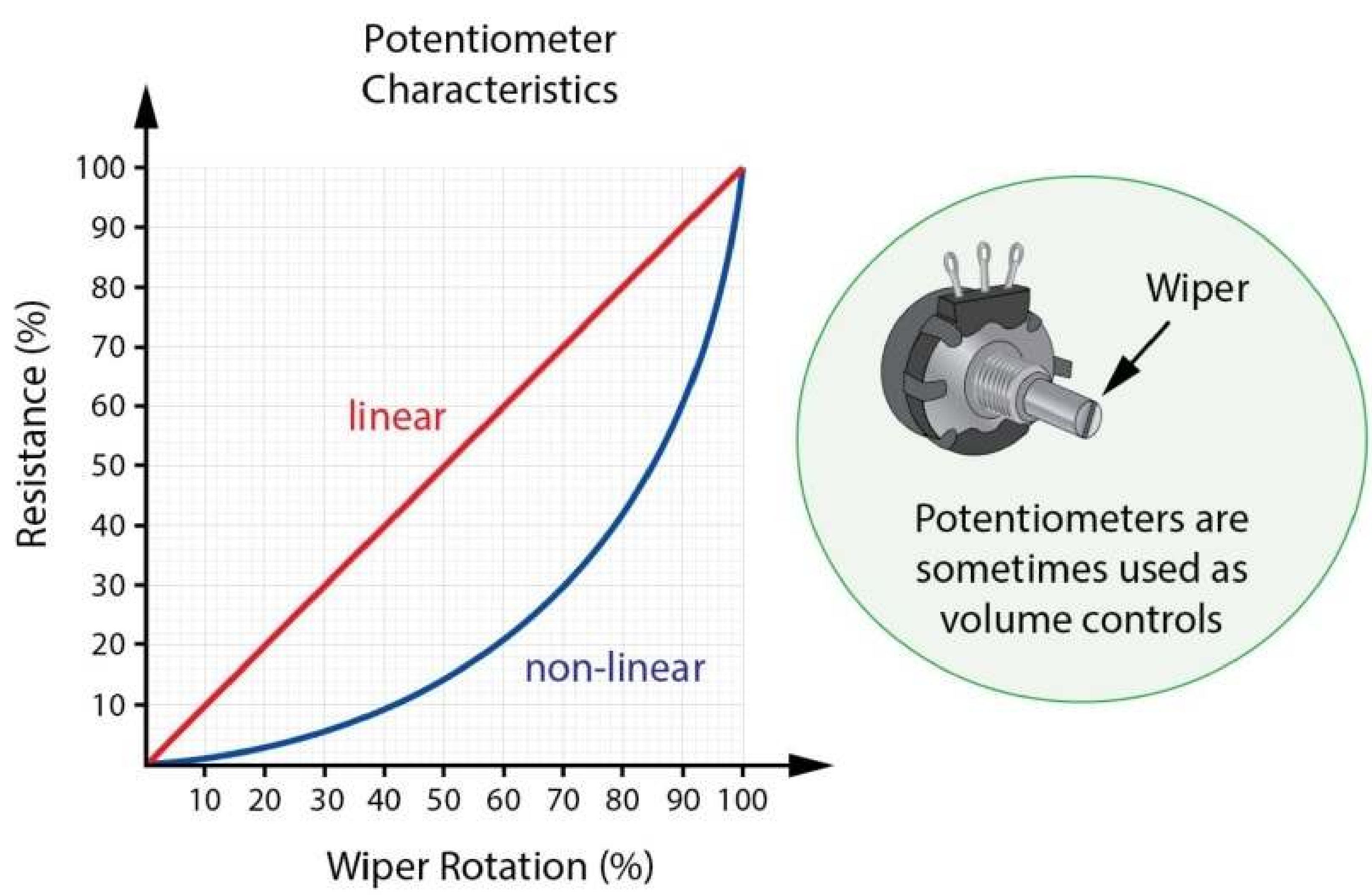
(answers at bottom of page)

Linear and Non-Linear Graphs

A linear graph is one in which the relationship is represented by a straight line – such as the voltage/current relationship shown above, whilst non-linear relationships are represented by a curve:

- For linear relationships, a change in one variable causes a proportional change in the other.
- For non-linear relationships this change is not proportional.

A potentiometer (adjustable resistor) is an electrical component that is available in both linear and non-linear types. The following graph compares the characteristics of linear and non-linear potentiometers:



Check your understanding of the content by answering the following questions.

1. For a 10 kΩ linear potentiometer, what percentage of wiper rotation is needed to get a resistance of 6 kΩ?

2. For a 10 kΩ non-linear potentiometer, what percentage of wiper rotation is needed to get a resistance of 6 kΩ?

(answers at bottom of page)

Constructing Graphs

In some situations it may be necessary to construct a graph to analyse data. The basic procedure for constructing a graph from a given data set is detailed in the following table:

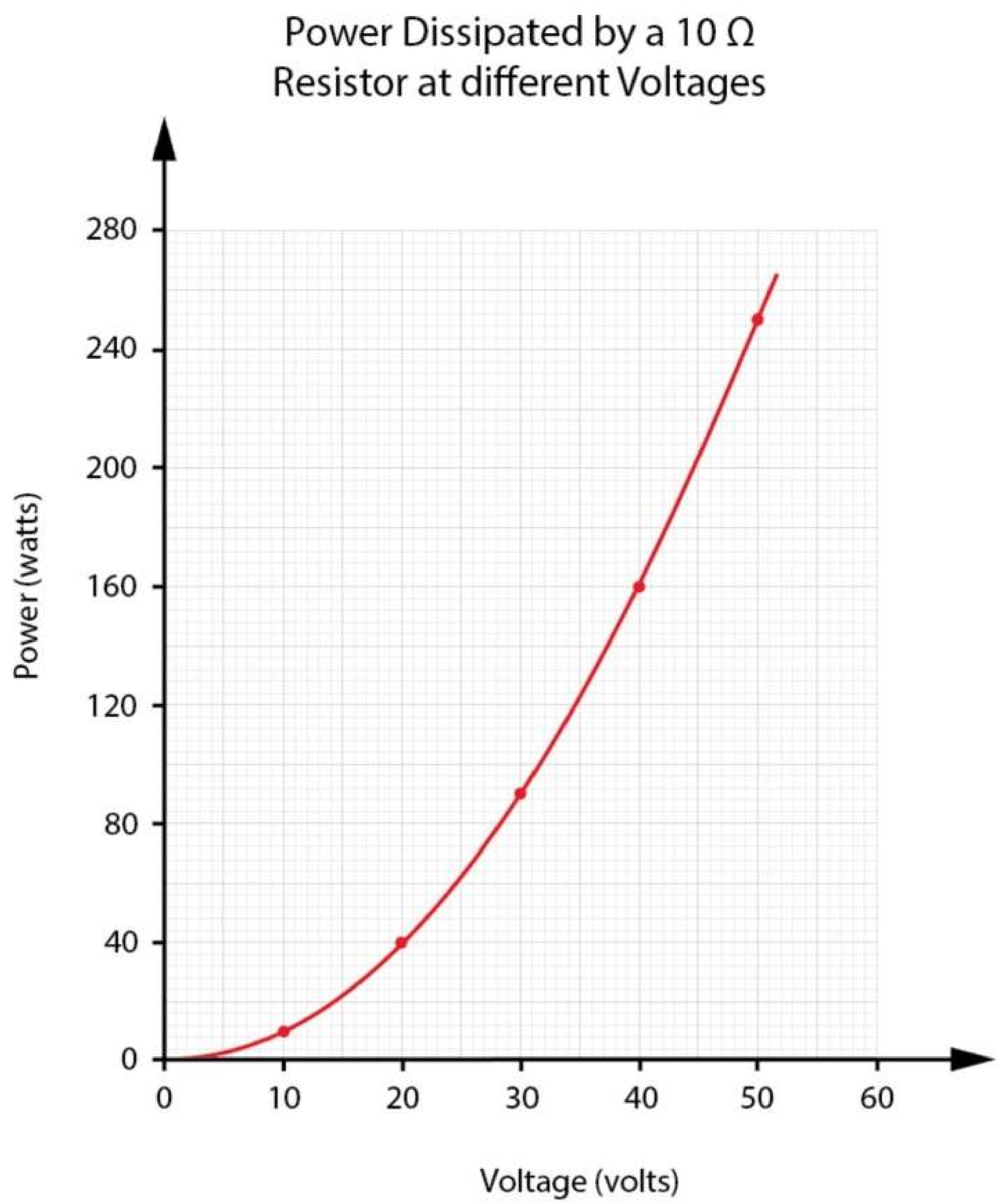
Constructing a Graph	
Step 1	Choose a heading/title: • This should describe what the graph is attempting to represent.
Step 2	Draw the axes: • The controlled variable should typically be shown on the x axis, which is drawn horizontally. • The uncontrolled variable should typically be shown on the y axis, which is drawn vertically.
Step 3	Draw the scales: • The size of each scale should maximise the use of the available graph area, i.e. they should be as large as is convenient – this will make the graph easier to interpret. • Make sure the scale is calibrated accurately – it can help to use graph paper. • Label each axis to indicate the quantity and the units of measure represented by the scale.
Step 4	Plot the data • Neatly draw in the points/co-ordinates on the graph. • Draw in the line/curve of 'best fit' to represent the relationship between the two variables.

Example Graph Construction

The following diagram shows a line graph that has been constructed from the following set of circuit measurements:

Power Dissipated by a 10 Ω Resistor at different Voltages

Voltage (volts)	0	10	20	30	40	50
Power (watts)	0	10	40	90	160	250



View

Introduction

In the electrotechnology industry, workers often need to understand and solve problems involving very large numbers (e.g. 6,730,000,000,000), and very small numbers (e.g. 0.000000000483). Numbers like these can be difficult to work with, as there can be lots of digits, zeros and decimal places to keep track of. In this topic you will learn about the various rules for expressing values within the metric system, including the use of indices, scientific and engineering notations, and multiple and sub-multiple units.

Indices

An index is a small number written at the top right hand side of another number, as shown below:

An index tells us that we need to multiply the base number by itself a number of times. The number of times we need to multiply is indicated by the value of the index, for example:

$5^1 = 5$

$5^2 = 5 \times 5 = 25$

$5^3 = 5 \times 5 \times 5 = 125$

$5^4 = 5 \times 5 \times 5 \times 5 = 625$

$5^5 = 5 \times 5 \times 5 \times 5 \times 5 = 3{,}125$

$5^6 = 5 \times 5 \times 5 \times 5 \times 5 \times 5 = 15{,}625$

Etc.

Indices are also commonly referred to as 'exponents' or 'powers'. An index of 2 is also called a square, and an index of 3 is a cube. For example, you may have heard 5^2 expressed as '5 to the power of 2', or '5 squared'.

When using a calculator or computer, it can be more convenient to use the ^ symbol to express indices, for example 5^2 can also be expressed as 5^2. Take note of where the ^ button is on your calculator, try entering 5^2, and hit the equals button – you should get an answer of 25.

Note that this button may not be present on some older scientific calculators. It's important to become familiar with the functionality and layout of your own calculator.

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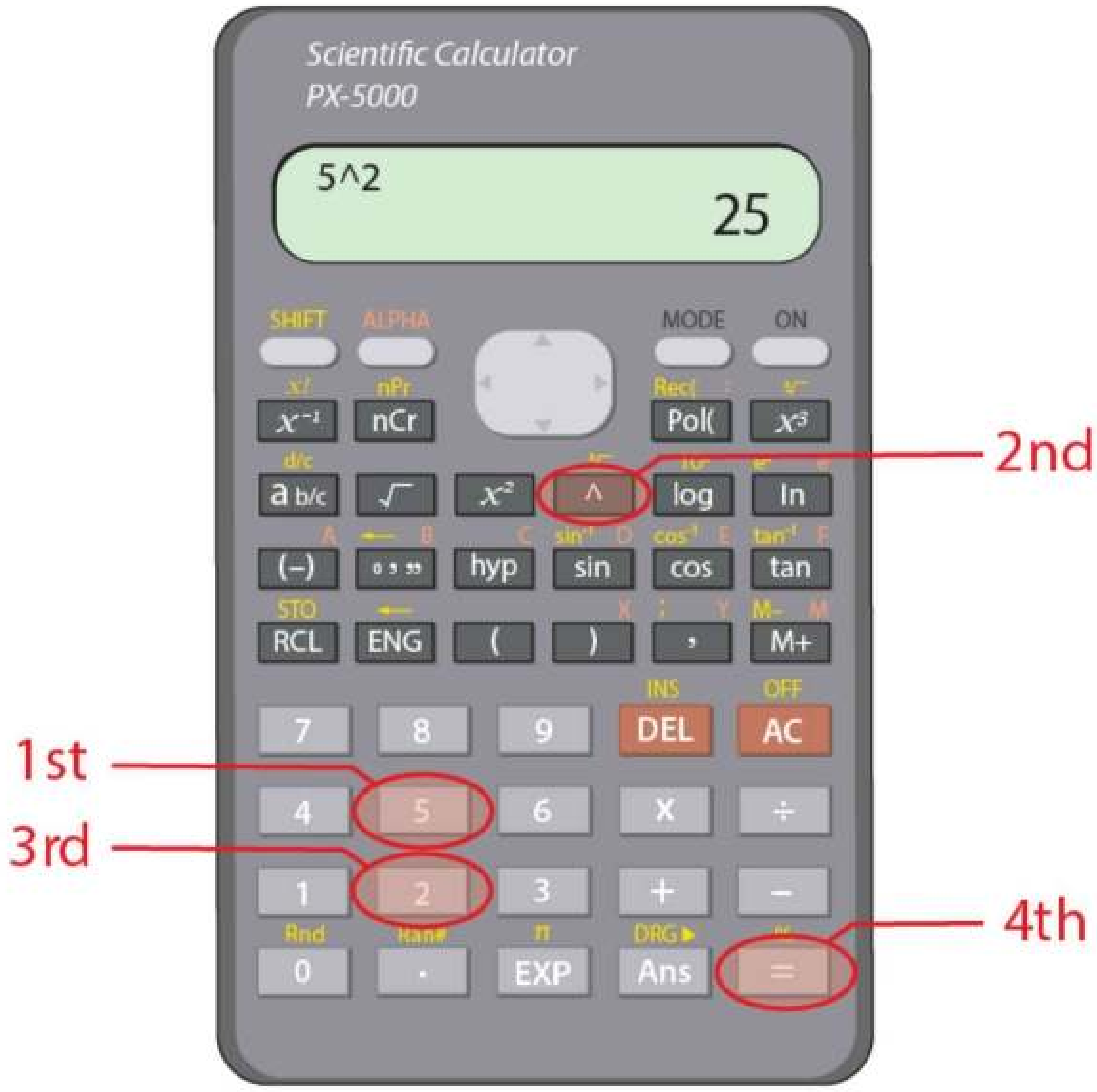


Two further tips to remember are:

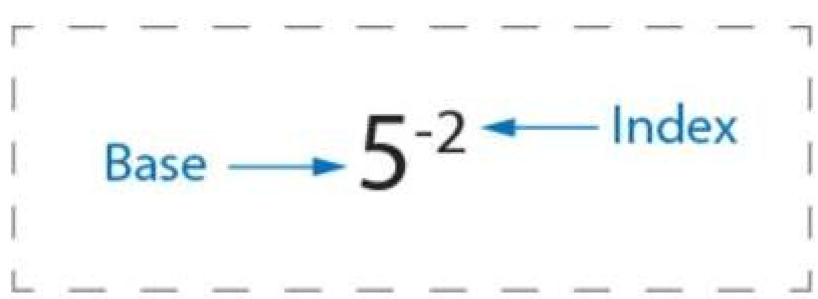
- Any base number with an index of 1 is equal to the base number
  - $3^1 = 3$
  - $4^1 = 4$
  - Etc.
- Any base number with an index of 0 is equal to 1, e.g. $5^0 = 1$
  - $3^0 = 1$
  - $4^0 = 1$
  - Etc.

Check your understanding of the content by clicking on the link below then undertaking the activity.

Load the Activity

Negative Indices

Indices can also be negative, as shown in the following example:



Essentially, a negative index tells us how many times we need to divide the base number into 1, for example:

$5^{-1} = 1 \div 5 = 0.2$

$5^{-2} = 1 \div 5 \div 5 = 0.04$

$5^{-3} = 1 \div 5 \div 5 \div 5 = 0.008$

$5^{-4} = 1 \div 5 \div 5 \div 5 \div 5 = 0.0016$

$5^{-5} = 1 \div 5 \div 5 \div 5 \div 5 \div 5 = 0.00032$

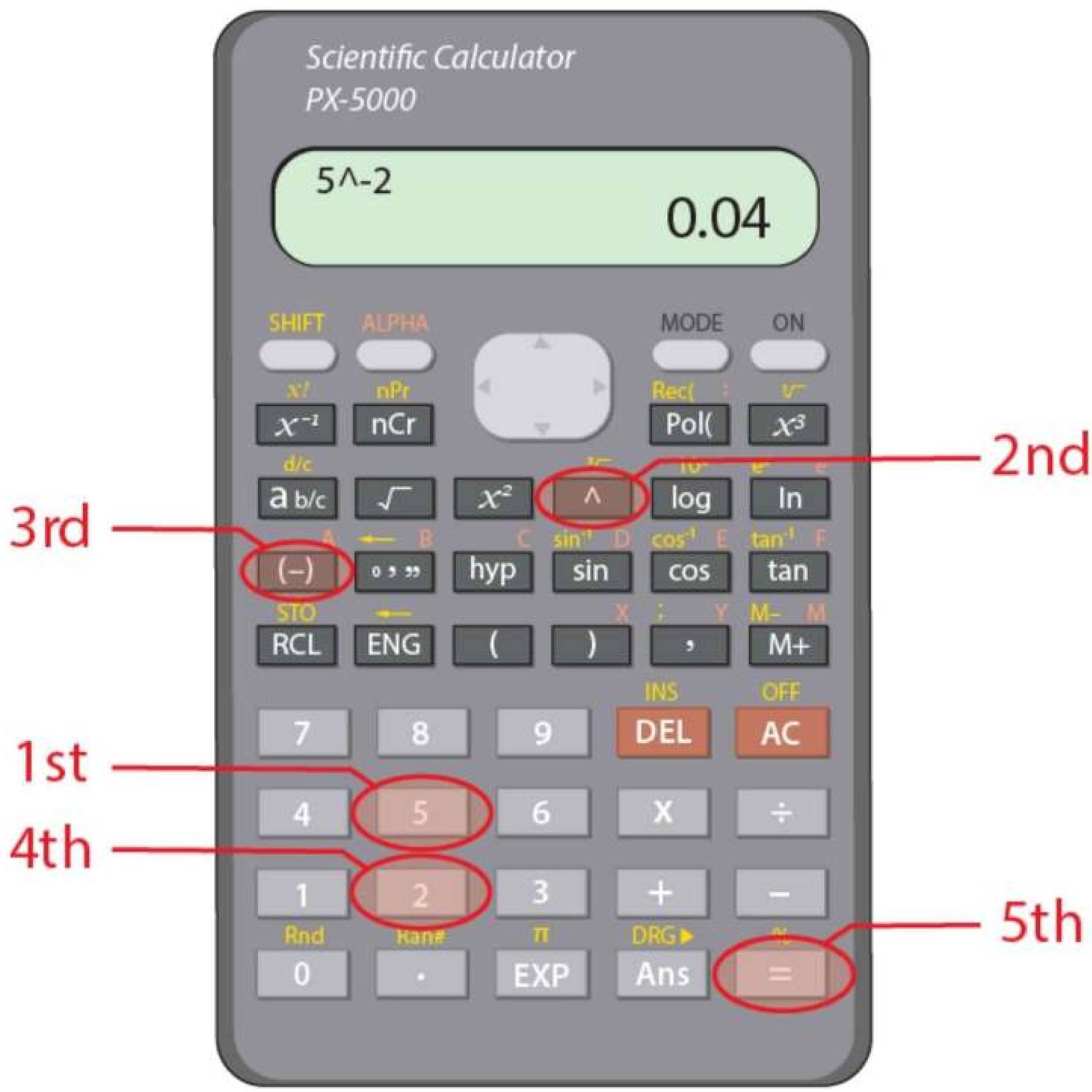
$5^{-6} = 1 \div 5 \div 5 \div 5 \div 5 \div 5 \div 5 = 0.000064$

Etc.

Another way of viewing a negative index is as the reciprocal of the associated positive index. That means that if we can remove the minus sign from the index, and then place the (now positive) expression under 1, we have the same number:

$$5^{-2} = \frac{1}{5^2}$$

As with positive indices, negative indices can be represented with the ^ symbol, for example 5^{-2} can be expressed as 5^-2. Try entering 5^-2 on your calculator – the button arrangement should be similar to that shown below:



Check your understanding of the content by clicking on the link below then undertaking the activity.

Load the Activity

Powers of Ten

Multiples of ten can be expressed as powers of ten, in which the index is a whole number. Some of the multiples of ten are represented as follows:

0.000001	=	10^{-6}	10	=	10^{1}
0.00001	=	10^{-5}	100	=	10^{2}
0.0001	=	10^{-4}	1,000	=	10^{3}
0.001	=	10^{-3}	10,000	=	10^{4}
0.01	=	10^{-2}	100,000	=	10^{5}
0.1	=	10^{-1}	1,000,000	=	10^{6}
1	=	10^{0}	10,000,000	=	10^{7}

Powers of ten provide a convenient way of expressing very large or very small numbers using scientific notation – which will be explored on the next content page.

This learning activity consists of 4 parts designed to develop your understanding of indices as applicable to electrotechnology work.

Topic 5.1 Learning Activity

Last modified: Tuesday, 16 April 2024, 12:24 PM

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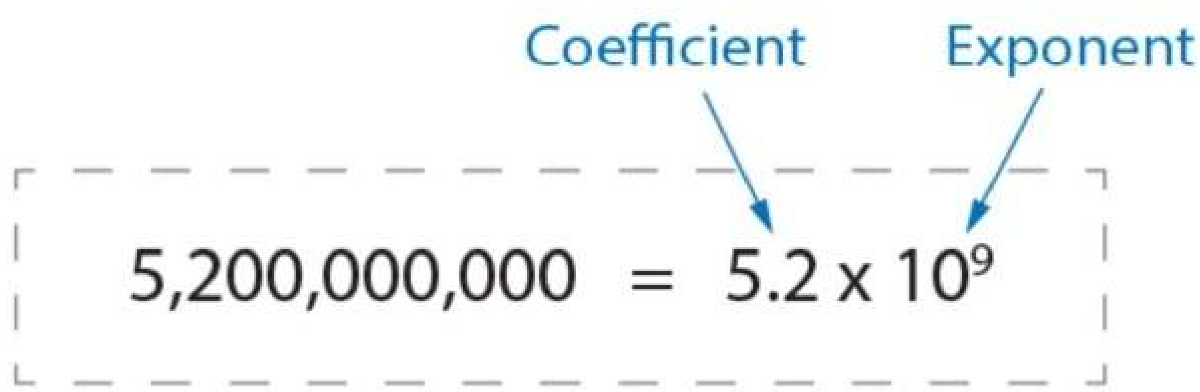
Scientific notation allows us to express very large and very small values in a simpler and more manageable form, by stating them as a number between 1 and 10 that is multiplied by 10 raised to some power.

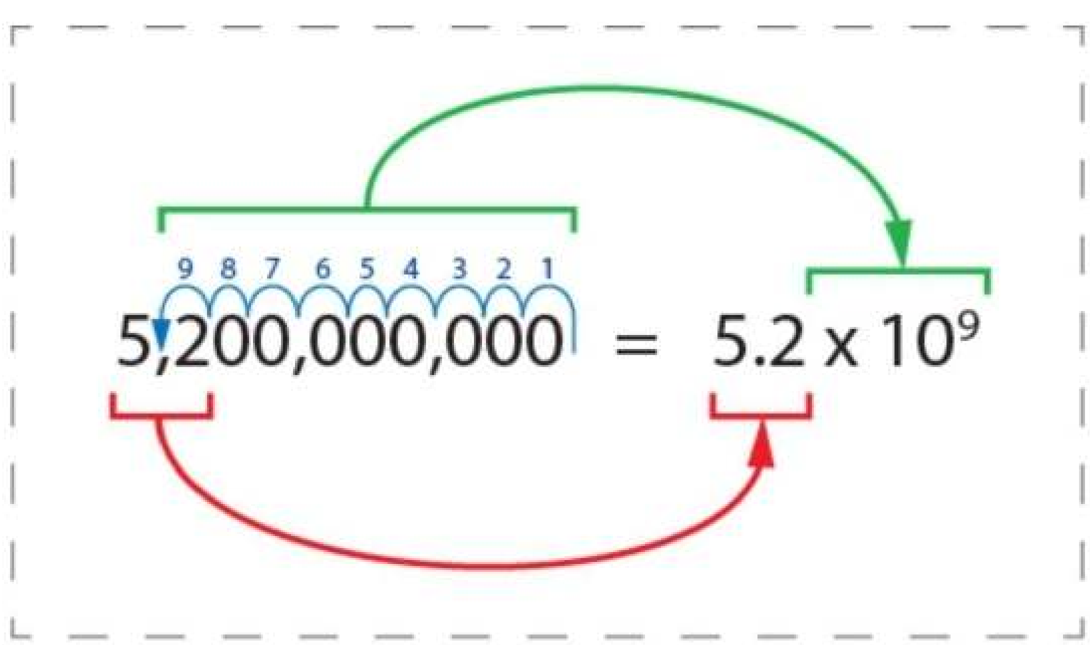
This might sound more complicated than it really is – all we're really doing is moving the decimal point to reduce the number of digits that we need to show. The following diagram shows how to use scientific notation to express the number 5 billion, 200 million:



When using scientific notation, the number gets split into a coefficient and an exponent:

The coefficient is the number expressed with fewer digits – making it easier to look at and comprehend. The coefficient should be expressed as a number between 1 and 10.

The exponent tells us how many places the decimal point has been moved.



If you enter 5,200,000,000 into your calculator and press the "=" button, it should automatically express the number in scientific notation. You can also use the "EXP" button to enter this number directly into your calculator in scientific notation:

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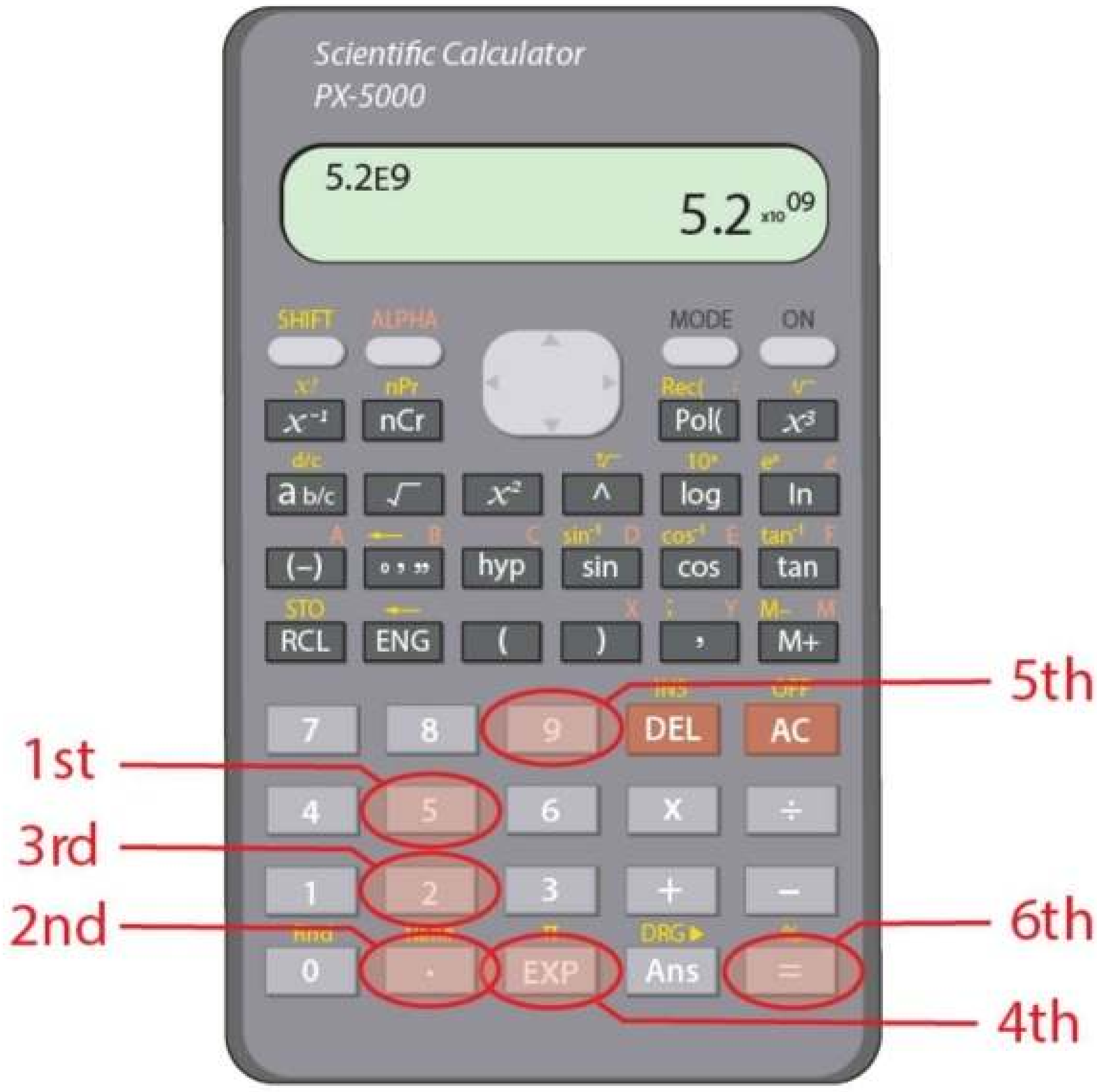


The following table provides some examples of how to express large numbers using scientific notation.

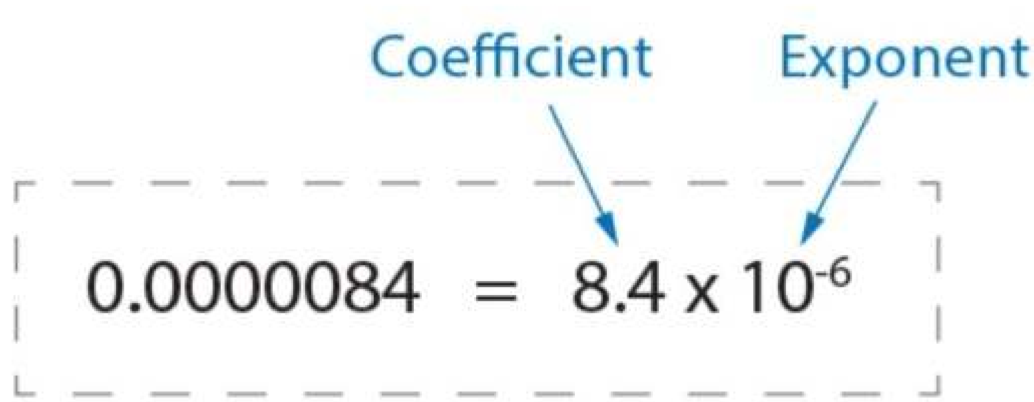
Scientific Notation Examples – Large Numbers	
Original Number	**Scientific Notation**
1,000	1×10^3
33,000	3.3×10^4
5,800,000	5.8×10^6
760,000,000	7.6×10^8

Expressing Very Small Numbers

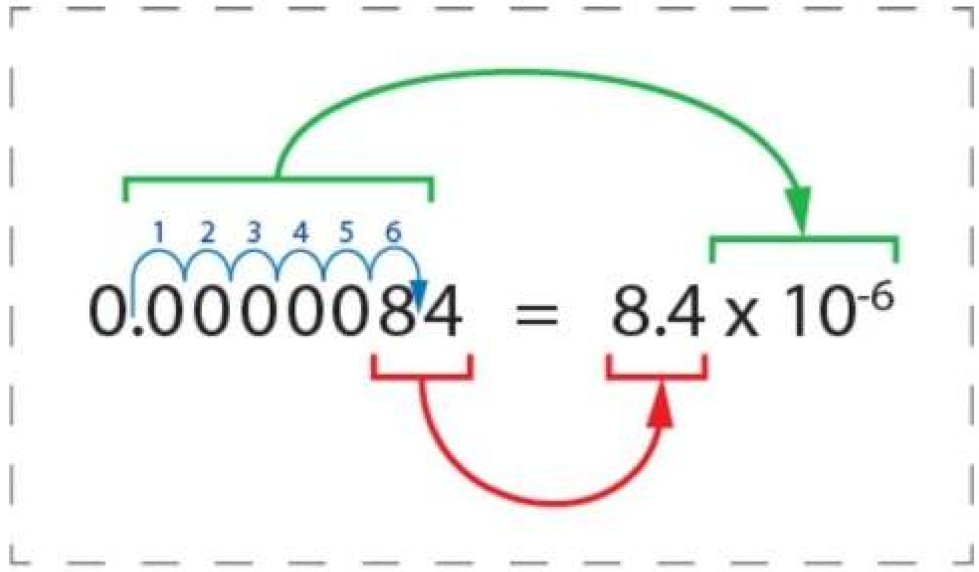
When we express very small numbers using scientific notation:

We move the decimal place of the number to the *right*.

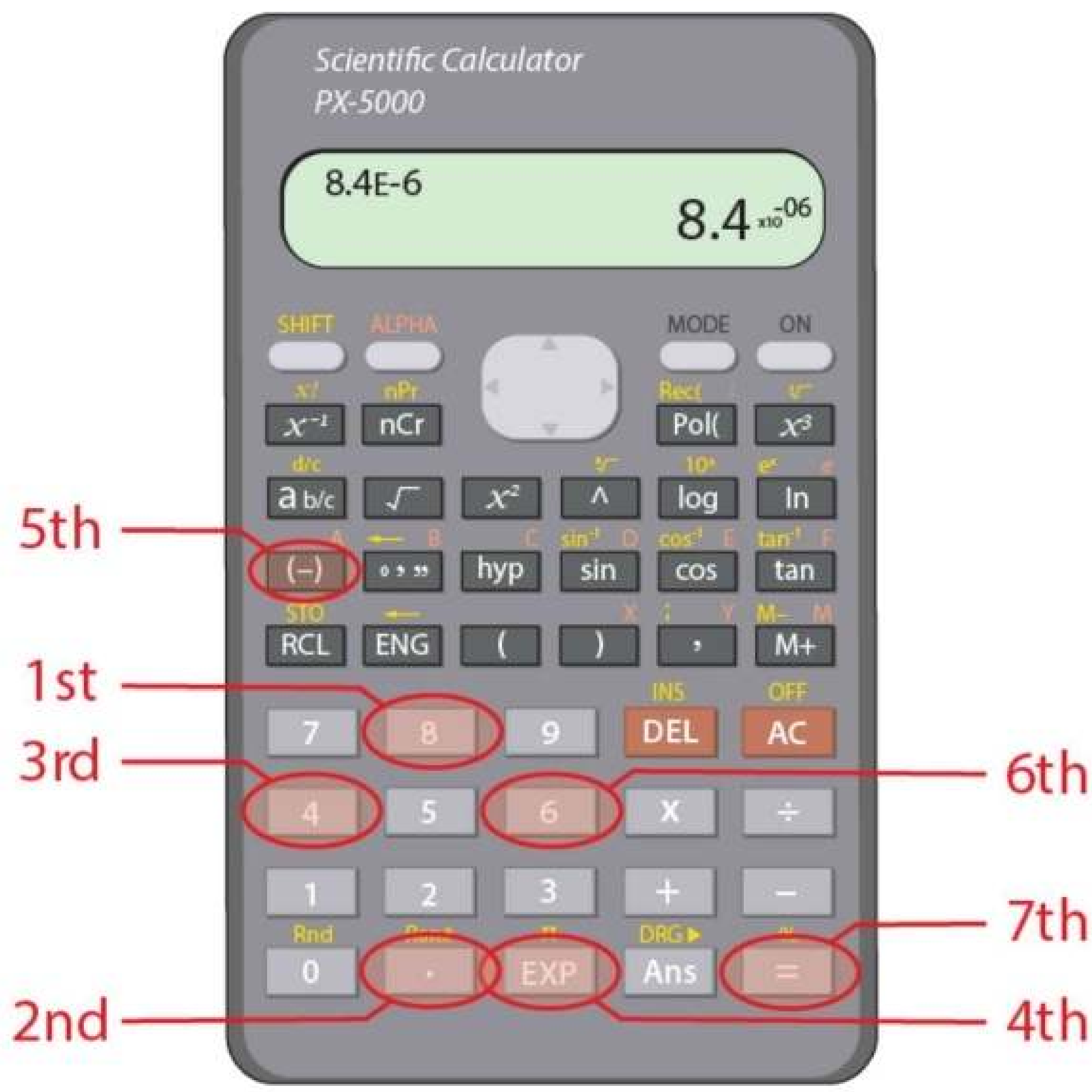
We add in a *negative* exponent (i.e. a multiplication of 10 to a negative power).



As with very large numbers, the exponent indicates the number of spaces that the decimal point has moved.



As with very large numbers, if you enter 0.0000084 into a scientific calculator and press the "=" button, it should automatically express the number as 8.4 x 10^{-6}. You can also enter these types of numbers into a calculator using the "EXP" button:



The following table provides some examples of how very small numbers can be expressed in scientific notation.

Scientific Notation Examples – Small Numbers	
Original Number	**Original Number**
0.03	3 x 10^{-2}
0.000044	4.4 x 10^{-5}
0.00000017	1.7 x 10^{-7}
0.0000000092	9.2 x 10^{-9}

Scientific notation allows us to express very large and very small values in a simpler and more manageable form, by stating them as a number between 1 and 10 that is multiplied by 10 raised to some power.

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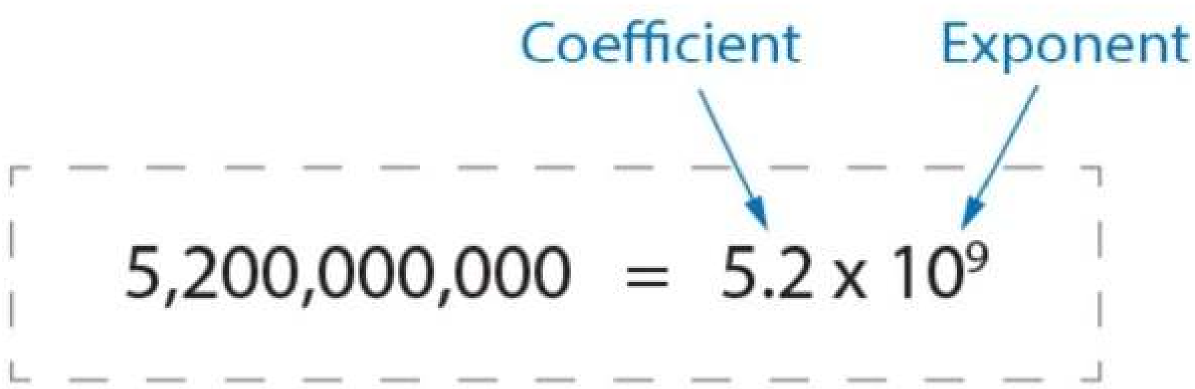
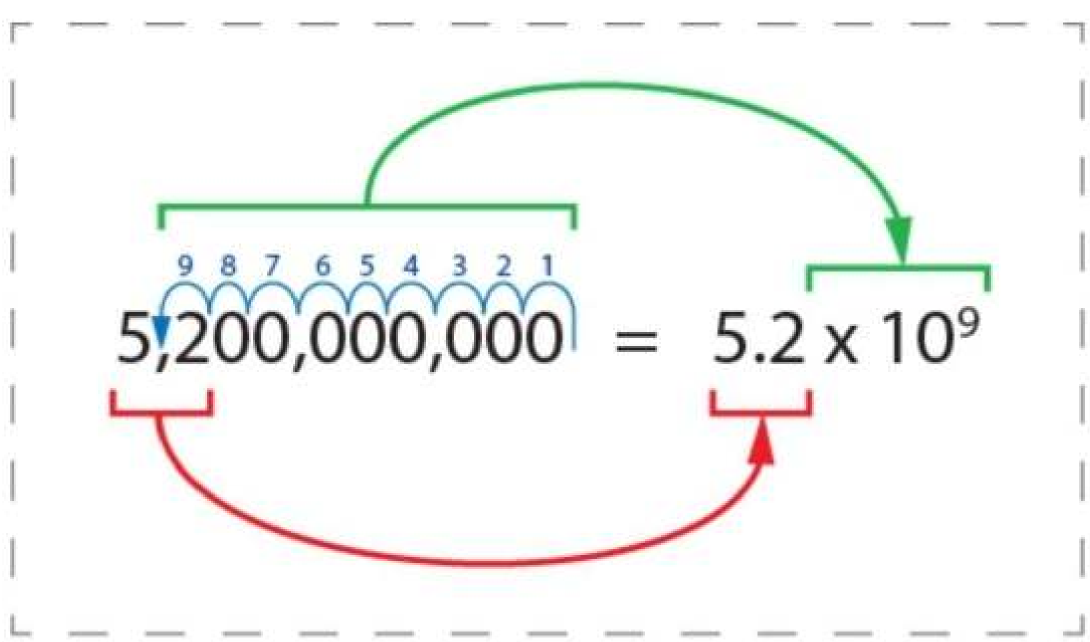


When using scientific notation, the number gets split into a coefficient and an exponent:

The coefficient is the number expressed with fewer digits – making it easier to look at and comprehend. The coefficient should be expressed as a number between 1 and 10.

The exponent tells us how many places the decimal point has been moved.



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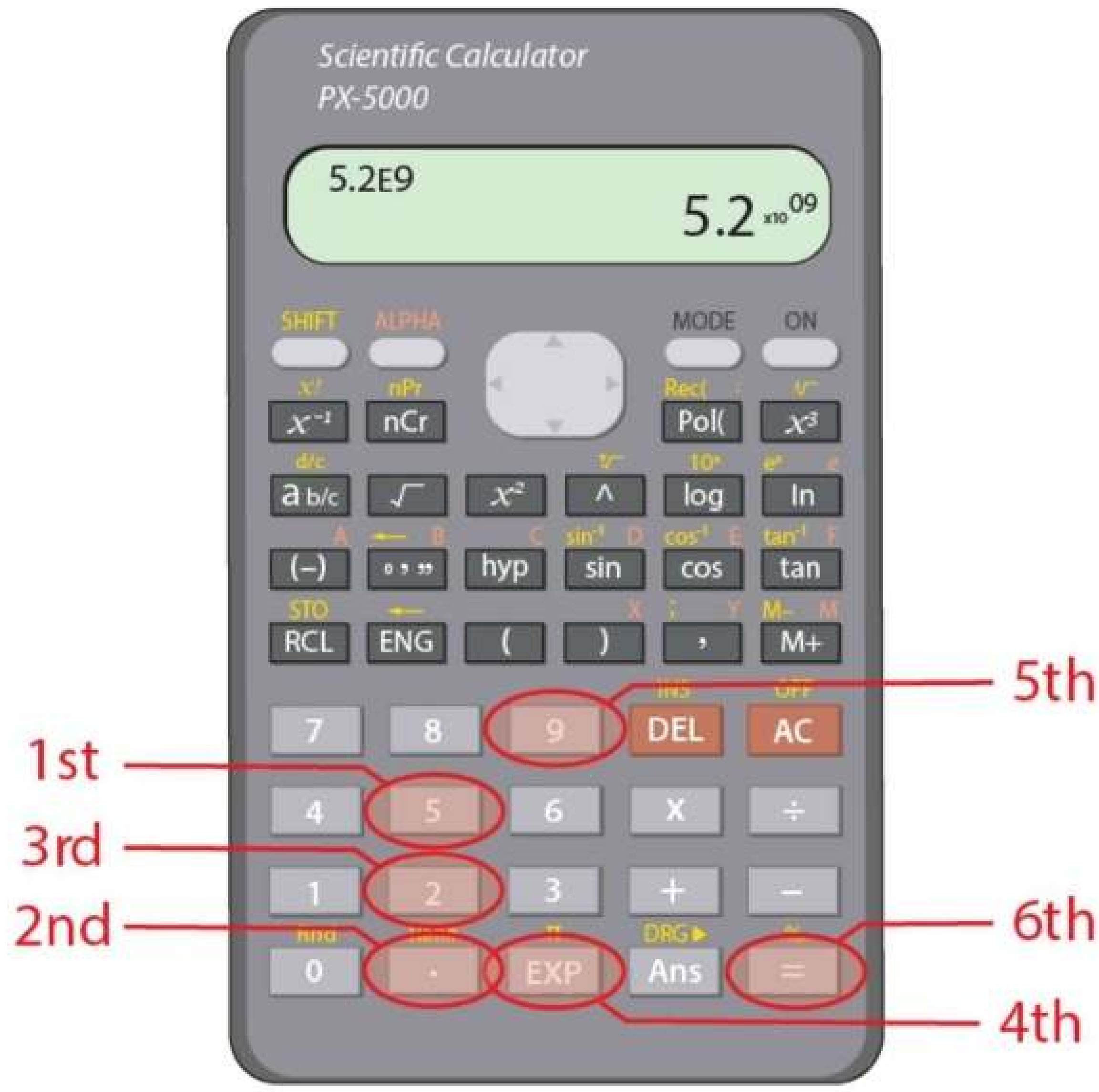

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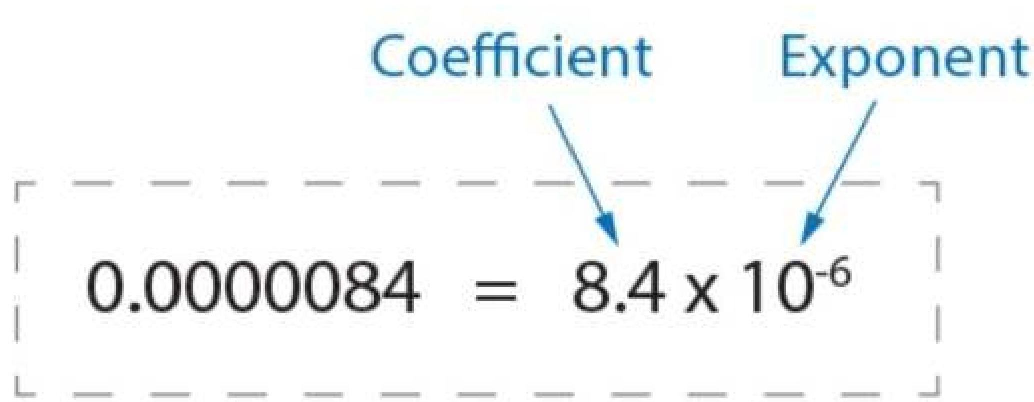

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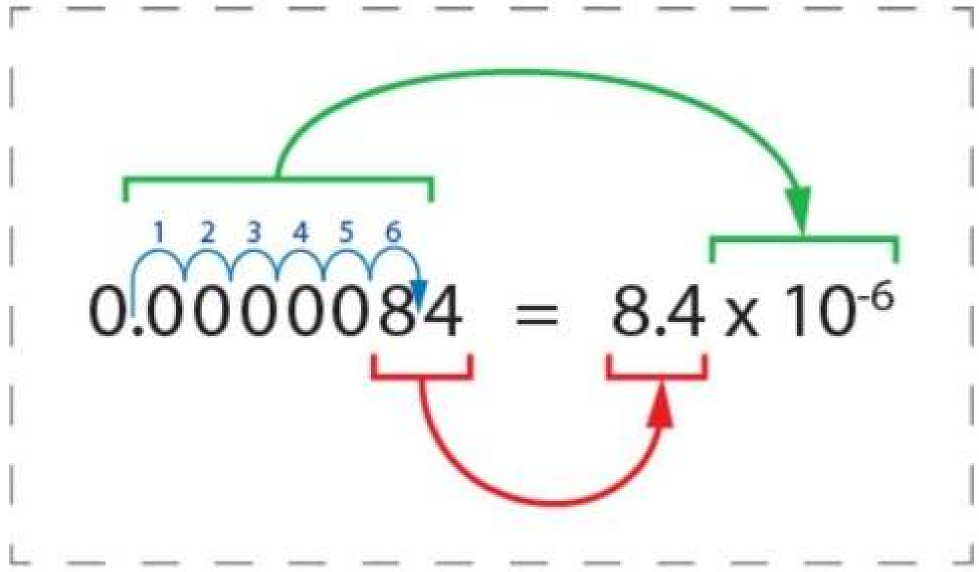

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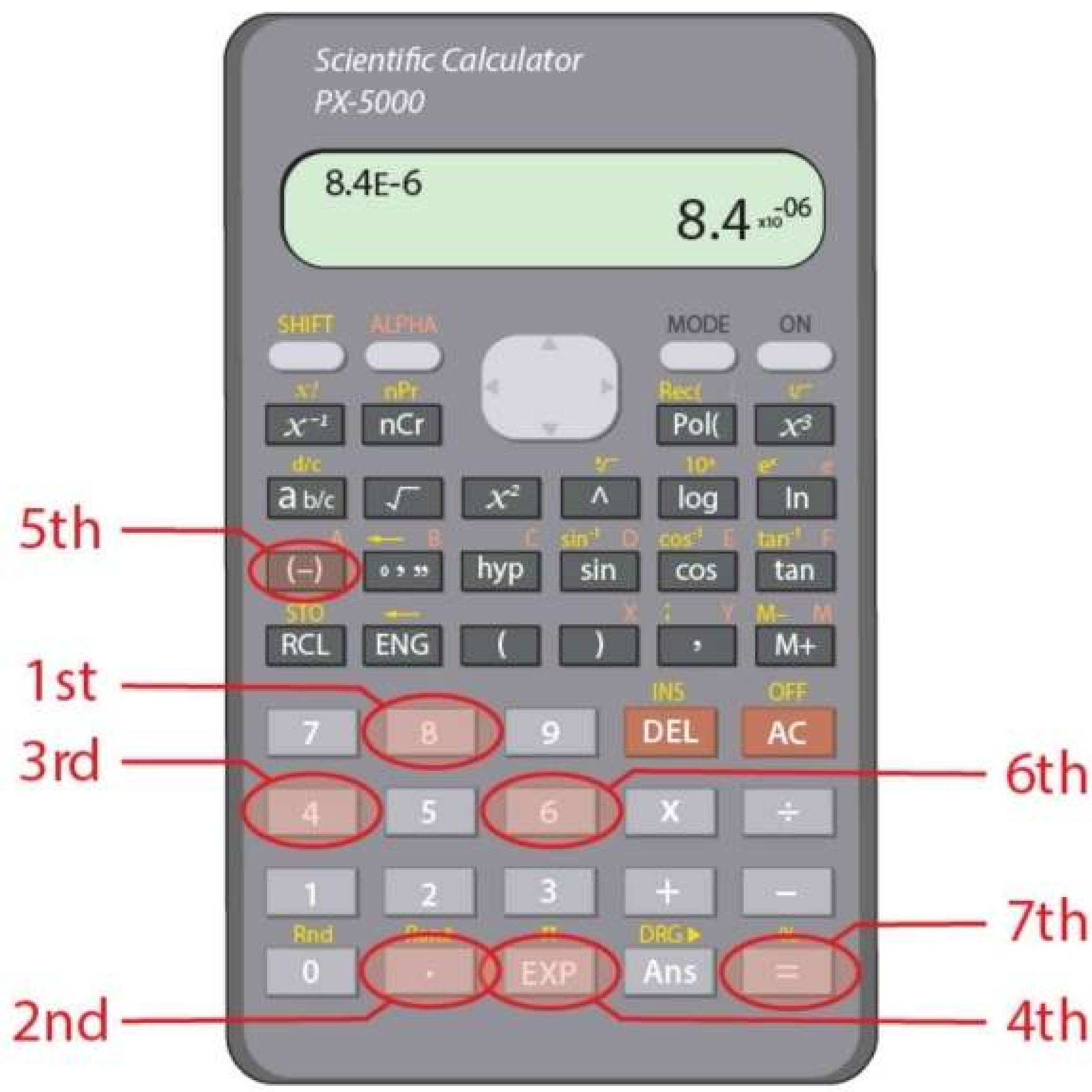

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0.0000000092	9.2×10^{-9}

SI Units

The International System of Units (SI) is a standard metric system for expressing measured quantities. In Australia, SI units are used in the electrotechnology industry to express quantities of voltage, current, resistance, power, as well as many others. For this reason, it is important to understand the SI system of units, including multiples and submultiples.

The following table defines some of the fundamental electrical SI quantities and units.

Common SI Units Used in Electrotechnology		
Quantity	**SI Unit**	**Basic Concept**
Voltage (V)	Volts (V)	Electrical pressure
Current (I)	Amperes (A)	Electrical flow
Resistance (R)	Ohms (Ω)	The opposition to electrical flow
Power (P)	Watts (W)	The rate at which electrical energy is converted into another form of energy, e.g. light, heat etc.

Multiple & Sub-Multiple Units

In order to express very large or very small quantities, a system of multiple and submultiple units is incorporated into the SI system. The following table shows the multiples and submultiples used to represent values. It also includes an example of how they can be applied to representing different values of voltage.

Multiples & Sub-Multiples		
Tera (T)	X 10^{12}	1 TV = 1,000,000,000,000 volts
Giga (G)	X 10^{9}	1 GV = 1,000,000,000 volts
Mega (M)	X 10^{6}	1 MV = 1,000,000 volts
kilo (k)	X 10^{3}	1 kV = 1,000 volts
Base unit	X 10^{0}	1 V = 1 volt
milli (m)	X 10^{-3}	1 mV = 0.001 volts
micro (μ)	X 10^{-6}	1 μV = 0.000001 volts
nano (n)	X 10^{-9}	1 nV = 0.000000001 volts

?

pico (p)	X 10^{-12}	1 pV = 0.000000000001 volts

Converting Multiples and Sub-Multiples

The only real difference between representing a number in the base unit and representing a number in a multiple or submultiple unit is the position of the decimal point. The following diagram illustrates the principle of converting between base and sub-multiple units by moving the decimal place.

Converting Base Units to Sub-Multiple Units	
0.0052 A ↓ 0.005.2 ↓ 5.2 mA	In this example, the decimal place is moved three places to the right in order to convert a quantity of amperes (A) into a quantity of milliamperes (mA). Remember: The *number* representing a given quantity will always be larger when represented using a smaller unit (i.e. 5.2 is larger than 0.0052)

The following diagram illustrates the principle of converting between base and multiple units by moving the decimal place.

Converting Base Units to Multiple Units	
3500 W ↓ 3.500. ↓ 3.5 kW	In this example, the decimal place is moved three places to the left in order to convert a quantity of watts (W) into a quantity of kilowatts (kW). Remember: The *number* representing a given quantity will always be smaller when represented using a larger unit (i.e. 3.5 is smaller than 3500)

Worked Examples 1 – Converting Between Base and Multiple/Sub-Multiple Units

The following examples show how to express base values in multiple and sub-multiple SI units.

a) Express 2,000 Ω in MΩ

The difference between Ω ($x10^0$) and MΩ ($x10^6$) is $x10^6$, therefore the decimal place needs to move six places to the left – remember, if the units get bigger, then the number should get smaller.

This means that 2,000 Ω is equal to 0.002 MΩ

b) Express 2,000 Ω in kΩ

The difference between Ω ($x10^0$) and kΩ ($x10^3$) is $x10^3$, therefore the decimal place needs to move three places to the left.

This means that 2,000 Ω is equal to 2 kΩ.

c) Express 2,000 Ω in mΩ

The difference between Ω ($x10^0$) and mΩ ($x10^{-3}$) is $x10^{-3}$, therefore the decimal place needs to move three places to the right – remember, if the units get smaller, then the number should get bigger.

This means that 2,000 Ω is equal to 2,000,000 mΩ.

d) Express 2,000 Ω in μΩ

The difference between Ω ($x10^0$) and μΩ ($x10^{-6}$) is $x10^{-6}$, therefore the decimal place needs to move six places to the right.

This means that 2,000 Ω is equal to 2,000,000,000 μΩ

Worked Examples 2 – Converting Between Multiple and Sub-Multiple Units

The following examples show how to convert between multiple and sub-multiple SI units.

a) Express 50,000,000 mΩ in MΩ

The difference between mΩ ($x10^{-3}$) and the MΩ ($x10^6$) is $x10^9$ therefore the decimal place needs to move nine places to the left.

This means that 50,000,000 mΩ is equal to 0.05 MΩ

b) Express 0.012 MΩ in μΩ

The difference between MΩ ($x10^6$) and the μΩ ($x10^{-6}$) is $x10^{12}$ therefore the decimal place needs to move twelve places to the right.

This means that 0.012 MΩ is equal to 12,000,000,000 μΩ

Introduction

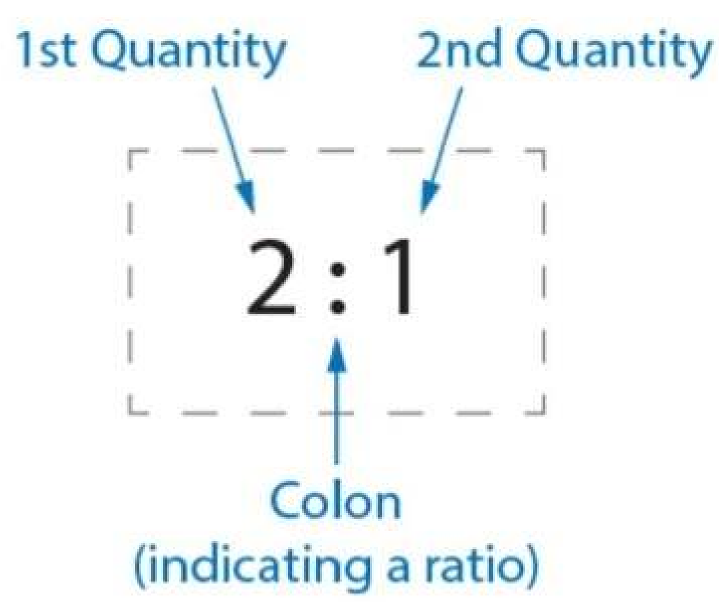
Ratios and proportions are very useful tools for understanding the operation and parameters of electrical circuits. Some basic examples of electrical parameters that behave according to designed ratios include:

- Voltages across circuit components.
- Current flow in branching circuit paths.
- Resistance of cables and conductors.
- Transformer input and output voltages and currents.

There are many more areas where ratios and proportions can be applied to understand and predict the behaviour of electrical equipment. In this topic you will learn about how to work with ratios and proportions to make useful mathematical comparisons.

What is a Ratio?

A ratio is a mathematical way of comparing two or more quantities. A ratio is expressed by stating the quantities separated by a colon, as shown below:



The ratio above is 2 to 1, i.e. there are 2 of one thing for every 1 of the other thing. If we know the value of one quantity, and we know that a ratio exists between it and a second quantity, then we can determine the value of the second quantity. Consider if the ratio of 2:1 above, applied to the number of men and women at a music festival:

?

We can immediately understand a few things about the make-up of people at the festival, such as that there are twice as many men as women, and that there are half as many women as men.

Further to this, if we find out any one of the following facts, then we can apply the ratio to determine the other two unknown facts:

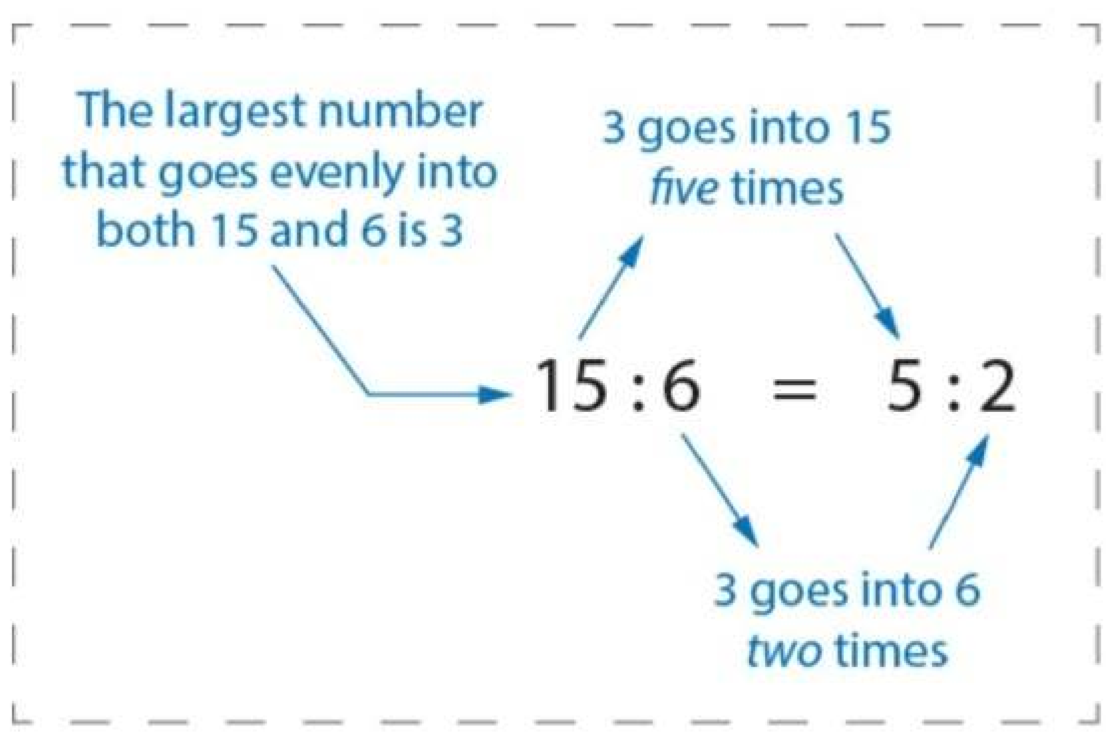
- How many men there are all together.
- How many women there are all together.
- How many people there are all together.

Applying the Ratio		
Scenario	**Known**	**Determining the Unknowns**
Scenario 1	We find out that there are a total of 200 men.	• We know that there are half as many women as men. • 200 ÷ 2 = 100 women. • We now know that there are 200 men and 100 women. • 200 + 100 = 300 people in total.

Scenario 2	We find out that there are a total of 150 women.	• We know that there are twice as many men as women. • 150 x 2 = 300 men at the festival. • We now know that there are 300 men and 150 women. • 300 + 150 = 450 people in total.
Scenario 3	We find out that there are 1,200 people all together	• In this case, to determine the number of men and women we need to divide the total number of people into 3 equal groups – two of these groups will be made up of men, and one group will be made of women, i.e. twice as many men as women. • 1,200 ÷ 3 = 400 people in each group. • Two groups are men, so 400 x 2 = 800 men. • One group is women, so 400 x 1 = 400 women.

Simplifying Ratios

Ratios, like fractions, should always be expressed in their simplest form – that means they should be expressed using the smallest numbers possible. To simplify a ratio, you need to divide the two numbers that make up the ratio by the largest common factor – that is the largest number that will divide evenly into both.



What are Proportions?

Proportions are mathematical statements saying that one fraction or ratio is equal to another fraction or ratio, for example:

$$\frac{1}{10} = \frac{5}{50} \quad \text{or} \quad 1:10 = 5:50$$

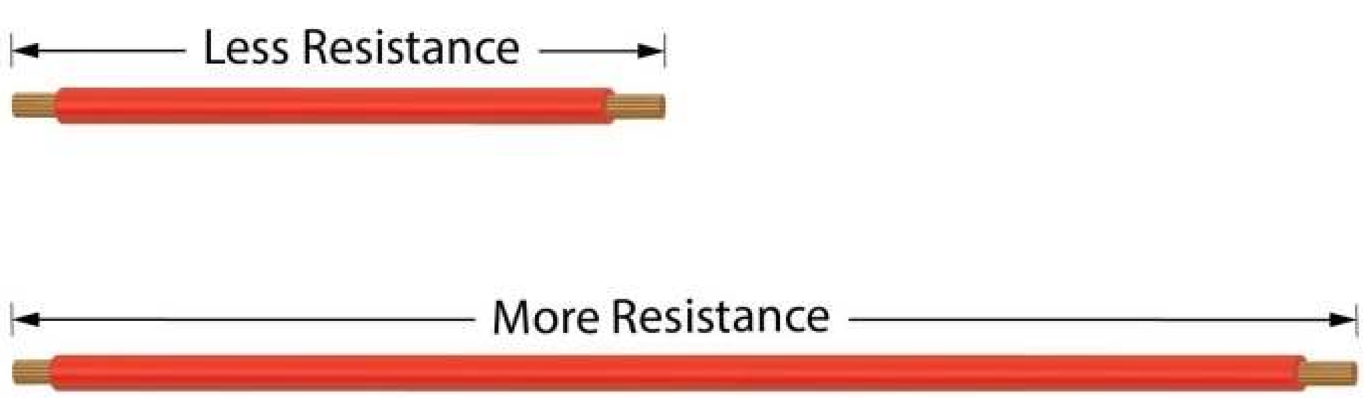
Proportions in Electrotechnology

Proportions are very useful in electrotechnology work, as many electrical characteristics and parameters are 'proportional'. That means that if you change one parameter, a second parameter will also change in a predictable way. Understanding these relationships allows you to understand and predict the behaviour of electricity, which is critical for the safety of yourselves and others.

Example – Conductor Resistance

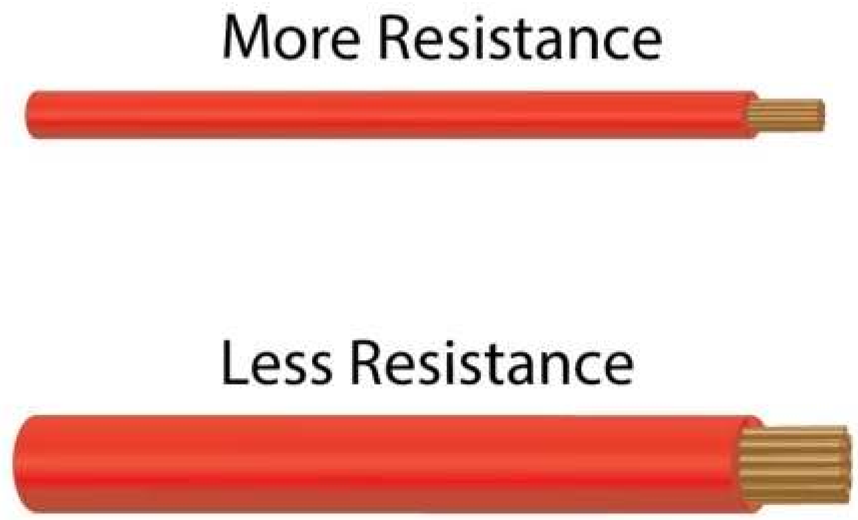
A good example of proportions in electrotechnology is the resistance of electrical wires/conductors. Remember – resistance is the force that *opposes* the flow of electricity in a circuit. The purpose of electrical conductors is to carry electricity from one place to another, so we want as little resistance as possible in our electrical conductors.

It turns out that the resistance of a conductor is *directly proportional* to its length. In fact, for any given conductor, a piece that is exactly twice as long will have exactly twice as much resistance!



Further to this, the resistance of a conductor is *inversely proportional* to its cross-sectional area (i.e. the size of the cable). That means that the bigger the cross-sectional area of a cable, the *less* resistance it has!

?



The implications of this significantly influence the selection and installation of electrical cables, and have very real and important consequences on the safety and functionality of electrical installations.

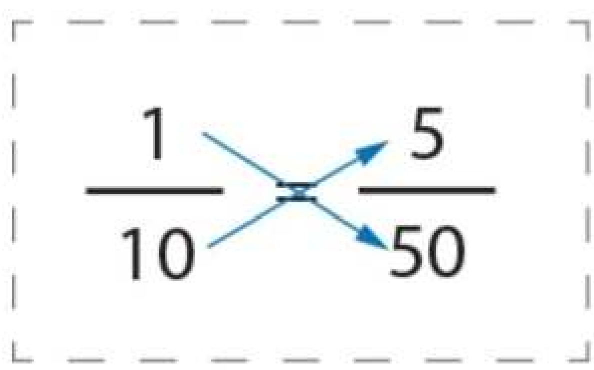
Check your understanding of the content by answering the question below.

1. If a 100 metre length of cable has a resistance of 0.5 ohms, then what would be the resistance of a 50 metre length of the same cable?

(Remember: the resistance of a cable is directly proportional to its length)

Solving Problems with Proportions

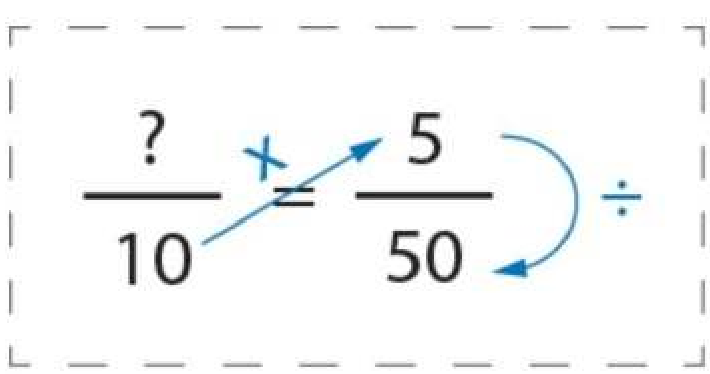
The important rule to remember when using proportions to solve problems is the rule of cross-multiplication, which states that the cross products of a proportion will always be equal, as shown below:



$10 \times 5 = 50$

$1 \times 50 = 50$

This principle can be used to solve problems where one element of a proportion is unknown, for example, if we didn't know the top part of the first fraction:

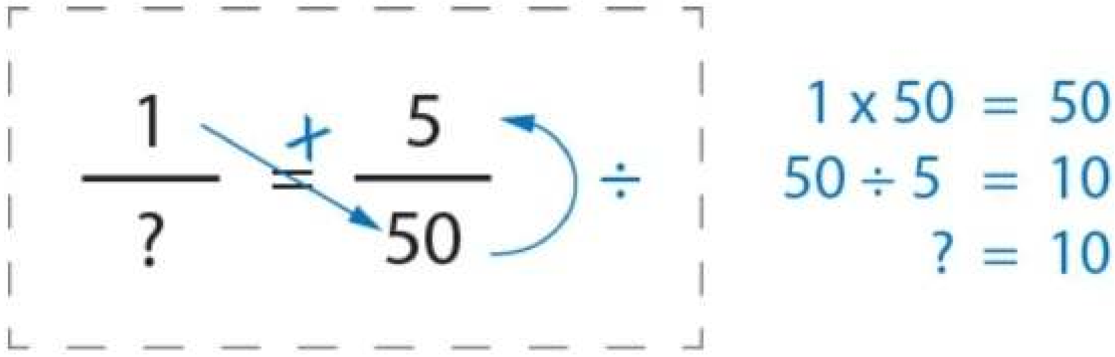


$10 \times 5 = 50$

$50 \div 50 = 1$

$? = 1$

Alternately, if we didn't know the bottom part of the first fraction:



Worked Example 1 – Proportions

Consider the following problem:

$$\frac{?}{7} = \frac{12}{21}$$

1. The first step is to cross-multiply:

$$7 \times 12 = 84$$

2. The second step is to divide:

$$84 \div 21 = 4$$

3. Therefore:

$$\frac{4}{7} = \frac{12}{21}$$

Worked Example 2 – Proportions

Consider the following problem:

$$15 : ? = 60 : 20$$

1. The first step is to cross-multiply:

$$15 \times 20 = 300$$

2. The second step is to divide:

$$300 \div 60 = 5$$

3. Therefore:

$$\frac{15}{5} = \frac{60}{20}$$

Introduction

Electricity behaves according to mathematical principles that we can express as equations. In order to interpret and apply these equations to solve problems, we need to understand the fundamentals of how they are expressed, and the rules and methods for rearranging these expressions so that they tell us what we want to know.

In this topic you will learn the basics of algebraic expressions, and about how to transpose algebraic expressions to solve common problems encountered in the electrotechnology workplace.

Mathematical Statements

An equation is simply a mathematical statement of truth, which states that one thing is equal to another thing. A basic example of this is shown below:

$$5 + 3 = 8$$

You can think of all equations as being split down the middle at the equals sign:

- Whatever is to the left of the equals is the 'left-hand side' of the equation.
- Whatever is to the right of the equals is the 'right-hand side' of the equation.
- For the equation to be true, the left-hand side must exactly equal the right-hand side.

What is Algebra?

Algebra is a way of expressing mathematical equations, in which there are unknown values. To represent an unknown value, a letter is used. For example, if one of the numbers on the left-hand side of the mathematical statement above was unknown, then the algebraic expression could look like this:

Unknown value

$$b + 3 = 8$$

In this case, we can determine that b = 5, as it is only five plus three that equals eight.

In the following example, two of the values are unknown:

$$b + b = 8$$

In this instance, we can determine that the unknown value is 4, as this is the only number that equals 8 when added to itself (4 + 4 = 8). Another way of expressing this same statement is:

$$2 \times b = 8$$

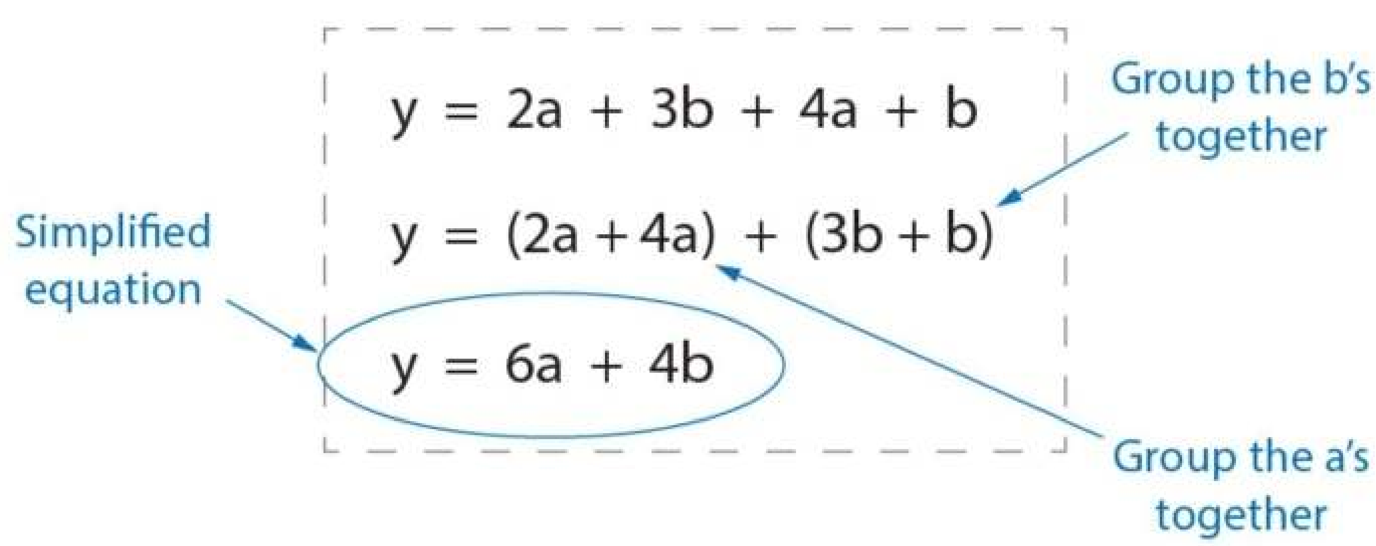
$$2b = 8$$

Note that multiplication signs are usually not shown in algebra:

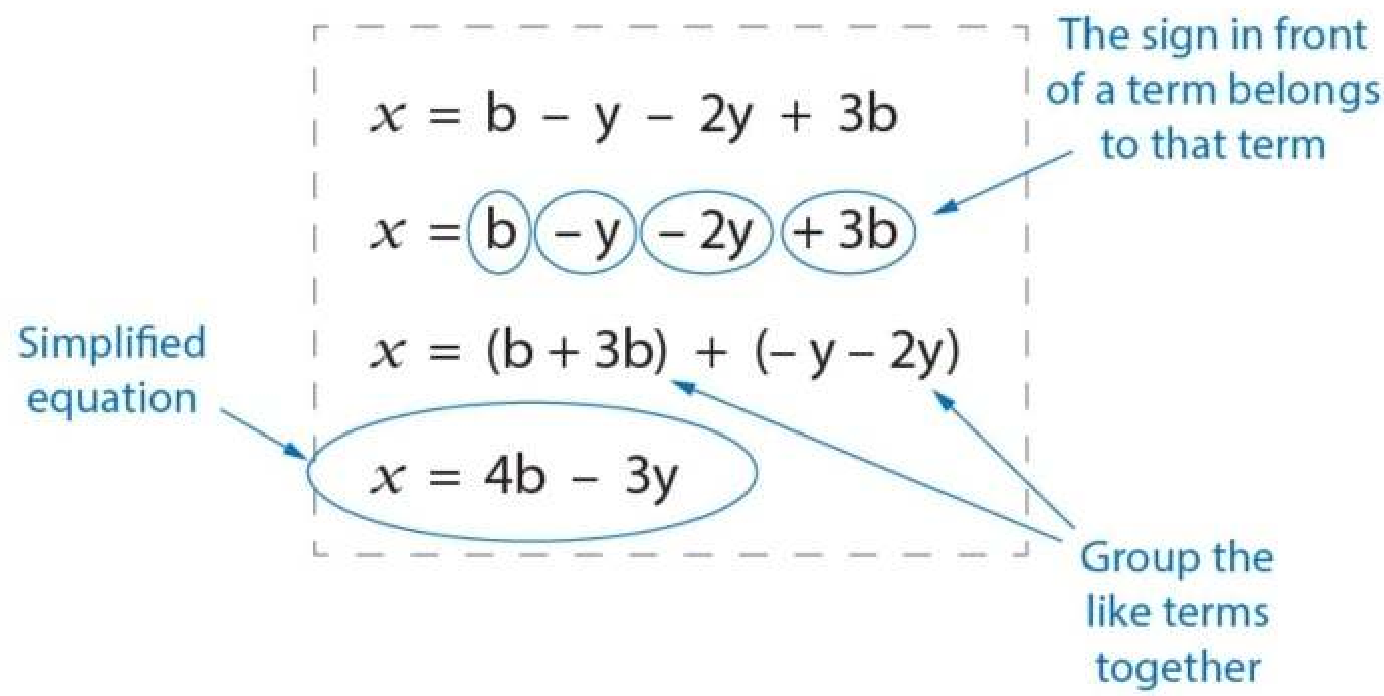
- '2 x b' would be expressed as '2b'
- 'a x b x c' would be expressed as 'abc'

Simplifying Algebraic Equations

When adding and subtracting in algebra, only terms containing the same symbols can be added or subtracted. For example, we can simplify the following algebraic equation by adding the a's together, and adding the b's together:



It's important to remember that the addition or subtraction sign in front of a term belongs to that term, for example:



Check your understanding of the content by answering the following questions.

Simplify the following algebraic expressions:

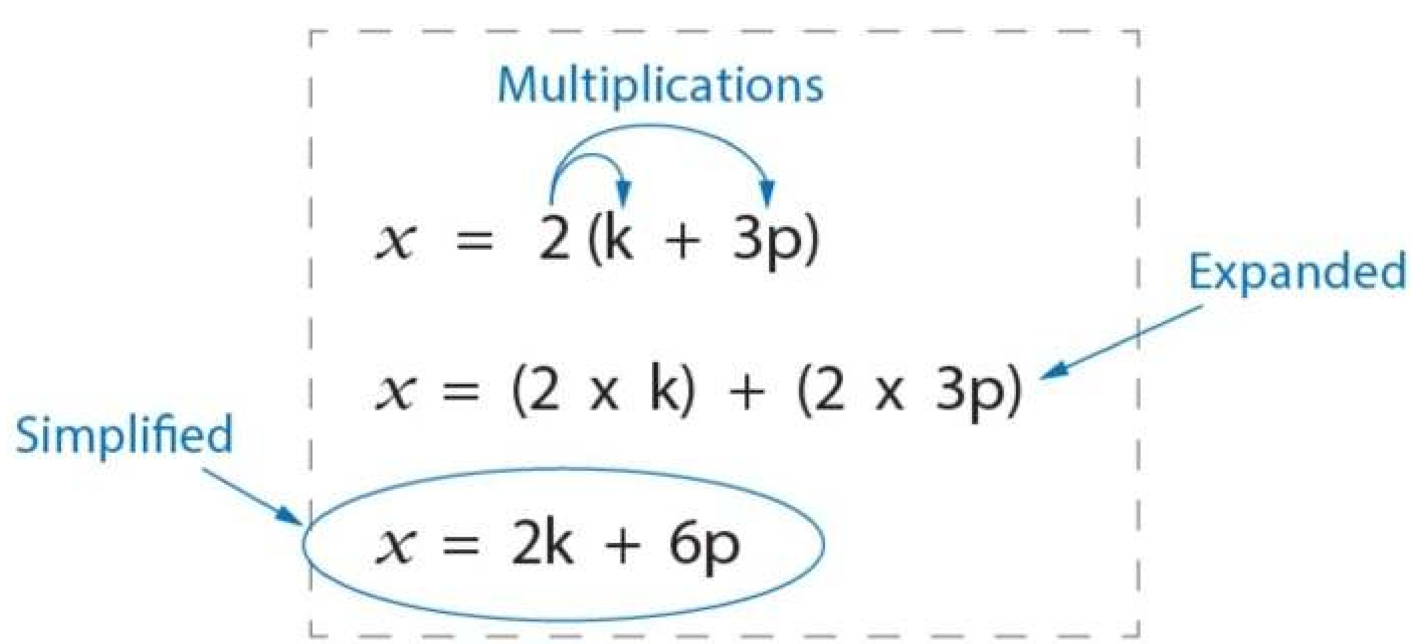
b = 3y + 4y + 5z – 2z

2ab = xy – 3c + 2xy – 5c

(answers at bottom of page)

Expanding Algebraic Equations

Sometimes, in order to simplify equations, it may be necessary to first expand out brackets.



The following example shows how to expand, group and simplify an algebraic equation:

Problem	$x = y(2b - a) + 2b(y + 3a)$
↓ Expand	$x = 2by - ay + 2by + 6ab$
↓ Group	$x = (2by + 2by) - ay + 6ab$
↓ Simplify	$x = 4by - ay + 6ab$

Check your understanding of the content by answering the following questions.

Simplify the following algebraic expressions:

$c = 2(ab - 4ay) + a(5b - 2y)$

$f = d(5e - 5) - e(3d - 2)$

(answers at bottom of page)

Electrotechnology Relationships

In the electrotechnology industry, understanding the relationships between electrical quantities is essential to working safely and effectively. To represent these relationships, algebraic equations are used.

The following equation, known as 'Ohm's Law', shows the relationship between voltage, current and resistance in a circuit:

Ohm's Law		
$$I = \frac{V}{R}$$		
Where:		
I	=	Current in amperes
V	=	Voltage in volts
R	=	Resistance in ohms

This fundamental mathematical relationship is true for all circuits and all situations, and it can teach us some valuable things about how electricity behaves, for example:

- If we increase the voltage applied to a circuit, then the current will also increase.
- If we increase the resistance in a circuit, then the current will decrease.

Applying Equations

If we know any two of the values in Ohm's Law, then we can calculate the third. For example, consider that we want to know how much current will flow if we connect a 6 ohm resistor to a 12 volt battery. To do this, we simply substitute the known values into the equation as shown below:

$$I = \frac{V}{R}$$

$$I = \frac{12 \text{ volts}}{6 \text{ ohms}}$$

$$I = 2 \text{ amperes}$$

Notice that the numbers entered into the equation must be in the correct units – generally this is the base SI units. For example if the resistance was 1.2 kilohms, we would actually use the number 1200 in the equation, as 1.2 kilohms is 1200 ohms.

Check your understanding of the content by answering the following questions.

How much current will flow if we connect a 24 ohm resistor to a 12 volt battery?

How much current will flow if we connect a 10 ohm resistor to a 48 volt battery?

Answers to Check your progress questions.

Simplify the following algebraic expressions:

b = 3y + 4y + 5z – 2z

Answer: b = 7y + 3z

2ab = xy – 3c + 2xy – 5c

Answer: 2ab = 3xy – 8c

c = 2(ab – 4ay) + a(5b – 2y)

Answer:

c = 2ab – 8ay + 5ab – 2ay

c = (2ab + 5ab) + (– 8ay – 2ay)

c = 7ab – 10ay

f = d(5e – 5) – e(3d – 2)

Answer:

f = 5de – 5d – 3de + 2e

**note that -e times -2 = +2e*

f = (5de – 3de) + 2e – 5d

f = 2de + 2e – 5d

How much current will flow if we connect a 24 ohm resistor to a 12 volt battery? *Answer: 12 / 24 = 0.5 amperes (or 500 milliamperes)*

How much current will flow if we connect a 10 ohm resistor to a 48 volt battery? *Answer: 48 / 10 = 4.8 amperes*

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What is Transposition?

Transposition is the act of rearranging an equation so that it tells us what we want to know. Consider Ohm's Law as an example:

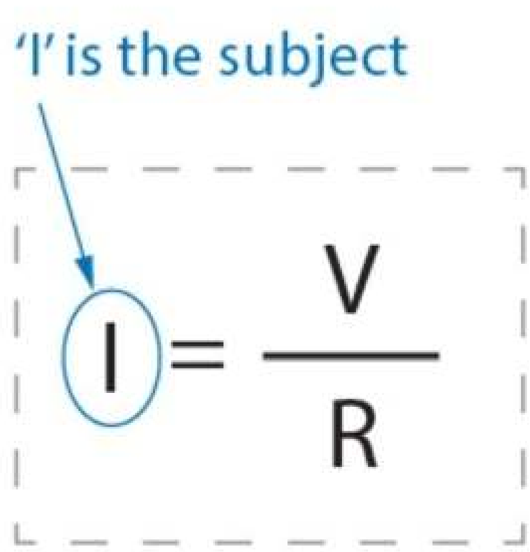
Ohm's Law

$$I = \frac{V}{R}$$

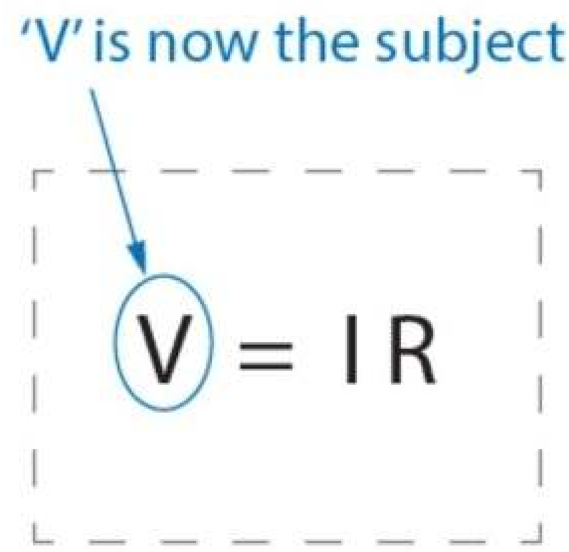
Where:

I	=	Current in amperes
V	=	Voltage in volts
R	=	Resistance in ohms

The arrangement of Ohm's Law shown above tells us what the current equals. In this arrangement, we say that the current (I) is the *subject* of the equation, because "I = something".



Although, what if we know what the current is, and what we actually want is to find out what the voltage is? To do this we need to rearrange (i.e. *transpose*) the equation, so that the voltage (V) becomes the subject, i.e. it says "V = something". When transposed so that 'V' is the subject, Ohm's Law looks like this:

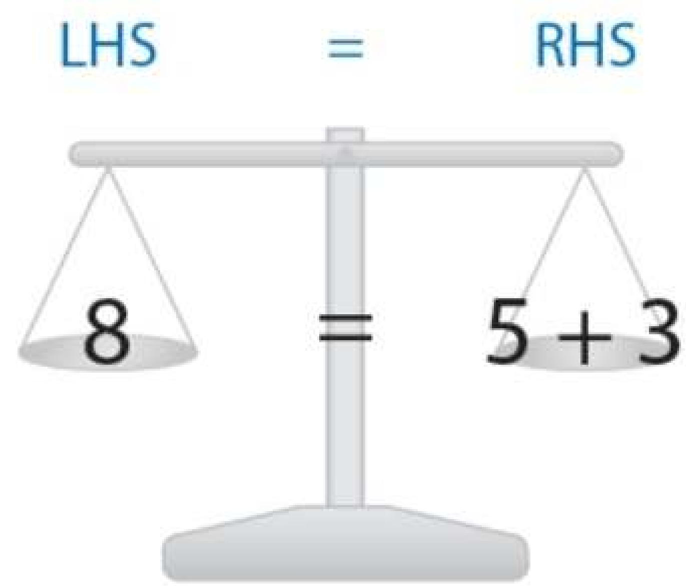


We will re-visit how we got to this answer further down the page. To understand the process, you must first learn about the fundamental mathematical rules for transposition. If these rules are not followed, the equation will not remain true, and will return incorrect answers when applied to a problem.

Maintaining Balance

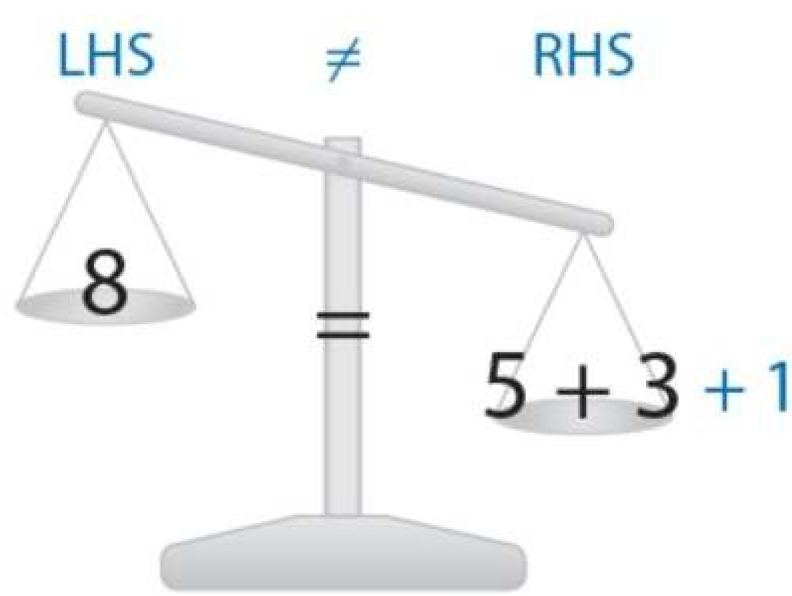
The most fundamental rule of transposition is that for the equation to remain true, it must remain balanced. This means that if you do something to one side, then you must do the exact same thing to the other side.

Consider the following equation:



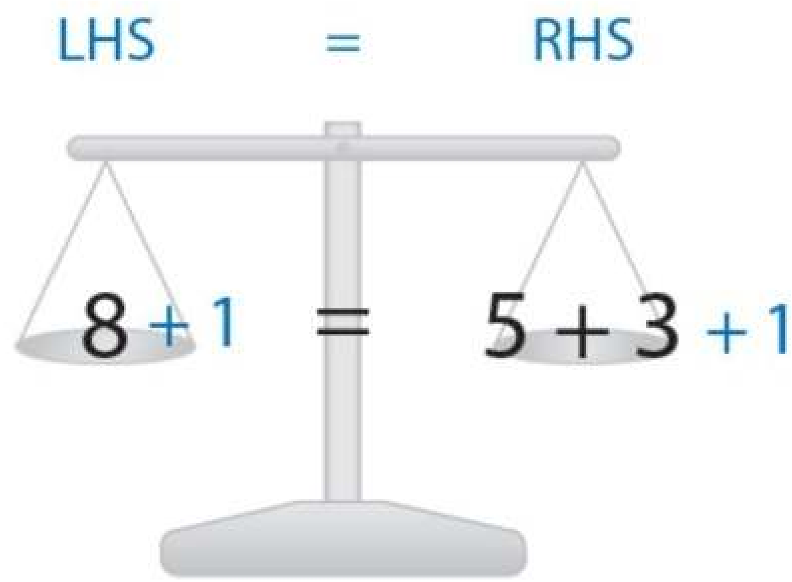
In this arrangement, the left-hand side (LHS) and the right-hand side (RHS) are both equal to 8.

If we add 1 to the RHS, then the equation becomes unbalanced, and is therefore no longer true, as shown below:



Now the LHS equals 8 but the RHS equals 9.

However, if we add 1 to *both* sides, then the equation remains balanced:



Now both sides equal 9. Note that it doesn't matter that the absolute value of each side has changed from 8 to 9, it only matters that both sides remain equal to one another.

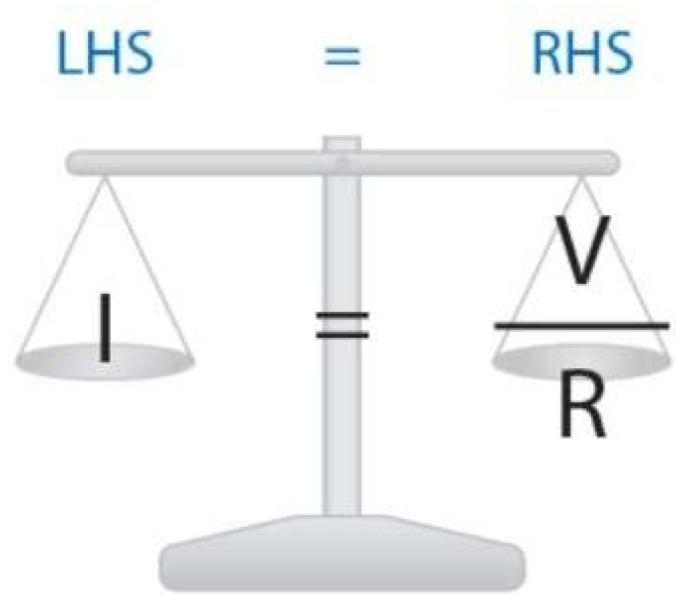
Rules of Transposition

The fundamental rule for transposition essentially states that an equation will remain balanced if:

- The same value is added to both sides.
- The same value is subtracted from both sides.
- The same value is multiplied to both sides.
- The same value is divided into both sides.
- Both sides are squared.
- Both sides are square rooted.

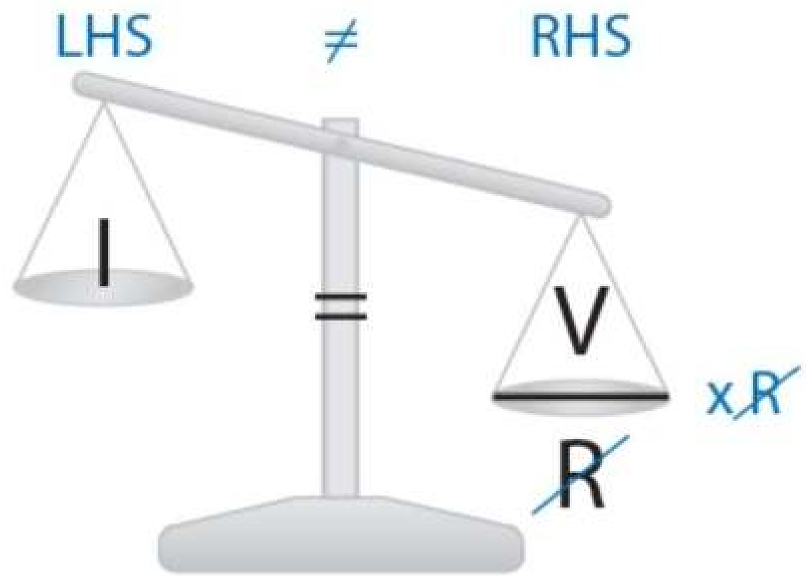
Transposition of Ohm's Law

So now that you understand the rules of how to keep an equation balanced, we can return to the transposition of Ohm's Law.

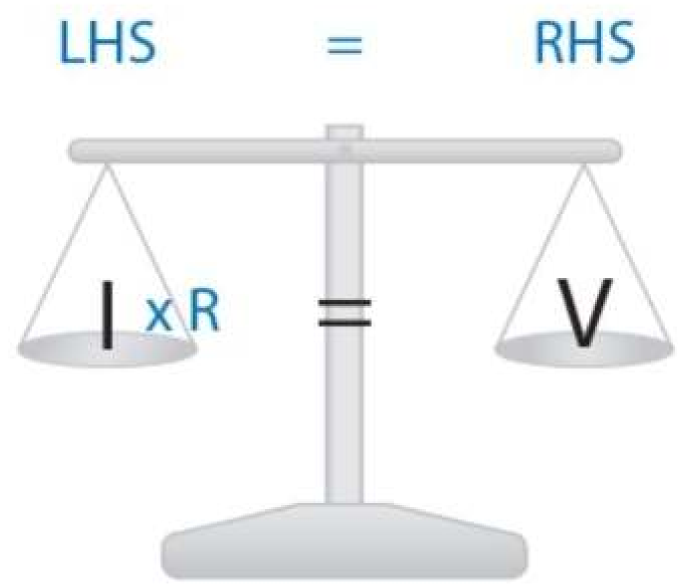


In order to make voltage (V) the subject, we need to get V all by itself. In this case, this means removing R from the RHS of the equation.

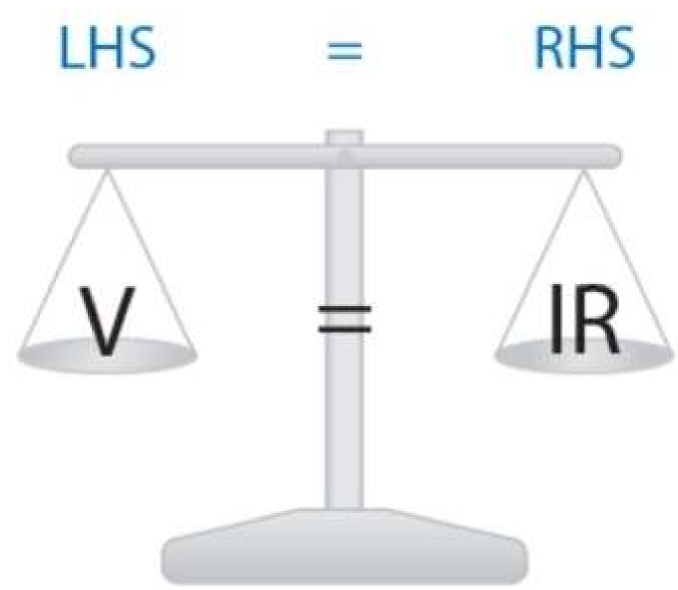
The first step is to look at what the R is 'doing' – in this case, it's dividing into V. So if we *multiply* by R, then this will effectively cancel out the effect of the division by R, as shown below:



Now **because we multiplied the RHS by R, we must also multiply the LHS by R,** to keep the equation balanced and true. So we end up with:



Finally, it is convention to express equations with the subject on the left, which gives us the following:



or

$$V = IR$$

We will examine these methods for transposing various different equations in more depth in the next subtopic.

Check your understanding of the content by answering the following question.

Try transposing 'V = IR' so that resistance (R) becomes the subject of the equation.

Removing Additions

If a value is being added to one side of an equation, it can be removed by *subtracting* it from both sides.

Worked Examples – Removing Subtractions

1. Make 6 the subject of the following equation:

   9 = 6 + 3

   If we subtract 3 from both sides, this will cancel out the (+ 3) from the RHS, leaving the 6 by itself as the subject of the equation.

   9 (– 3) = 6 + 3 (– 3)

   9 – 3 = 6

   6 = 9 – 3

2. Make 'h' the subject of the following equation:

   f = g + h

   If we subtract 'g' from both sides, this will cancel out the (+ g) from the RHS, leaving the 'h' by itself as the subject of the equation.

   f (– g) = g (– g) + h

   f – g = h

   h = f – g

Check your understanding of the content by answering the following question.

Make 'k' the subject of the following equation:

b = y + k + t

?

Removing Subtractions

If a value is being subtracted from one side of an equation, it can be removed by *adding* it to each side.

Worked Examples – Removing Subtractions

1. Make 10 the subject of the following equation:

$$2 = 10 - 8$$

If we add 8 to both sides, this will cancel out the (– 8) from the RHS, leaving the 10 by itself as the subject of the equation.

$$2\ (+\ 8) = 10 - 8\ (+\ 8)$$

$$2 + 8 = 10$$

$$10 = 2 + 8$$

2. Make 'b' the subject of the following equation:

$$\mathbf{a = b - c}$$

If we add 'c' to both sides, this will cancel out the (– c) from the RHS, leaving 'b' by itself as the subject of the equation.

$$\mathbf{a\ (+\ c) = b - c\ (+\ c)}$$

$$\mathbf{a + c = b}$$

$$\mathbf{b = a + c}$$

3. Make 'b' the subject of the following equation:

$$\mathbf{a = c - b}$$

The first thing we need to notice about this equation is that the 'b' is a (– b), and we need to make 'b' the subject, not (– b). To make 'b' positive, we simply add 'b' to both sides.

$$\mathbf{a\ (+\ b) = c - b\ (+\ b)}$$

$$\mathbf{a + b = c}$$

We then need to subtract 'a' from both sides to get 'b' by itself on the LHS.

$$\mathbf{a\ (-\ a) + b = c\ (-\ a)}$$

$$\mathbf{b = c - a}$$

Check your understanding of the content by answering the following questions.

Make ‘y’ the subject of the following equation:

t = y – b

Make ‘c’ the subject of the following equation:

a = b – c + d

(answers at bottom of page)

Removing Multiplications

If a value is being multiplied on one side of an equation, it can be removed by *dividing* each side of the equation by that same value.

Worked Examples – Removing Multiplications

1. Make 5 the subject of the following equation:

15 = 5 x 3

If we divide both sides by 3, this will cancel out the (x 3) from the RHS, leaving the 5 by itself as the subject of the equation.

15 (÷ 3) = 5 x 3 (÷ 3)

15 ÷ 3 = 5

5 = 15 ÷ 3

2. Make ‘z’ the subject of the following equation:

k = xyz

If we divide both sides by ‘xy’, this will cancel ‘xy’ from the RHS, leaving ‘z’ by itself as the subject of the equation.

$$k\,(\div\ xy) = xyz\,(\div\ xy)$$

$$\frac{k}{xy} = z$$

$$z = \frac{k}{xy}$$

Check your understanding of the content by answering the following questions.

Make ‘m’ the subject of the following equation:

F = ma

Make ‘b’ the subject of the following equation:

a = 5yb

(answers at bottom of page)

Removing Divisions

If a value is being divided into one side of an equation, it can be removed by *multiplying* that same value to each side.

Worked Examples – Removing Divisions

1. Make 20 the subject of the following equation:

5 = 20 ÷ 4

If we multiply both sides by 4, this will cancel out the (÷ 4) from the RHS, leaving the 20 by itself as the subject of the equation.

5 (x 4) = 20 ÷ 4 (x 4)

5 x 4 = 20

20 = 5 x 4

2. Make 'T' the subject of the following equation:

b = T ÷ dg

If we multiply both sides by 'dg', this will cancel out the (÷ dg) from the RHS, leaving the T by itself as the subject of the equation.

b (x dg) = T ÷ dg (x dg)

bdg = T

T = bdg

3. Make 'y' the subject of the following equation:

$$a = \frac{yr}{p}$$

The first step is to multiply by 'p', as this will remove the fraction from the equation.

$$a\,(\times p) = \frac{yr}{p}(\times p)$$

$$ap = yr$$

We can now divide both sides by 'r' to leave the 'y' by itself as the subject of the equation.

$$ap\,(\div r) = yr\,(\div r)$$

$$ap \div r = y$$

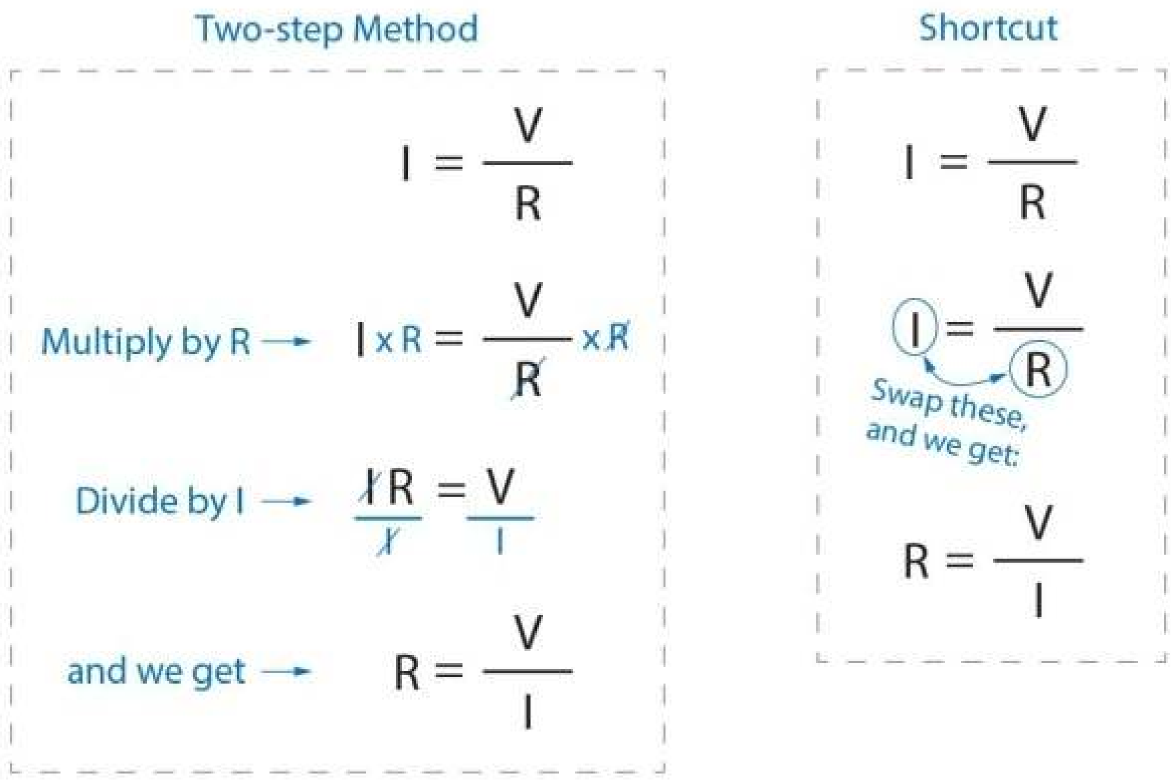
$$y = ap \div r$$

or

$$y = \frac{ap}{r}$$

Tips for Working with Fractions

Notice the short cut that can be employed when transposing equations with fractions.



Removing Squares

If a value is being squared on one side of an equation, the square can be removed by *square rooting* each side. Remember that when you perform an action to a side of an equation, you must perform that action to the *entire* side, not just part of it.

Worked Examples – Removing Squares

1. Make 3 the subject of the following equation:

$$10 = (3)^2 + 1$$

The first step is to subtract the 1 from each side.

$$10\ (-1) = (3)^2 + 1\ (-1)$$

$$10 - 1 = (3)^2$$

The next step is to square root each side, as this will remove the square from the 3.

$$\sqrt{10-1} = \sqrt{(3)^2}$$

$$\sqrt{10-1} = 3$$

$$3 = \sqrt{10-1}$$

2. Make 'e' the subject of the following equation:

$$d = \frac{e^2 - g}{f^2}$$

The first step is to multiply by 'f^2', as this will remove the fraction.

$$d\,(\times f^2) = \frac{e^2 - g}{f^2}\,(\times f^2)$$

$$df^2 = e^2 - g$$

The next step is to add 'g' to each side.

$$df^2(+g) = e^2 - g\,(+g)$$

$$df^2 + g = e^2$$

The final step is to remove the square by square rooting each side.

$$\sqrt{df^2 + g} = \sqrt{e^2}$$

$$\sqrt{df^2 + g} = e$$

$$e = \sqrt{df^2 + g}$$

Check your understanding of the content by answering the following question.

Make ‘k’ the subject of the following equation:

ab=kt/mz

(answer at bottom of page)

Removing Square Roots

If a value is being square rooted on one side of an equation, the square root can be removed by *squaring* each side.

Worked Examples – Removing Square Roots

1. Make 16 the subject of the following equation:

$$8 = \sqrt{16} + 4$$

The first step is to subtract 4 from each side.

$$8\,(-4) = \sqrt{16} + 4\,(-4)$$
$$8 - 4 = \sqrt{16}$$

The next step is to square each side to remove the square root over the 16. Remember that you must square the entirety of each side.

$$(8-4)^2 = (\sqrt{16})^2$$
$$(8-4)^2 = 16$$
$$16 = (8-4)^2$$

2. Make 'R' the subject of the following equation:

$$Z = \sqrt{R^2 + X^2}$$

The first step is to square both sides, as this will remove the square root from the RHS.

$$(Z)^2 = (\sqrt{R^2 + X^2})^2$$
$$Z^2 = R^2 + X^2$$

The next step is to subtract 'X^2', as this will leave the 'R^2' by itself.

$$Z^2(-X^2) = R^2 + X^2(-X^2)$$
$$Z^2 - X^2 = R^2$$

The final step is to square root each side to remove the square from the 'R^2'.

$$\sqrt{Z^2 - X^2} = \sqrt{R^2}$$
$$\sqrt{Z^2 - X^2} = R$$
$$R = \sqrt{Z^2 - X^2}$$

Order of Transposition

When considering what action to take first, second, third etc. when transposing equations, it's important to remember the following fundamental principle:

When you perform an action on a side of an equation, you must perform the action on the ***entirety*** *of that side.*

This means you need to see what actions are being performed to the *entire side*, and address those first. Generally this means that you 'work your way in from the outside'.

Consider the following example, in which we wish to make 'a' the subject – note how at each step, only that element that is affecting the *entire* RHS of the equation is addressed.

Order of Transposition – Make 'a' the Subject	
Entire side is being divided by $(d - c^2)$ $x = \dfrac{\sqrt{a^2b + y}}{d - c^2}$	Step 1 Multiply both sides by $(d - c^2)$
Entire side is being square rooted $x\,(d - c^2) = \sqrt{a^2b + y}$	Step 2 Square both sides
Entire side is having 'y' added $(x\,(d - c^2))^2 = a^2b + y$	Step 3 Subtract 'y' from both sides
Entire side is being multiplied by 'b' $(x\,(d - c^2))^2 - y = a^2b$	Step 4 Divide both sides by 'b'
Entire side is being squared $\dfrac{(x\,(d - c^2))^2 - y}{b} = a^2$	Step 5 Square root both sides

$$a = \sqrt{\frac{(x\,(d - c^2))^2 - y}{b}}$$	Step 6 Express with the subject on the LHS

Check your progress answers.

Make 'k' the subject of the following equation:

$b = y + k + t$

Answer: $k = b - y - t$

Make 'y' the subject of the following equation:

$t = y - b$

Answer: $y = t + b$

Make 'c' the subject of the following equation:

$a = b - c + d$

Answer: $c = b + d - a$

Make ‘m’ the subject of the following equation:

$F = ma$

Answer: $m = F/a$

Make ‘b’ the subject of the following equation:

$a = 5yb$

Answer: $b = a/5y$

Make ‘k’ the subject of the following equation:

$ab = kt/mz$

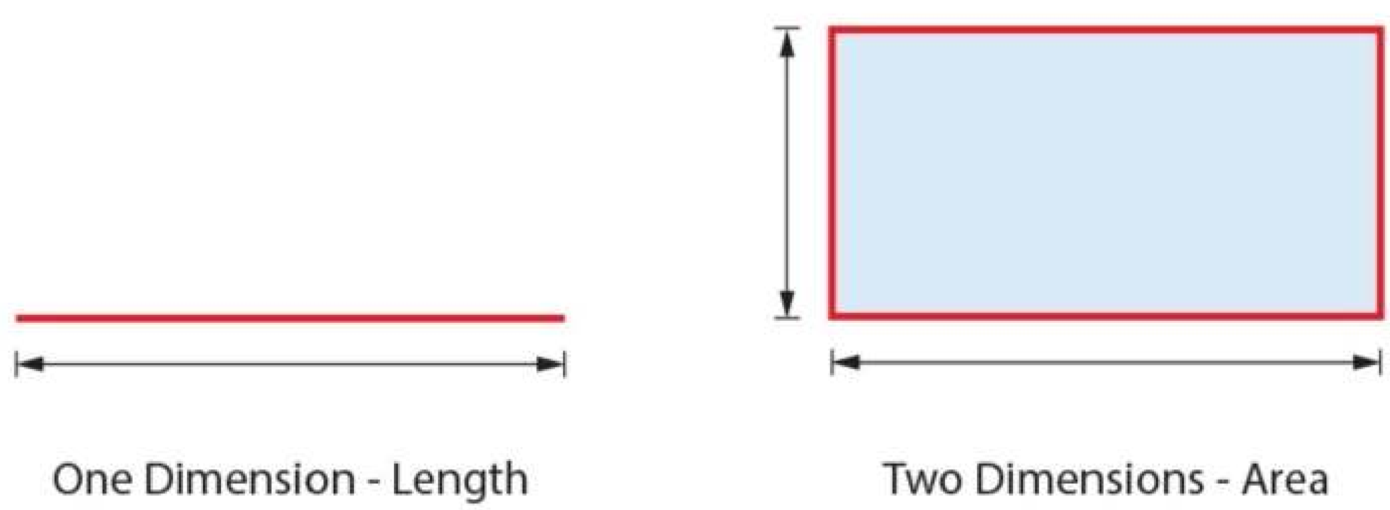
Answer: $k = (abmz)/t$

Introduction

Spatial awareness is important when measuring, marking up and installing electrical equipment. In this topic you will learn how to calculate the area and volume of various shapes used in the electrotechnology work environment.

What is Area?

Length, width and height are a measure of one spatial dimension, i.e. they are one dimensional measurements. 'Area' is a measurement of a two dimensional space or region, e.g. length by width, or width by height.



Application in Electrotechnology Work

There are all sorts of reasons that we might need to measure or calculate area whilst performing electrotechnology tasks, for example:

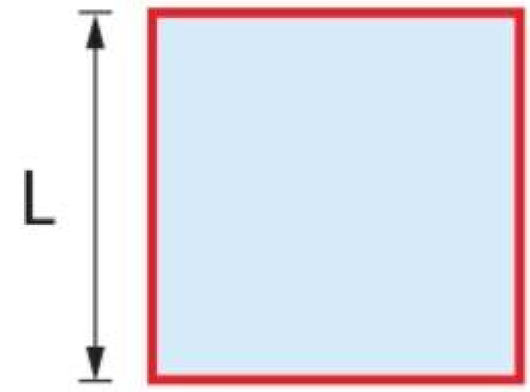
- To allow for adequate clearances around equipment, as required by the manufacturer and/or wiring regulations, e.g. around switchboards.
- To help with selecting equipment to achieve the required outcome, e.g. number and type of light fittings needed.
- To determine appropriate positioning for equipment, e.g. positions of light fittings to achieve the desired lighting effect.

Area can be determined by taking measurements and then entering the required dimensions into an equation. The basic principle of determining area is the same however there are a few variations between the equations needed for different *shaped* areas.

Area of a Square

The following diagram shows a red square, with the area of the square shaded blue:

?

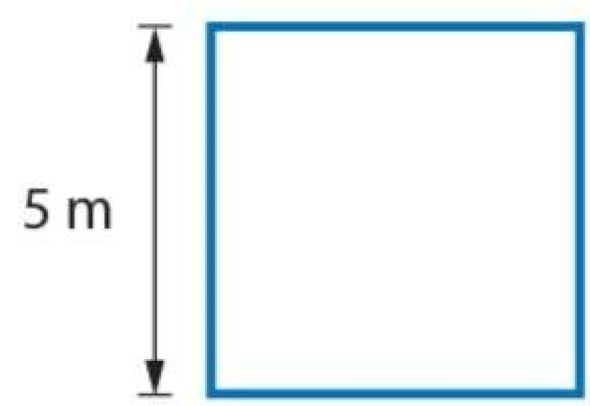


The diagram only shows a dimension on one side of the square – this is because all sides of a square are equal. The following equation can be used to determine the area of a square:

Area of a Square
$$A = L^2$$ Where: A = Area in square metres (m^2); L = Length of side in metres (m)

Worked Example – Area of a Square

Determine the area of the following square:



$$A = 5^2$$

$$A = 25\ m^2$$

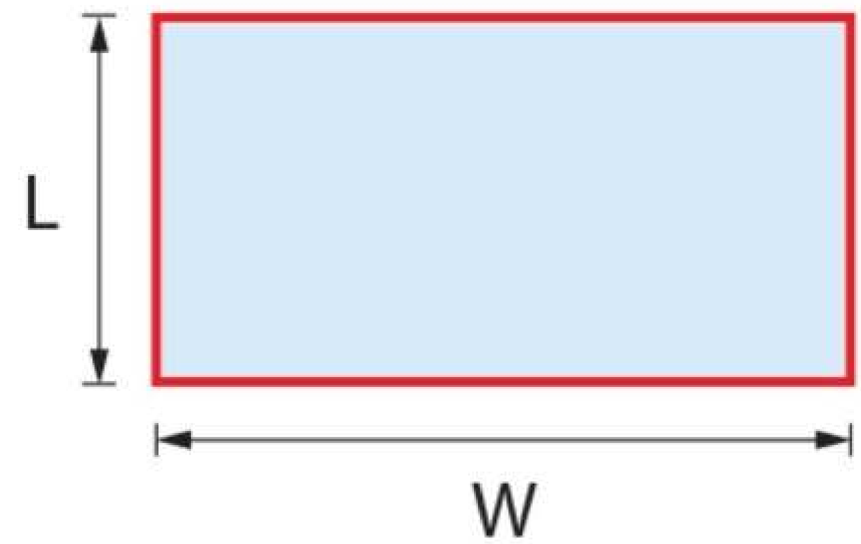
Check your understanding of the content by answering the following question.

Determine the area of a square with sides that are 3 metres in length.

(answer at bottom of page)

Area of a Rectangle

The following diagram shows a red rectangle, with the area of the rectangle shaded blue:

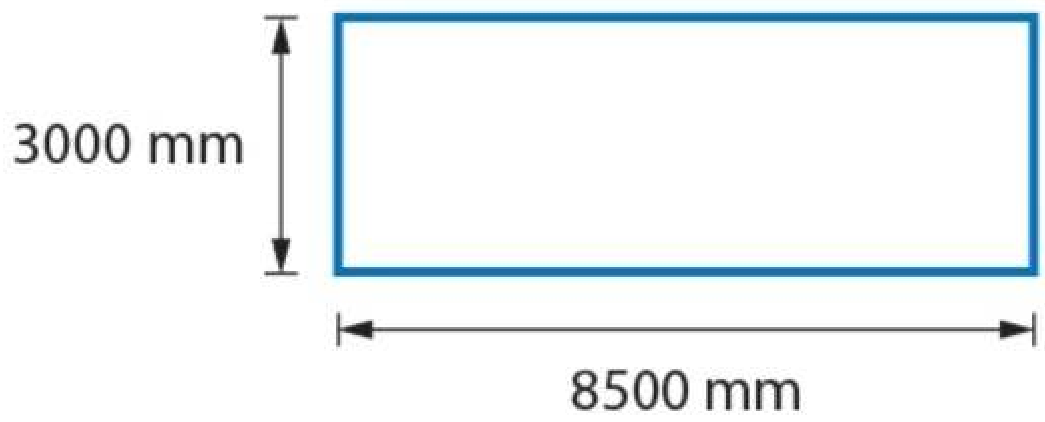


The following equation can be used to determine the area of a rectangle:

Area of a Rectangle
$$A = LW$$
Where:
A = Area in square metres (m^2)
L = Length in metres (m)
W = Width in metres (m)

Worked Example – Area of a Rectangle

Determine the area of the following rectangle:

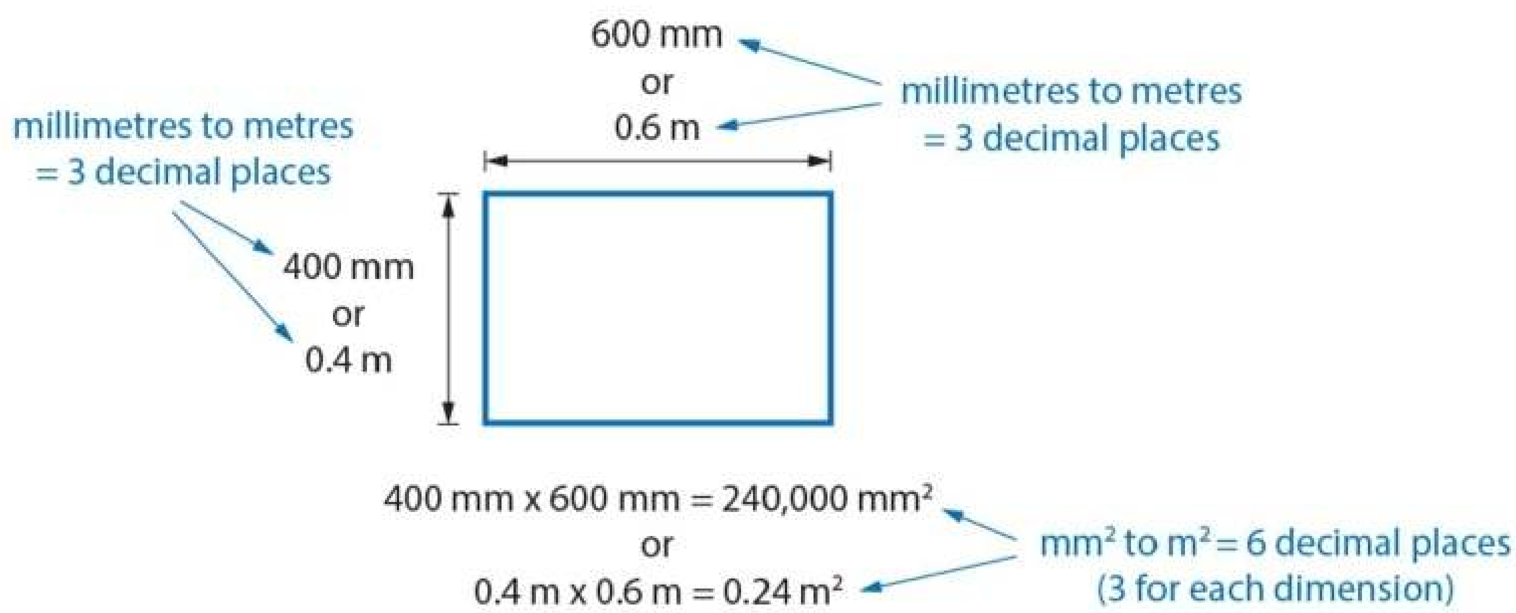


$A = 3000 \times 8500$

$A = 25{,}500{,}000 \text{ mm}^2$

$A = 25.5 \text{ m}^2$

*note: When converting between mm^2 and m^2, the decimal place needs to move *six* places, not three. This is because the unit of measure is two dimensional, i.e. the decimal place moves three places for each dimension in space:



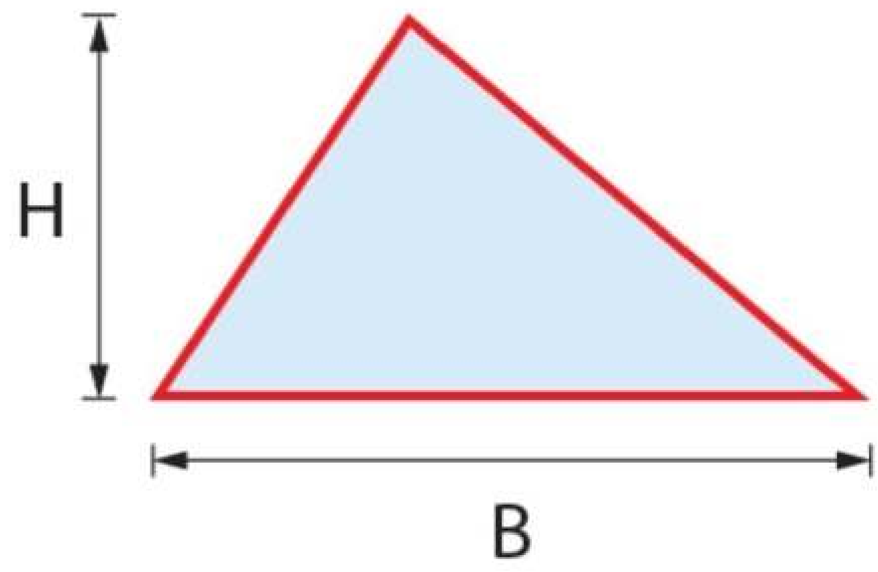
Check your understanding of the content by answering the following question.

Determine the area of a rectangle with a length of 7.2 metres and a width of 1.2 metres.

(answer at bottom of page)

Area of a Triangle

The following diagram shows a red triangle, with the area of the triangle shaded blue:



The following equation can be used to determine the area of a triangle:

Area of a Triangle

$$A = \frac{BH}{2}$$

Where:

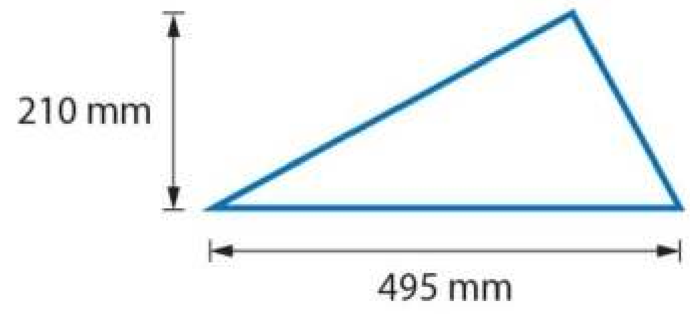
A = Area in square metres (m^2)

B = Base length in metres (m)

H = Height in metres (m)

Worked Example – Area of a Triangle

Determine the area of the following triangle:



$$A = \frac{210 \times 495}{2}$$

$$A = \frac{103{,}950}{2}$$

$$A = 51{,}975\ mm^2$$

or

$$\boldsymbol{A = 0.052\ m^2}$$

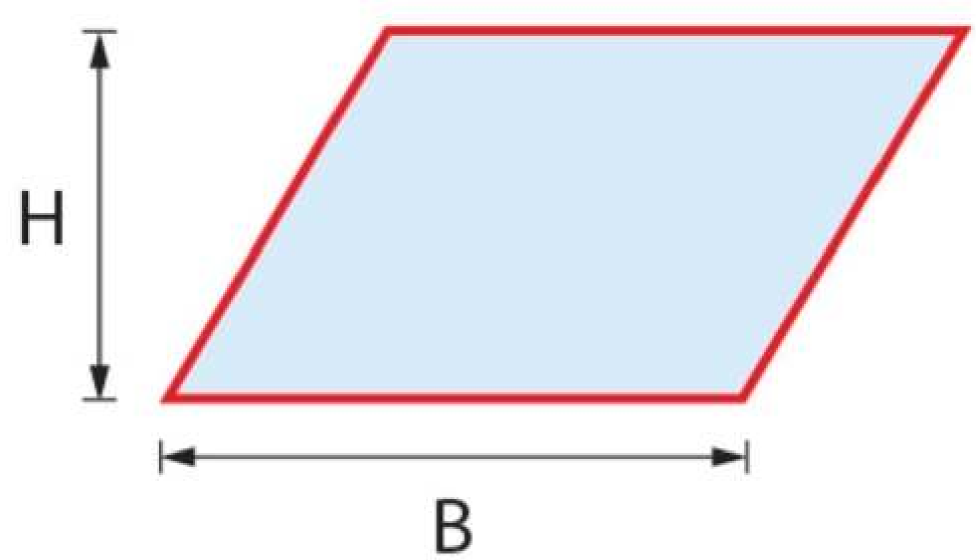
Check your understanding of the content by answering the following question.

Determine the area of a triangle with a base of 3 metres and a height of 4 metres.

(answer at bottom of page)

Area of a Parallelogram

The following diagram shows a red parallelogram, with the area of the parallelogram shaded blue:



The following equation can be used to determine the area of a parallelogram:

Area of a Parallelogram

$$A = BH$$

Where:

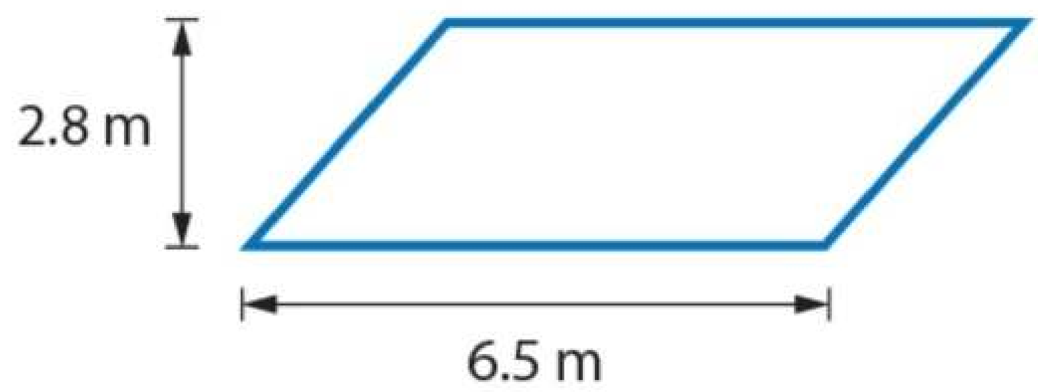
A = Area in square metres (m^2)

B = Base length in metres (m)

H = Height in metres (m)

Worked Example – Area of a Parallelogram

Determine the area of the following parallelogram:



A **= 2.8 x 6.5**

A **= 18.2 m^2**

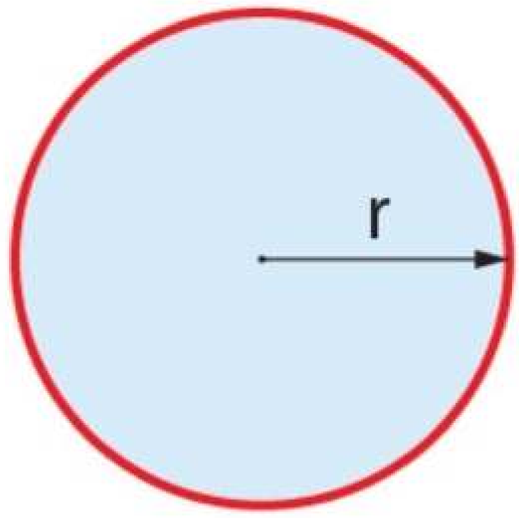
Check your understanding of the content by answering the following question.

Determine the area of a parallelogram with a base of 2.5 metres and a height of 0.5 metres.

(answer at bottom of page)

Area of a Circle

The following diagram shows a red circle, with the area of the circle shaded blue:

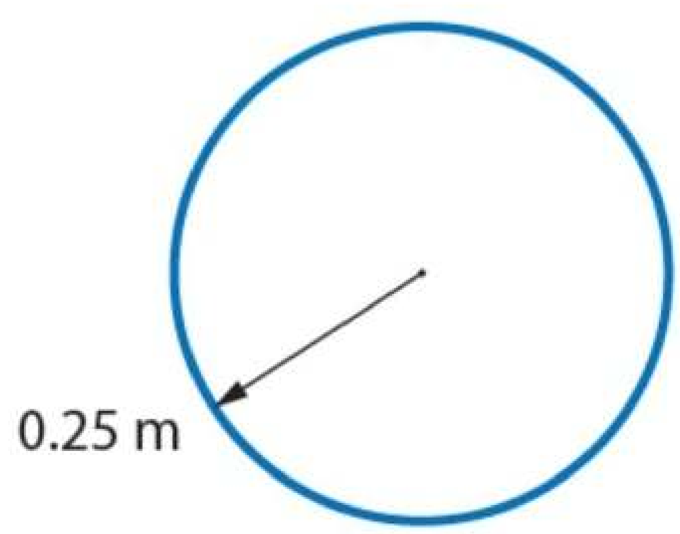


The following equation can be used to determine the area of a circle:

Area of a Circle
$$A = \pi r^2$$ Where: A = Area; π = 3.14... etc.; r = Radius of the circle

Worked Example – Area of a circle

Determine the area of the following circle:



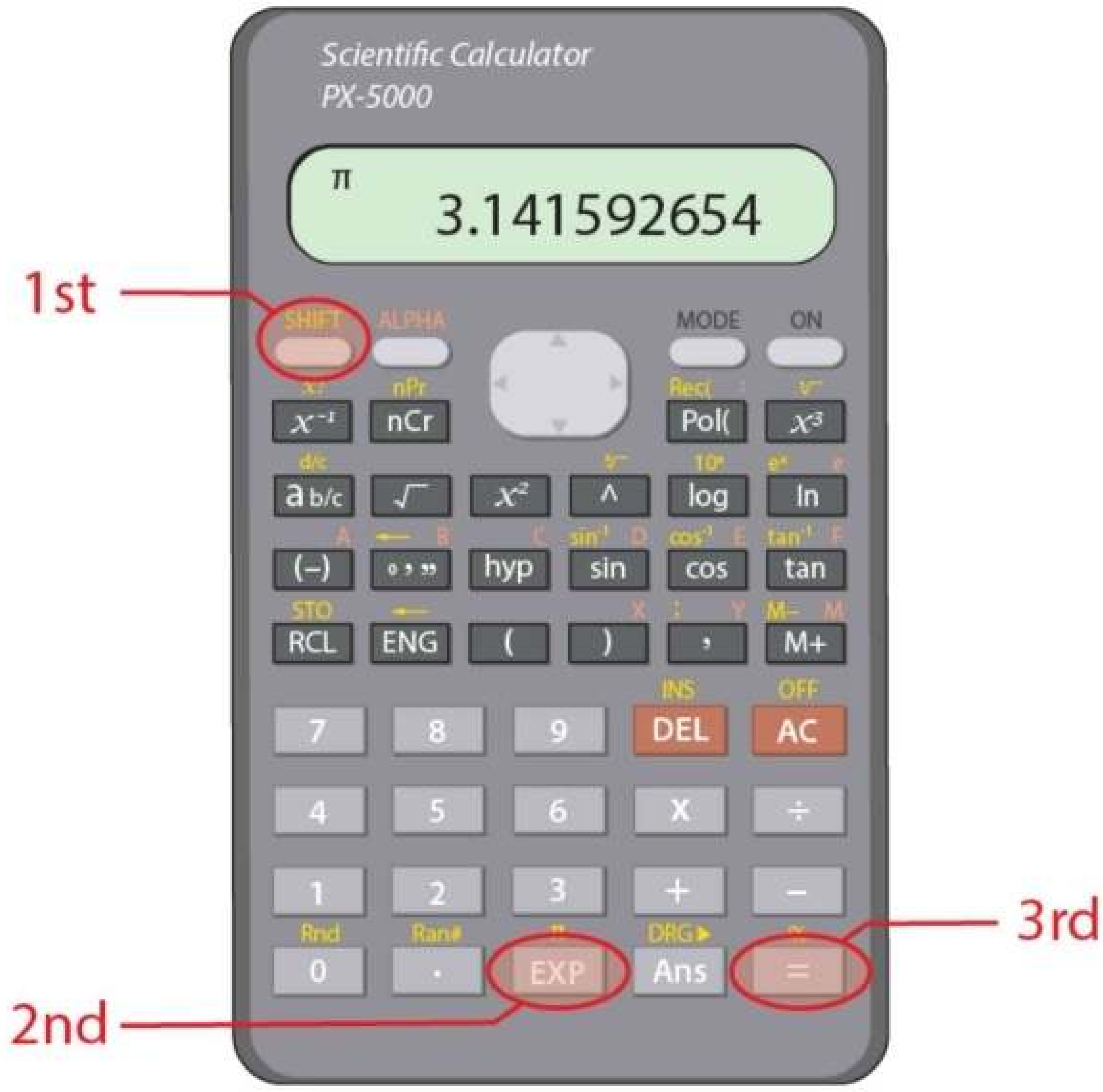
$$A = 3.14 \times (0.25)^2$$

$$A = 3.14 \times 0.0625$$

$$A = 0.196 \text{ m2}$$

Entering Pi on a Calculator

It is a good idea to familiarise yourself with how to use pi (π) on your own calculator. The following diagram shows an example how to enter pi on some scientific calculators:



Check your understanding of the content by answering the following question.

Determine the area of a circle with a radius of 1.4 metres

(answer at bottom of page)

Check your progress answers.

Determine the area of a square with sides that are 3 metres in length.

Answer: A = (3)2 = 9 m^2

Determine the area of a rectangle with a length of 7.2 metres and a width of 1.2 metres.

Answer: A = 7.2 x 1.2 = 8.64 m^2

Determine the area of a triangle with a base of 3 metres and a height of 4 metres.

Answer: A = (3 x 4) / 2 = 6 m^2

Determine the area of a parallelogram with a base of 2.5 metres and a height of 0.5 metres.

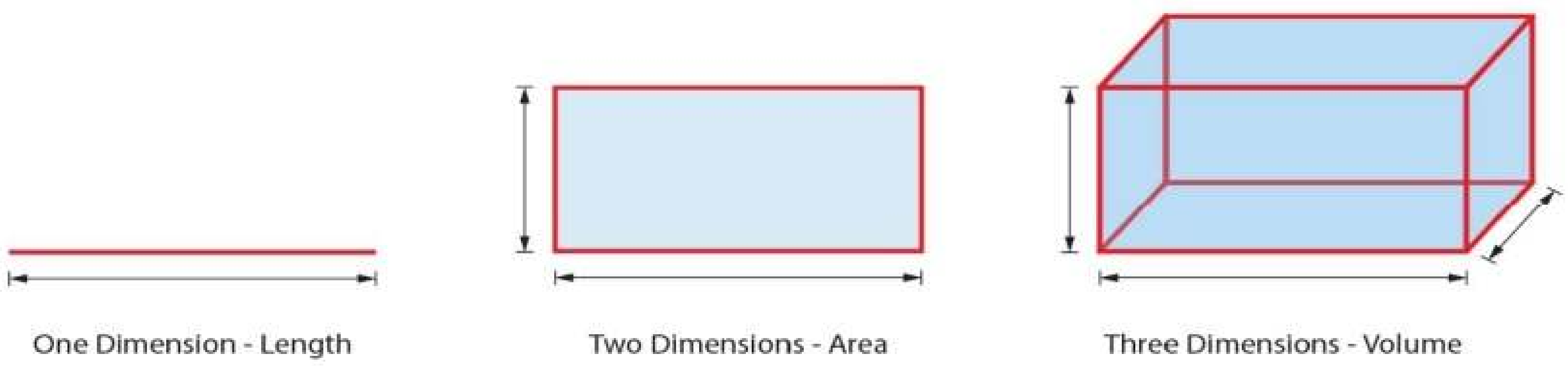
Answer: A = 2.5 x 0.5 = 1.25 m^2

Determine the area of a circle with a radius of 1.4 metres

Answer: A = 3.14 x (1.4)2 = 6.16 m^2

What is Volume?

Whilst area is a measurement of a two dimensional space, volume is a measure of a three dimensional space, e.g. the space within a container. This measurement takes three dimensions into account, such as length, width and height.

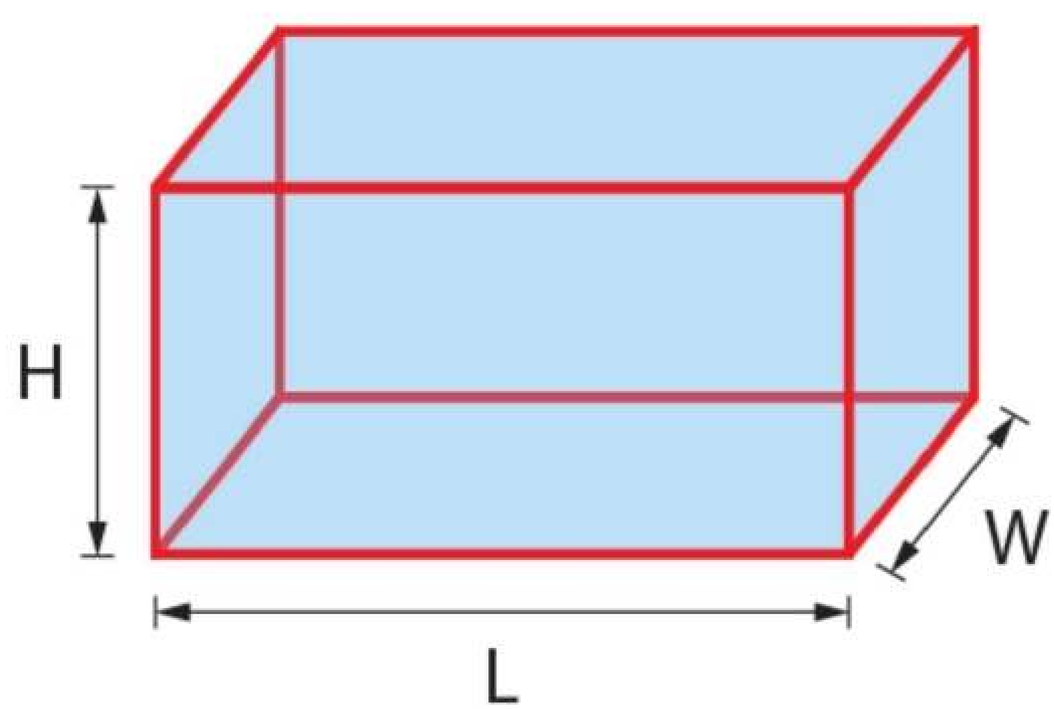


Application in Electrotechnology Work

Typical reasons we may need to determine volume in the electrotechnology industry would be to determine the capacity of tanks or containers. There are a few variations in the equations needed for determining the volume of different *shaped* prisms.

Volume of a Rectangular Tank

The following diagram shows a rectangular tank, with the volume shaded in blue:



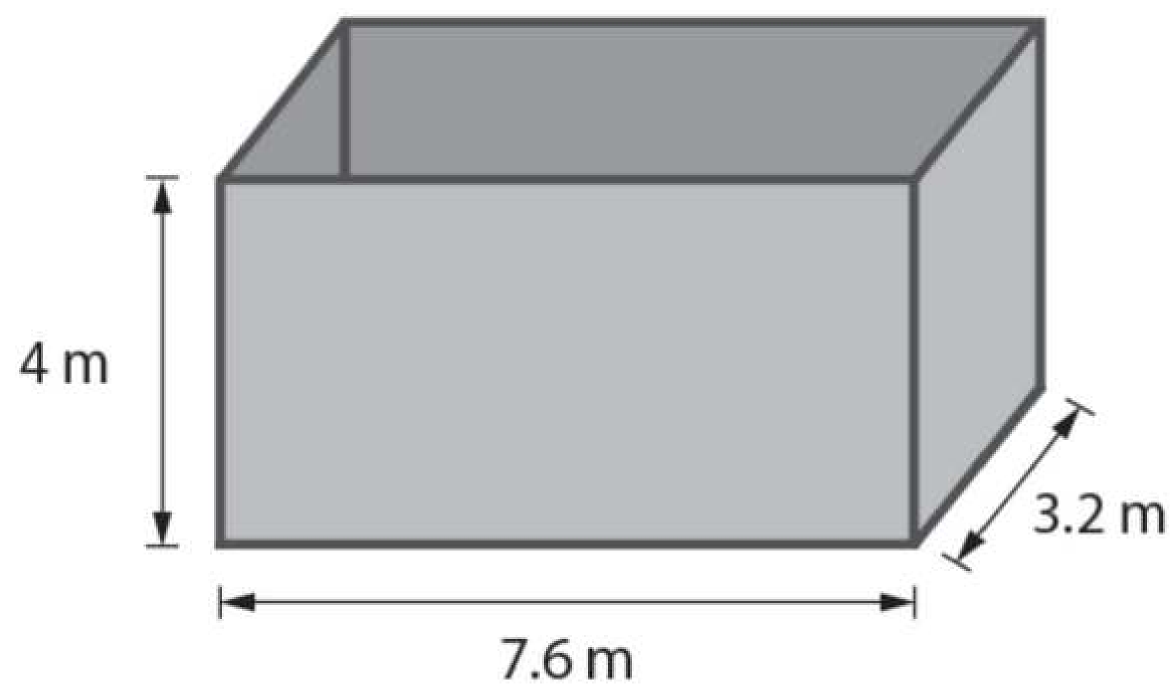
The following equation can be used to determine the volume of the tank:

?

Volume of a Rectangular Tank
$$V = LWH$$ Where: V = Volume in cubic metres (m^3); L = Length in metres (m); W = Width in metres (m); H = Height in metres (m)

Worked Example – Volume of a Rectangular Tank

Determine the area of the following rectangular tank:



$$V = 7.6 \times 3.2 \times 4$$

$$V = 97.3 \text{ m}^3$$

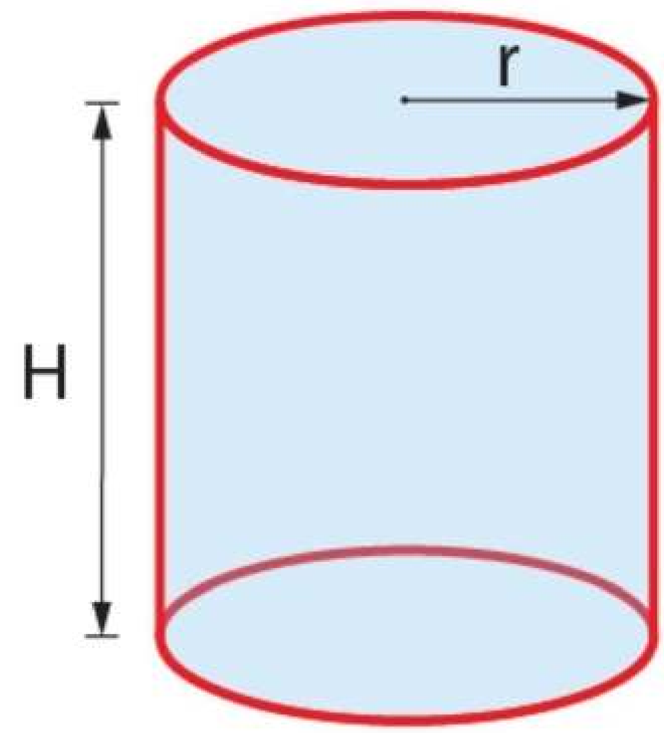
Check your understanding of the content by answering the following question.

Determine the area of a rectangular tank that measures 4 m x 3 m x 2 m (L x W x H).

(answer at bottom of page)

Volume of a Cylindrical Tank

The following diagram shows a cylindrical tank, with the volume shaded in blue:



The following equation can be used to determine the volume of the tank:

Volume of a Cylindrical Tank

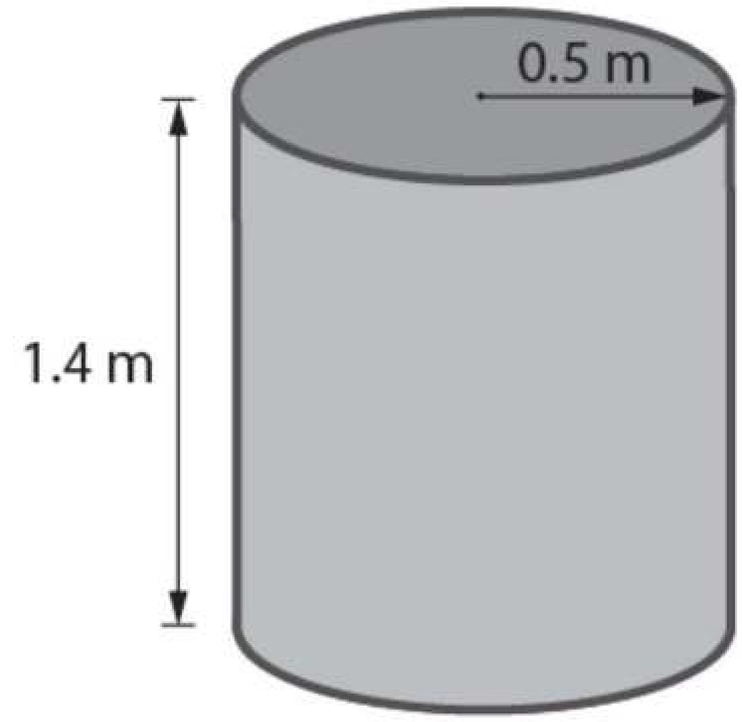
$$V = \pi r^2 H$$

Where:

V	=	Volume in cubic metres (m^3)
π	=	3.14... etc.
r	=	Radius of the circle in metres (m)
H	=	Height in metres (m)

Worked Example – Volume of a Cylindrical Tank

Determine the area of the following rectangular tank:



$V = 3.14 \times (0.5)^2 \times 1.4$

$V = 3.14 \times 0.25 \times 14$

$V = 1.1m^3$

Check your understanding of the content by answering the following question.

Determine the area of a cylindrical tank with a height of 1.8 metres and a *diameter* of 1.2 metres.

*Remember: the radius of a circle is half of the diameter!

(answer at bottom of page)

Introduction

Trigonometry ratios are based on the relationship between the sides and the angles of right angle triangles. Trigonometry is used widely in the electrotechnology industry, because certain electrical parameters behave according to trigonometry ratios. Another useful tool in determining electrical parameters is Pythagoras' Theorem, which states the relationship between the three sides of a right angle triangle.

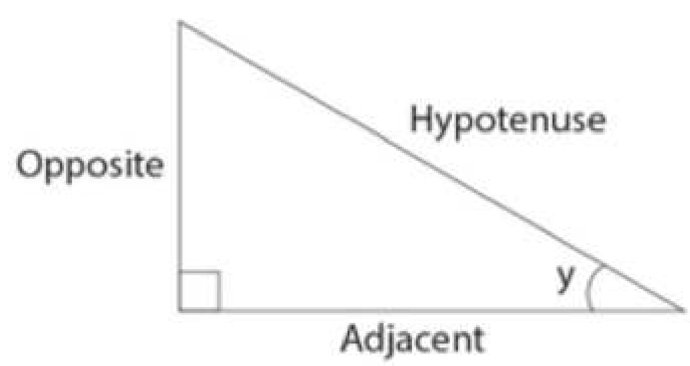
In this topic you will learn about how to apply trigonometry and Pythagoras Theorem to solve problems.

Right Angle Triangles

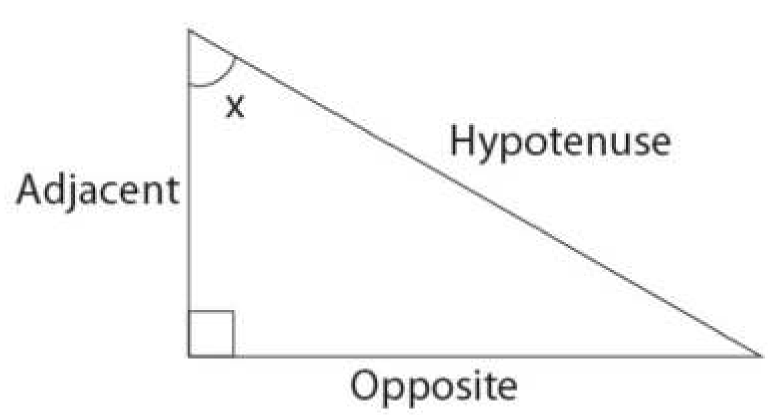
Before learning about trigonometry ratios, it's important to note a few things about right angle triangles, such as:

- One angle is always 90°.
- The sum of the three angles will always equal 180°.
- The side opposite to the right angle is called the 'hypotenuse'.
- The other two sides are called the 'opposite' or 'adjacent' side, depending on the angle of reference.

In the diagram below, angle 'y' is shown in relationship to the hypotenuse, the opposite side and the adjacent side.



In this diagram, the new reference angle is 'x'. Notice how the hypotenuse is unchanged, but the adjacent and opposite sides have switched when compared to the diagram above.



?

Trigonometry Ratios

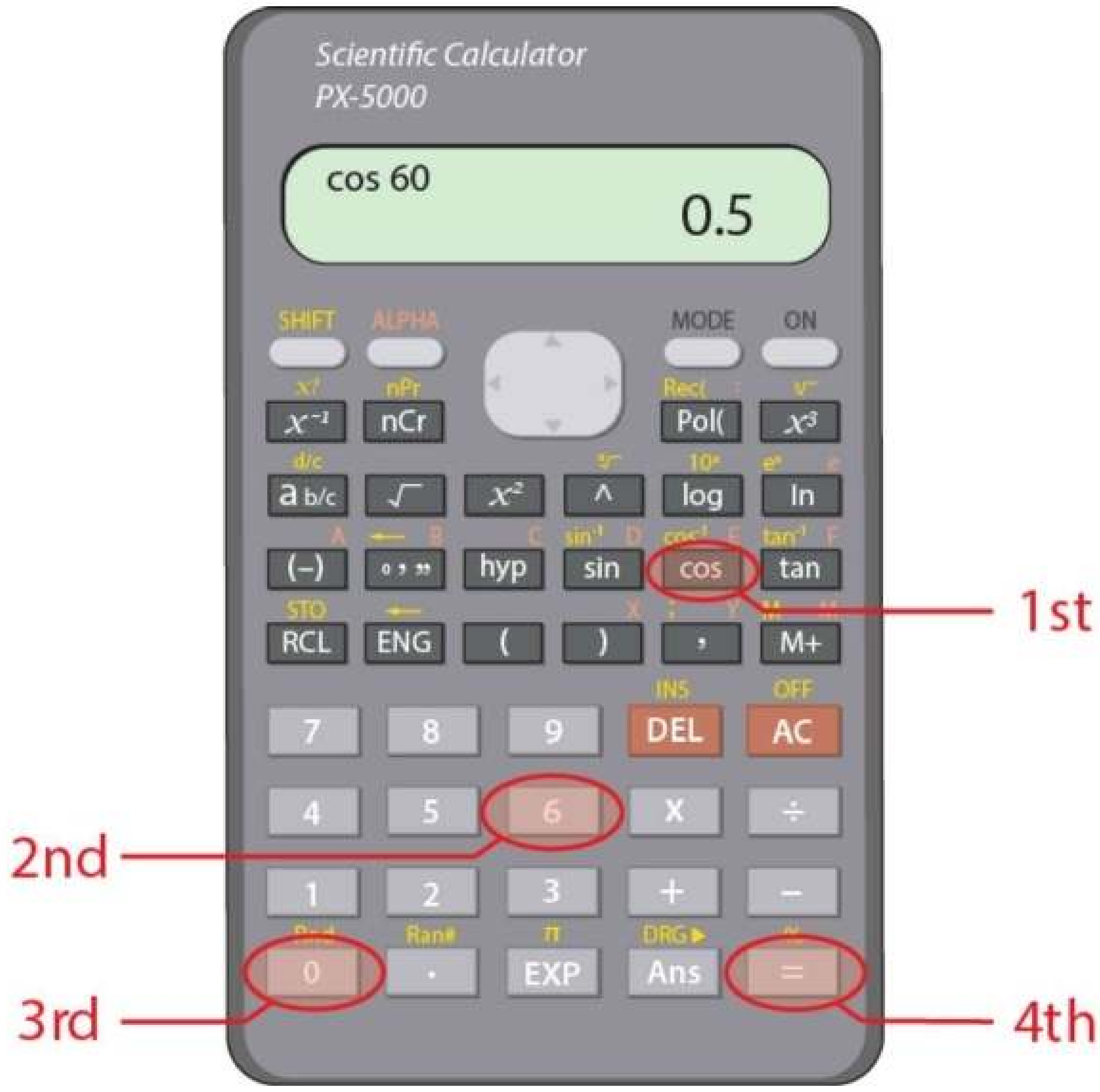
Sine, cosine and tangent represent ratios between the lengths of any two sides of a right angle triangle. These ratios can be used to find the angle (in degrees) between any two sides.

Trigonometry Ratios			
Ratio	**Abbreviation**	**Equation**	**Mnemonic**
Sine	Sin	$\text{Sin}\,\theta = \frac{\text{Opposite}}{\text{Hypotenuse}}$	SOH
Cosine	Cos	$\text{Cos}\,\theta = \frac{\text{Adjacent}}{\text{Hypotenuse}}$	CAH
Tangent	Tan	$\text{Tan}\,\theta = \frac{\text{Opposite}}{\text{Adjacent}}$	TOA

Using the Calculator

A calculator is required to perform trigonometry calculations, so it’s important to take note of the sin, cos and tan functions on your calculator.

The following diagram shows how to find the cosine of 60^0. This would tell us the ratio between the hypotenuse and the side adjacent to a 60^0 angle in a right angle triangle:



In this case, the answer of 0.5 indicates that the adjacent side of the triangle is half as long as the hypotenuse, i.e. adjacent/hypotenuse = 0.5/1.

Check your understanding of the content by answering the following questions.

Use your calculator to solve each of the following:

a) sin 23

b) cos 52

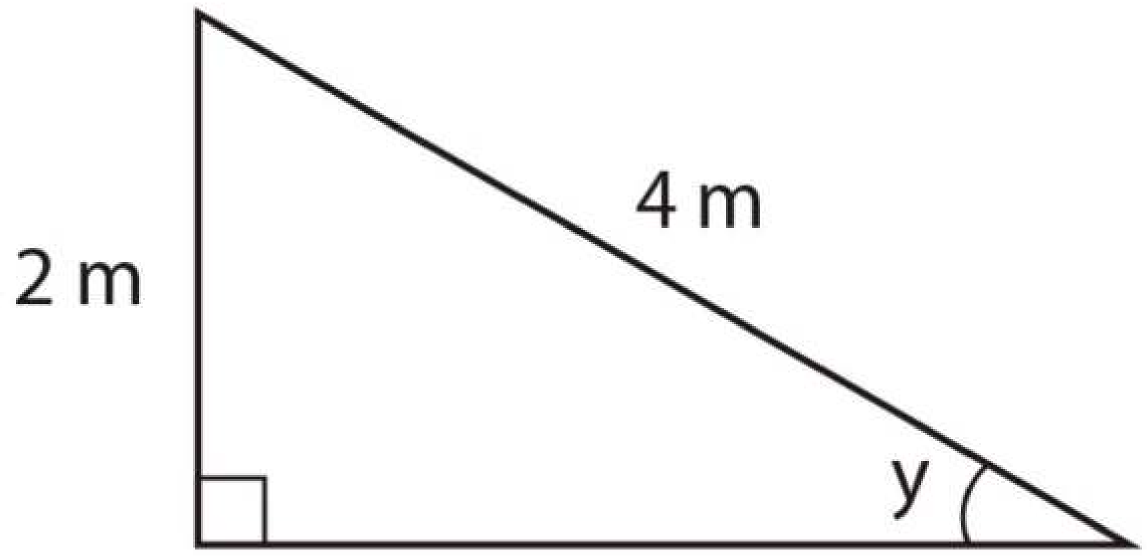
c) tan 35

(answer at bottom of page)

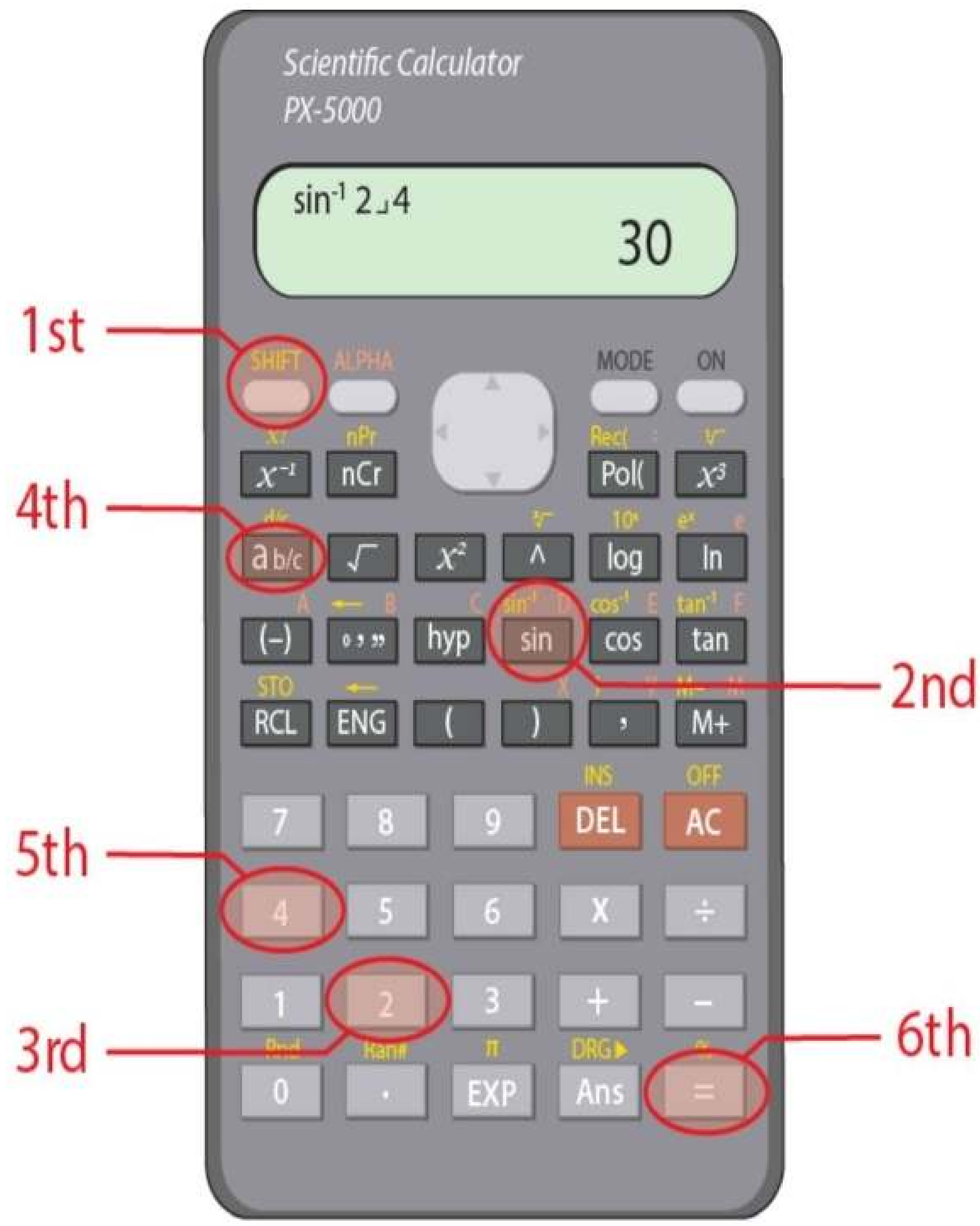
The inverse (opposite) of the sin, cos and tan functions are usually entered into a calculator by first pressing the shift button and then pressing the relevant sin, cos or tan button. This is used to calculate an unknown angle where two sides of a right angle triangle are known. Note that:

- The inverse of sin is $\sin^{-1}$.
- The inverse of cos is $\cos^{-1}$.
- The inverse of tan is $\tan^{-1}$.

Consider we know that the opposite side of a right angle triangle is 2 metres in length, and the hypotenuse is 4 metres in length, as shown below:



We could determine angle y using the inverse of the sin function as follows:



In this case, the answer of 30 indicates that the angle y is 30^0.

Check your understanding of the content by answering the following questions.

Use your calculator to solve each of the following:

a) $\sin^{-1} 0.22$

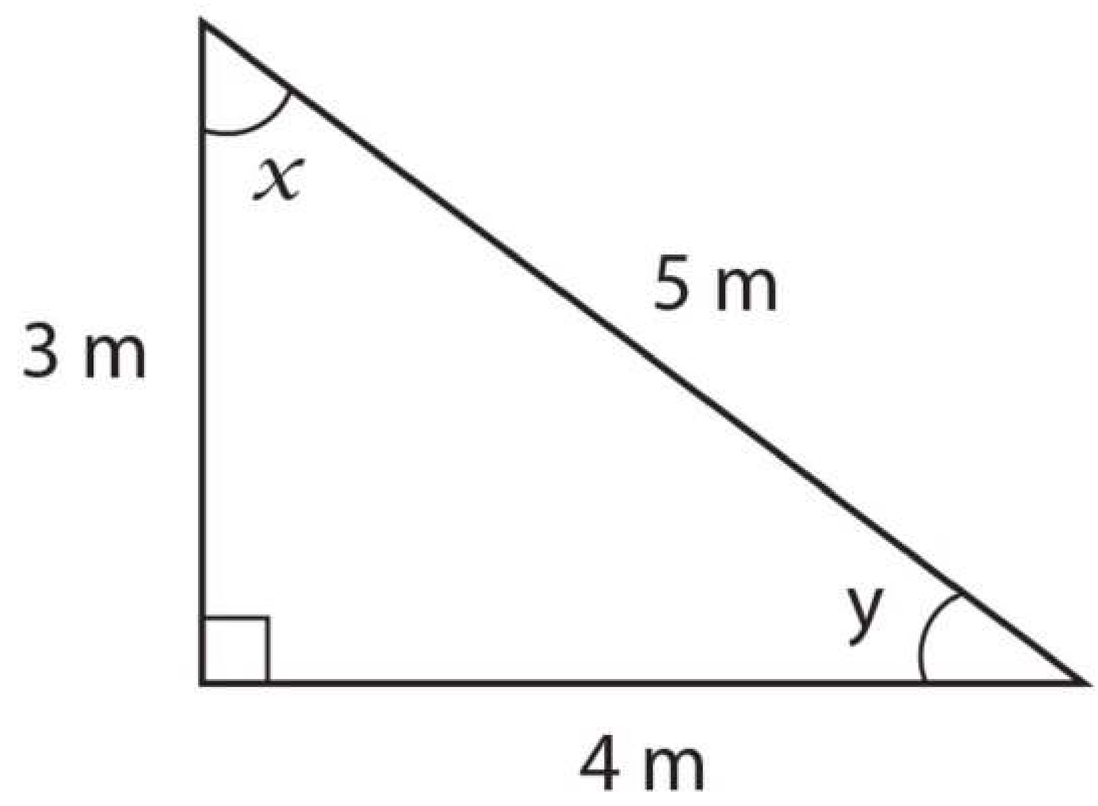
b) $\cos^{-1} 0.59$

c) $\tan^{-1} 0.92$

(answer at bottom of page)

Worked Example 1 – Calculating the sin, cos and tan ratios of angle y

In relation to the right angle triangle shown below, calculate the sin, cos and tan ratios for angle y. Also calculate the angle of y in degrees, using the ratios.



sin - SOH

$$\sin y = \frac{Opp}{Hyp}$$

$$\sin y = \frac{3}{5}$$

$$\underline{\sin y = 0.6}$$

$\underline{y = \sin^{-1}(0.6) = 36.9°}$

cos – CAH

$$\cos y = \frac{Adj}{Hyp}$$

$$\cos y = \frac{4}{5}$$

$$\underline{\cos y = 0.8}$$

$\underline{y = \cos^{-1}(0.8) = 36.9°}$

tan – TOA

$$\tan y = \frac{Opp}{Adj}$$

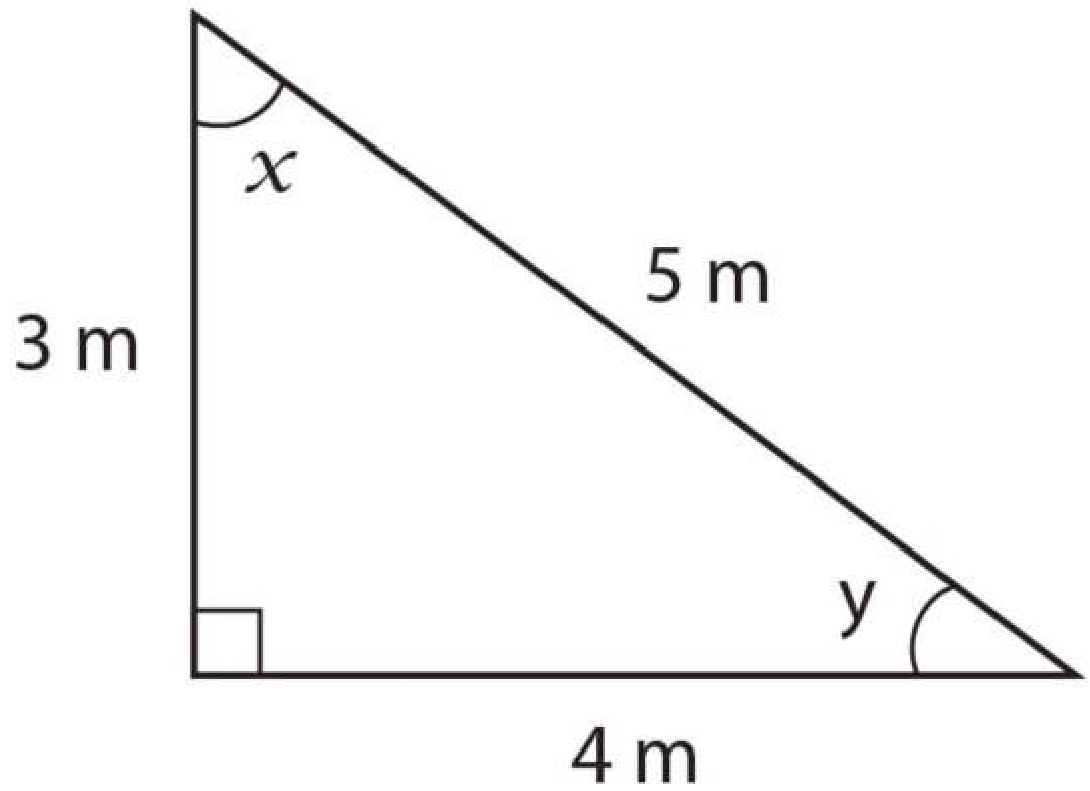
$$\tan y = \frac{3}{4}$$

$$\underline{\tan y = 0.75}$$

$$\underline{y = \tan^{-1}(0.75) = 36.9°}$$

Worked Example 2 – Calculating the sin, cos and tan ratios of angle x

In relation to the right angle triangle shown below, calculate the sin, cos and tan ratios for angle x. Also calculate the angle of x in degrees, using the ratios.



sin - SOH

$$\sin x = \frac{Opp}{Hyp}$$

$$\sin x = \frac{4}{5}$$

$$\underline{\sin x = 0.8}$$

$$\underline{x = \sin^{-1}(0.8) = 53.1°}$$

cos – CAH

$$\cos x = \frac{Adj}{Hyp}$$

$$\cos x = \frac{3}{5}$$

$$\underline{\cos x = 0.6}$$

$$\underline{x = \cos^{-1}(0.6) = 53.1°}$$

tan – TOA

$$\tan x = \frac{Opp}{Adj}$$

$$\tan x = \frac{4}{3}$$

$$\underline{\tan x = 1.33}$$

$\underline{x = \tan^{-1}(1.33) = 53.1°}$

Check your progress answers.

sin 23 Answer: 0.391

cos 52 Answer: 0.616

tan 35 Answer: 0.7

$\sin^{-1}$ 0.22 Answer: 12.7°

$\cos^{-1}$ 0.59 Answer: 53.8°

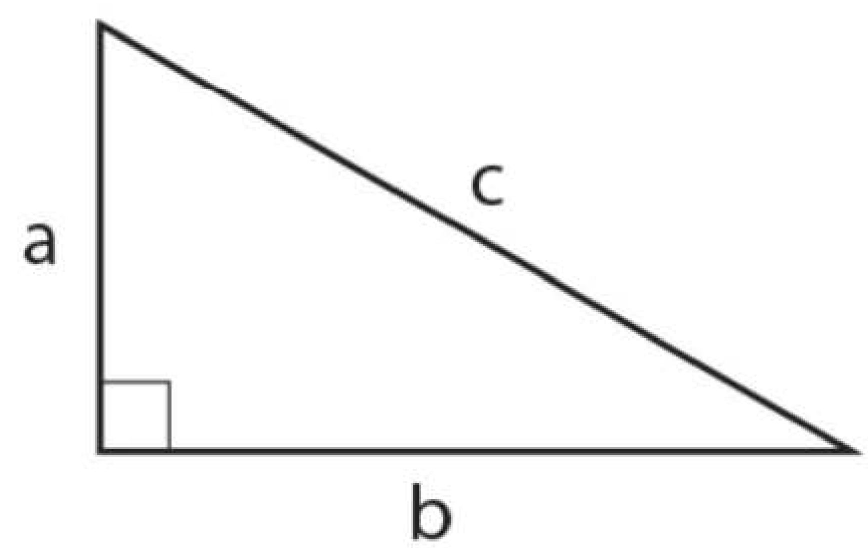
$\tan^{-1}$ 0.92 Answer: 42.6°

Pythagoras's Theorem is another tool that is used to analyse the relationships between the sides of a right angle triangle.

Pythagoras' Theorem states that:

'In a right angled triangle, the square of the hypotenuse is equal to the sum of the squares of the other two sides.'

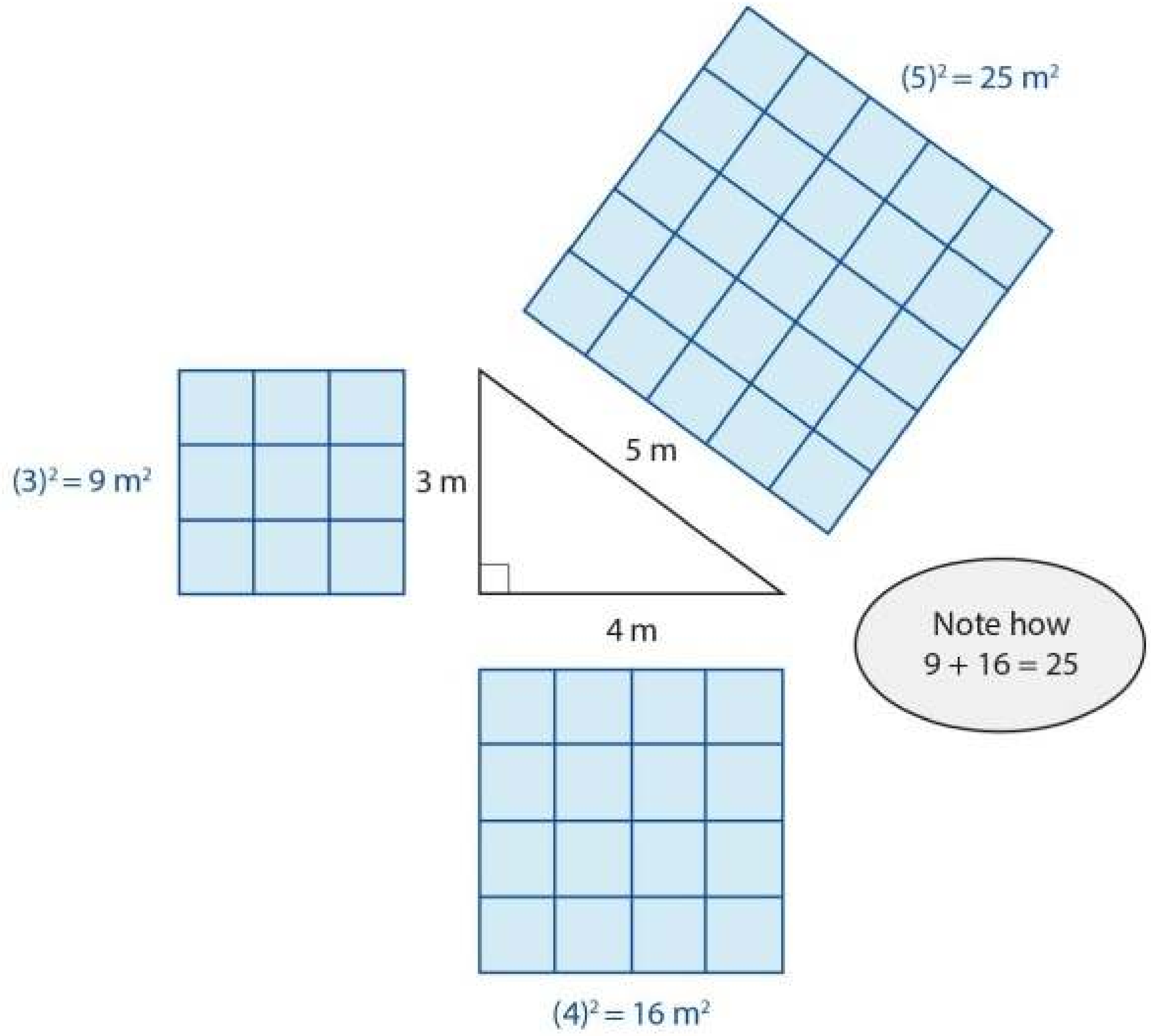
This can be expressed as an equation as follows:



$$c^2 = a^2 + b^2$$

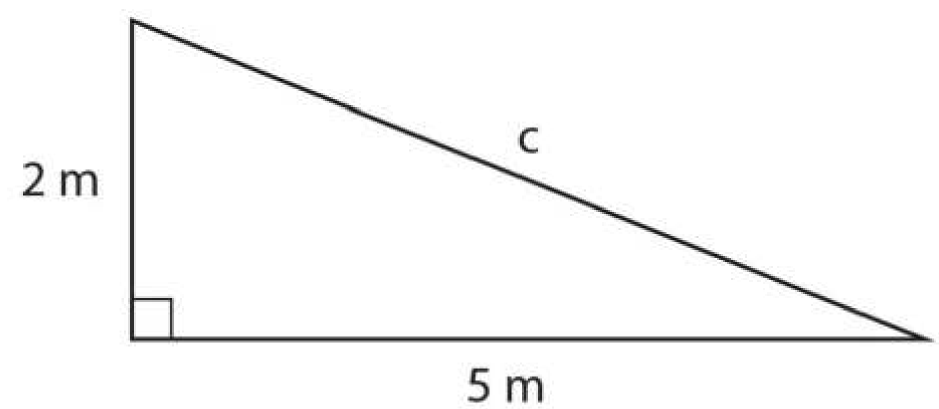
The following diagram illustrates the truth of Pythagoras' Theorem using a basic 3-4-5 triangle:

?



Worked Example 1 – Pythagoras' Theorem

For the right angle triangle shown below, calculate the value of the hypotenuse.



$$c^2 = a^2 + b^2$$

$$c^2 = 2^2 + 5^2$$

$$c = \sqrt{(2^2 + 5^2)}$$

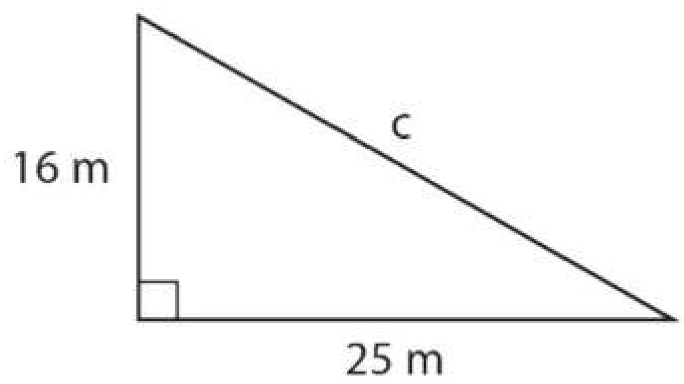
$$c = \sqrt{(4 + 25)}$$

$$c = \sqrt{(29)}$$

$$\underline{c = 5.39 \text{ m}}$$

Check your understanding of the content by answering the following question.

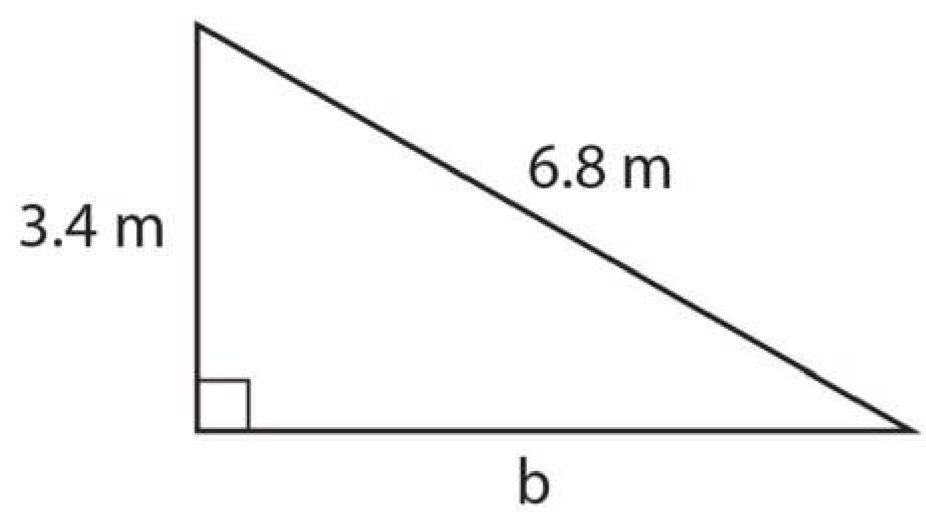
1. Calculate the value of the hypotenuse in the following right angle triangle:



(answer at bottom of page)

Worked Example 2 – Pythagoras' Theorem

For the right angle triangle shown below, calculate the value of the unknown side 'b'.



$$c^2 = a^2 + b^2$$

$$b^2 = c^2 - a^2$$

$$b = \sqrt{(c^2 - a^2)}$$

$$b = \sqrt{(6.8^2 - 3.4^2)}$$

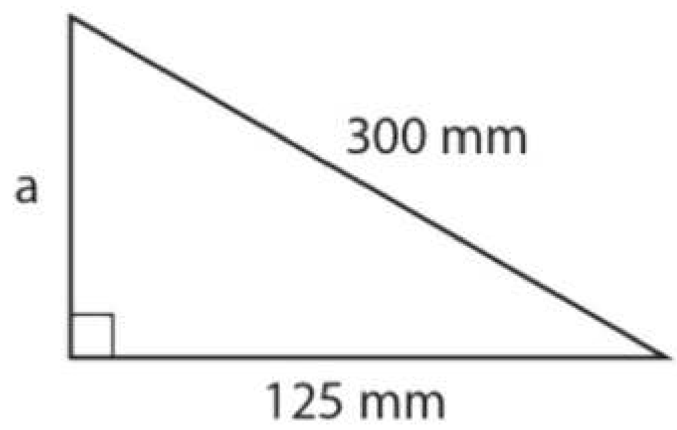
$$b = \sqrt{(46.24 - 11.56)}$$

$$b = \sqrt{(34.68)}$$

$$\underline{b = 5.89 \text{ m}}$$

Check your understanding of the content by answering the following question.

2. Calculate the value of the unknown side in the following right angle triangle:



(answer at bottom of page)

Check your progress answers.

1. *Answer:*

$c = \sqrt{(16^2 + 25^2)}$

c = 29.7 m

2. Answer:

$a = \sqrt{(300^2 - 125^2)}$

a = 273 mm

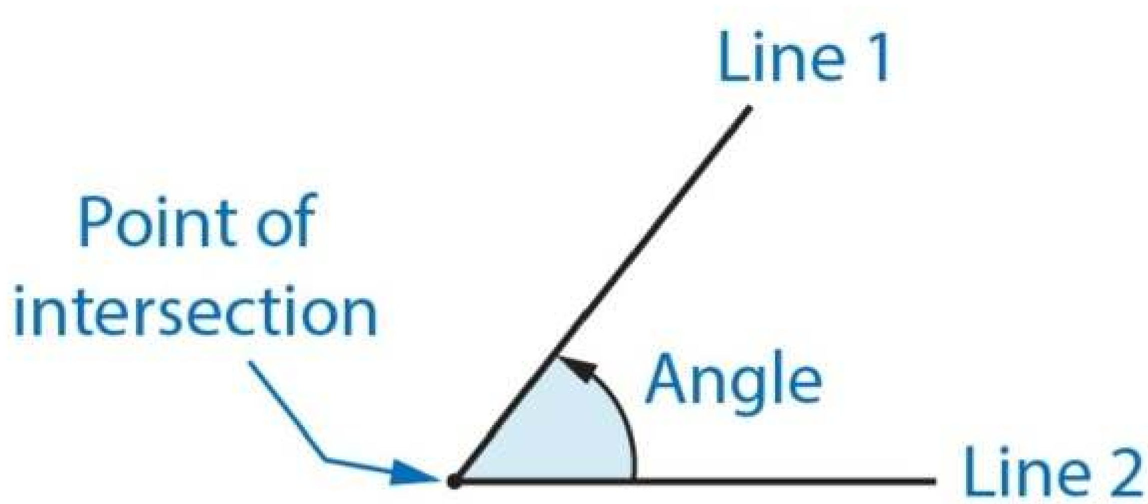
Introduction

It can often be necessary to draw and construct various angles and triangles whilst fabricating and installing electrotechnology components, such as cable supports. As we touched on this in the previous topic, certain electrical parameters can be represented using right angle triangles, so being able to draw accurate angles can also be very useful when evaluating circuits.

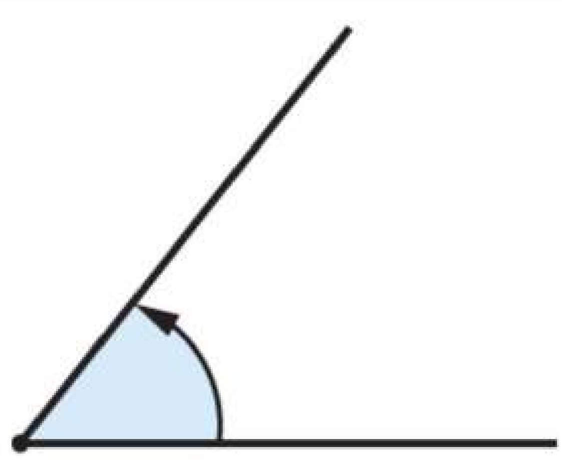
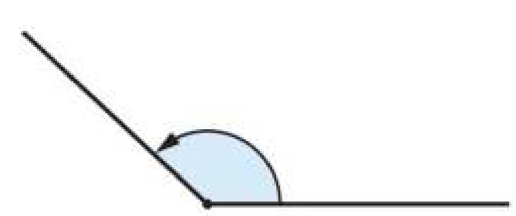
In this topic you will learn about the significance of angles and triangles to electrotechnology work, as well as how to construct and use angles and triangles to solve common electrotechnology problems.

What is an Angle?

An angle is a measure of the space between two intersecting lines, expressed in degrees (^{0}):



The following table explains some different types of angles. Note that a 90^0 angle is indicated by a square line rather than a curved line:

Types of Angles		
		

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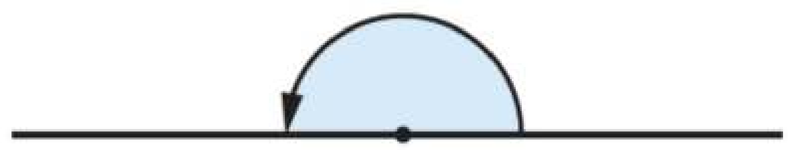
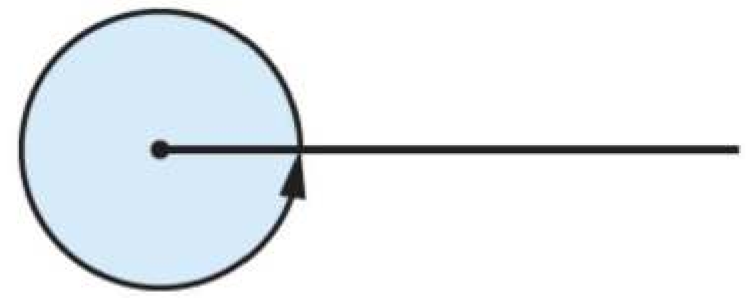
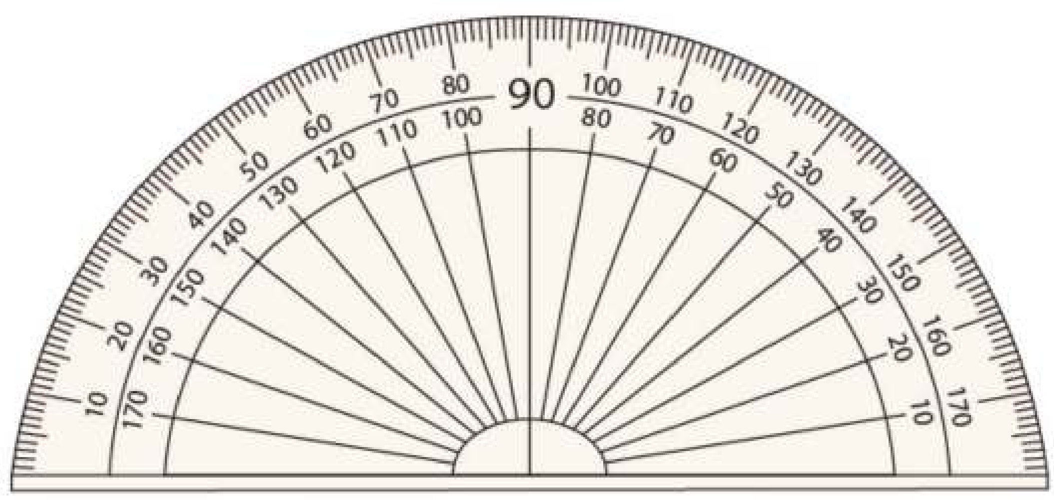
Acute (less than 90^0)	Right angle (90^0)	Obtuse (greater than 90^0)

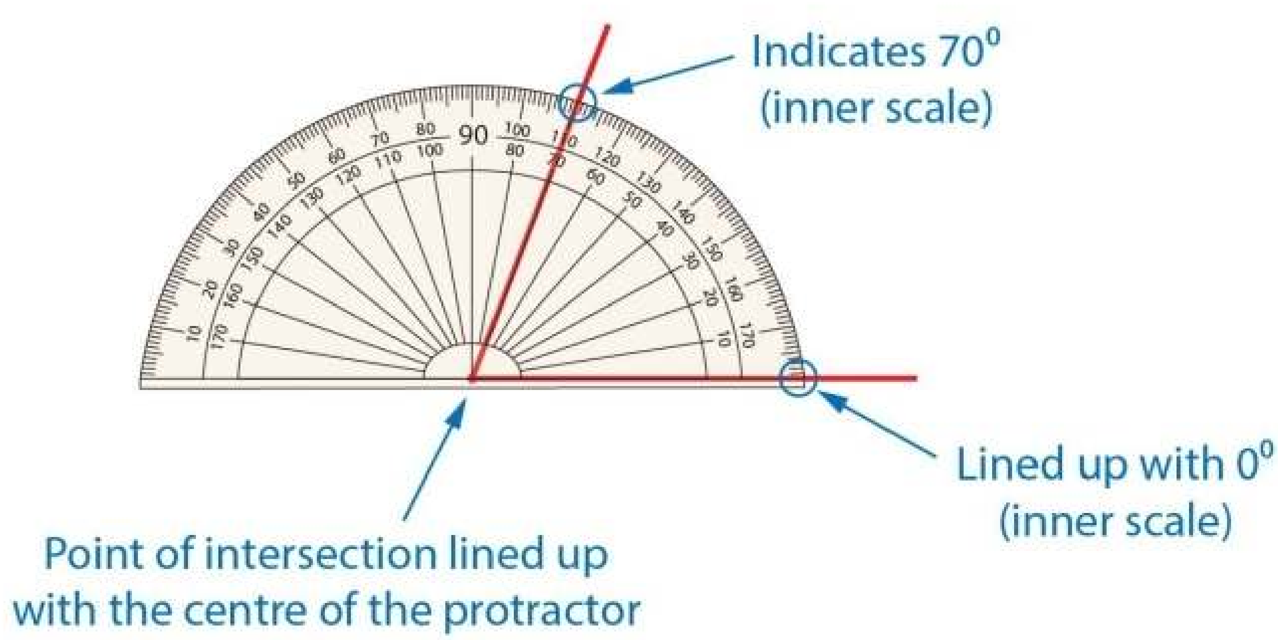
	
Flat (180^0)	Full circle/revolution (360^0)

Using a Protractor

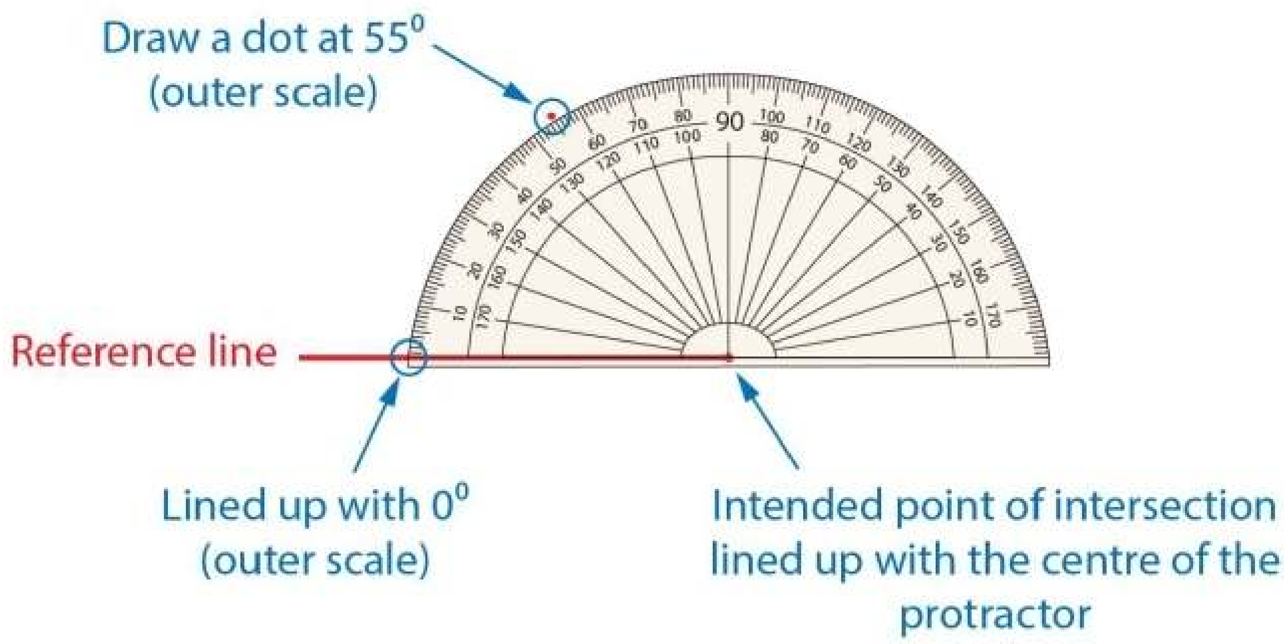
A protractor, shown below, is an instrument that can be used to measure and construct angles.



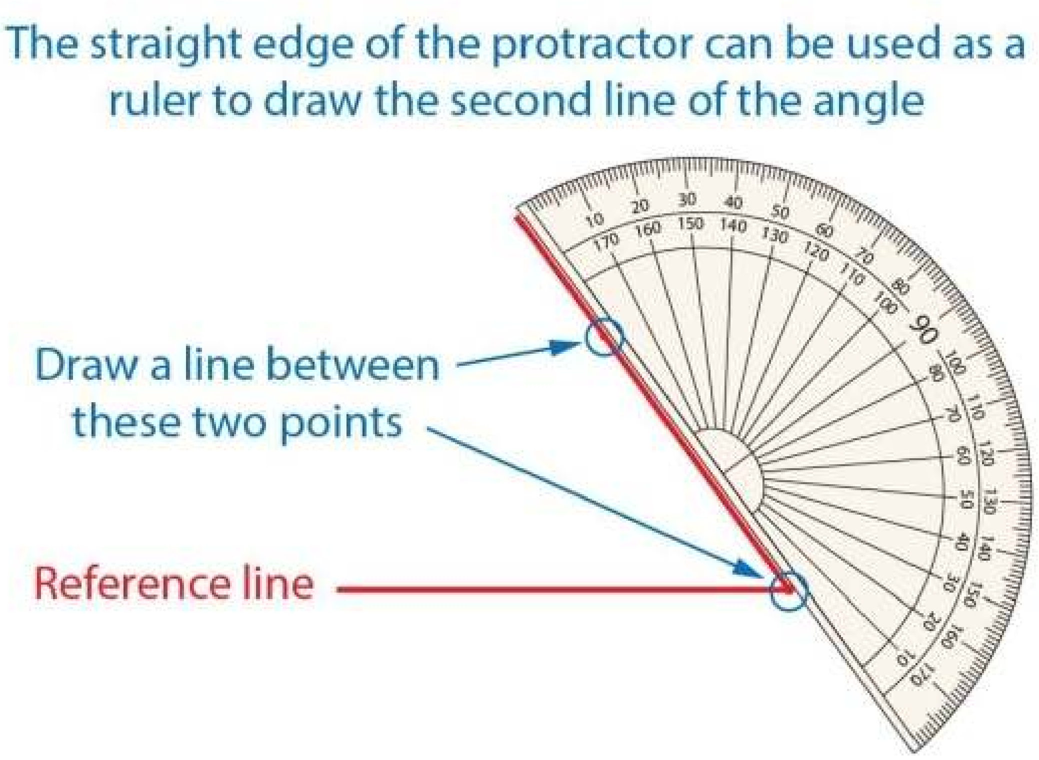
To measure an angle, line up the centre of the protractor with the point of intersection, and the base increment (i.e. 0^0) on the protractor with one line of the angle. Note where the other line of the angle falls on the scale – this will indicate the size of the angle in degrees.



You can also use a protractor to draw lines at specific angles. To do this, draw the first line of your angle, and then line the base increment of the protractor the same way, i.e. with the intended point of intersection at the centre. Draw a dot at the required angle – the example below shows how to draw a 55^0 angle (this time using the outer scale):

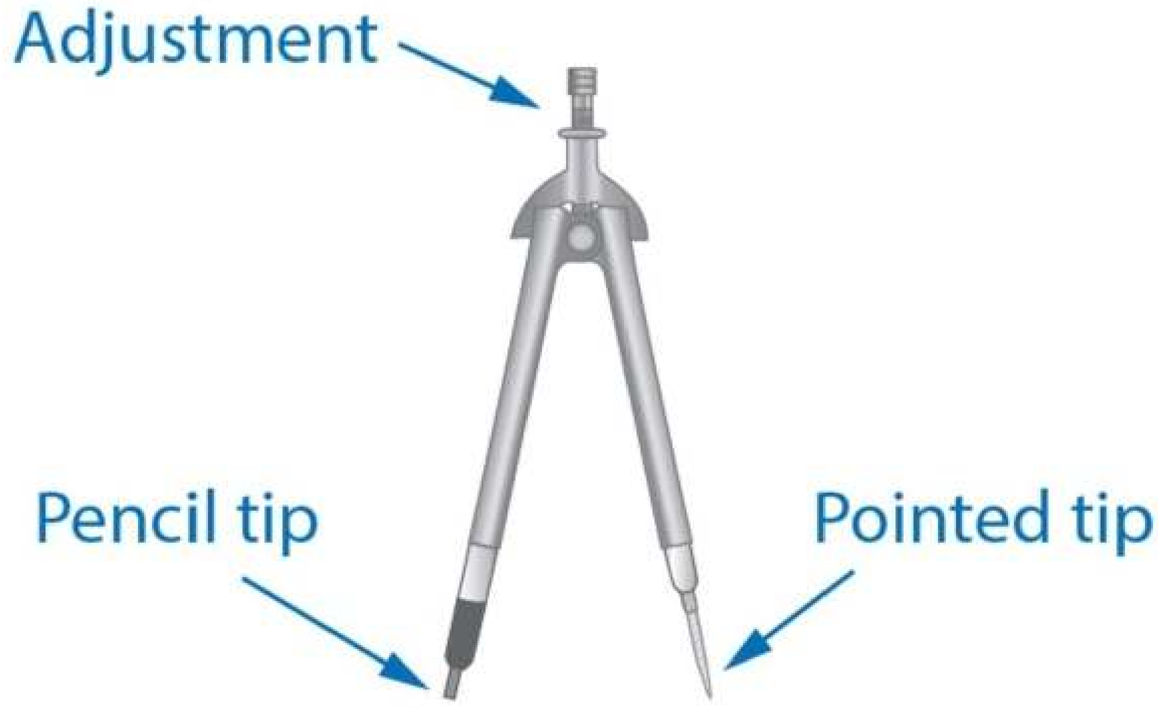


Then remove the protractor and use a ruler to draw a line from the point of intersection to the dot.

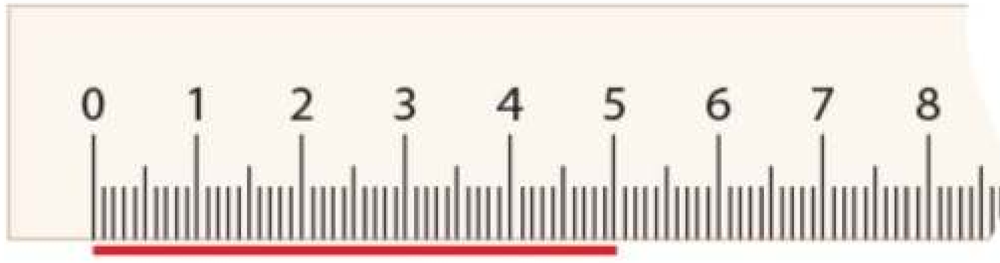


Using a Compass

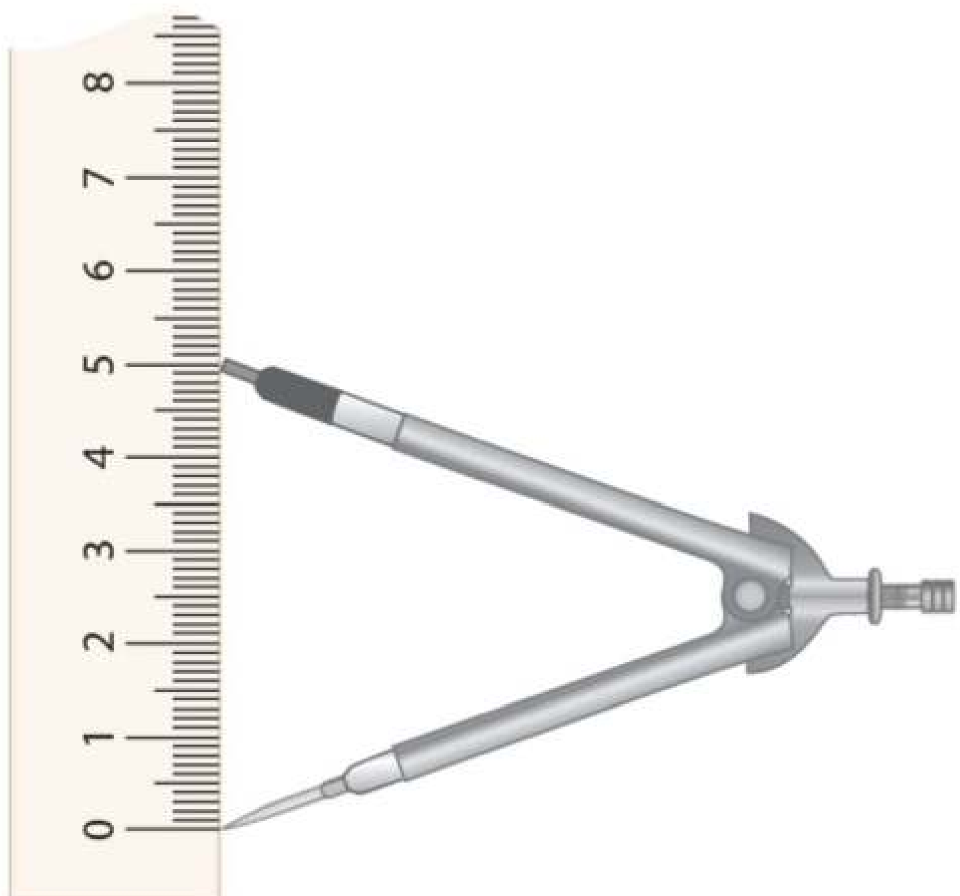
A compass, shown below, is another instrument that can be used to construct angles. The device consists of two legs – one with a point and the other with a drawing implement. The distance between the legs can be adjusted, allowing arcs and circles of different radii to be drawn.



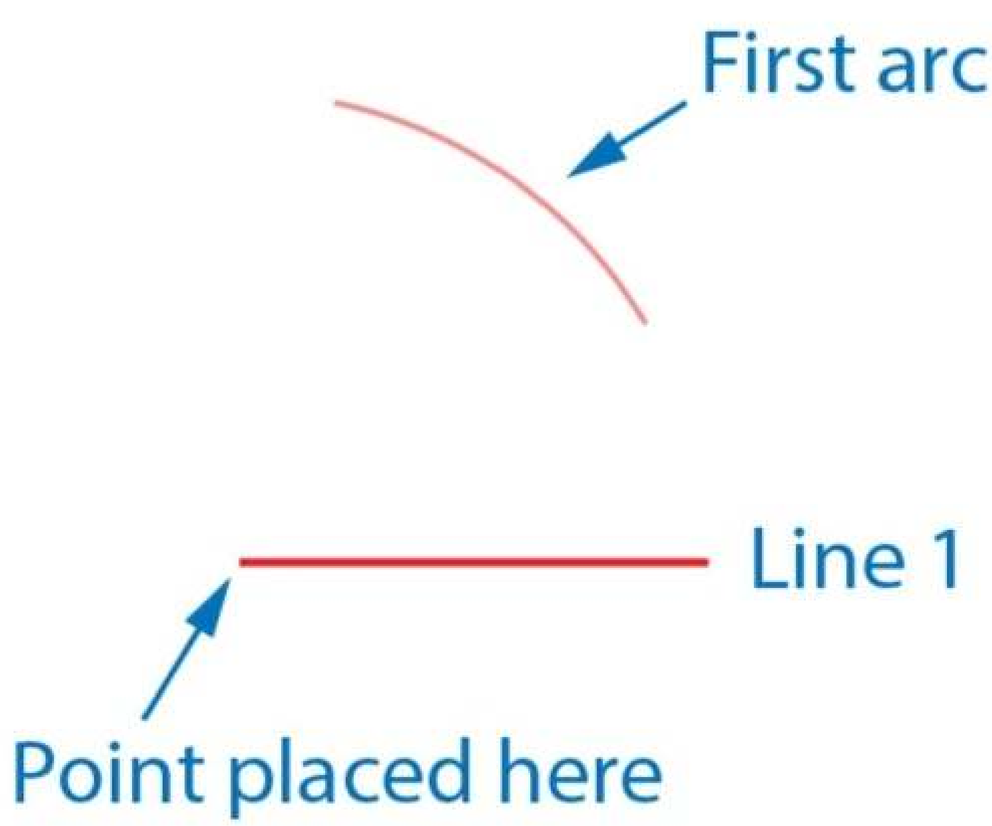
To construct a 60^0 angle, first draw a line at a specific length, e.g. 50 mm, as shown below:



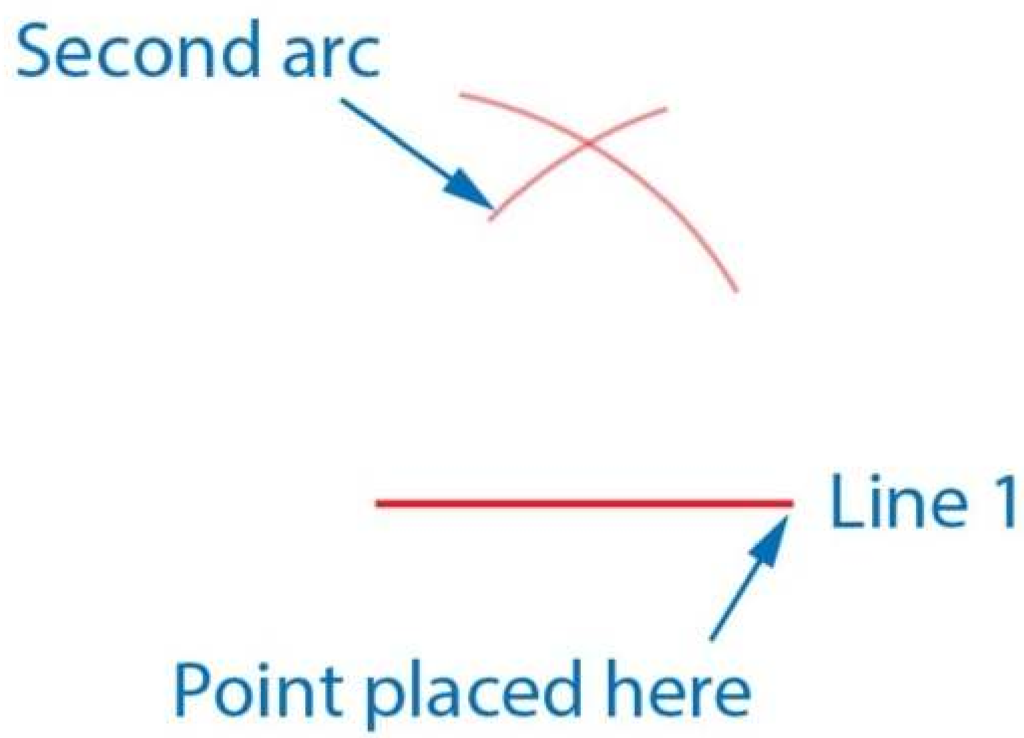
Next, adjust the width of the compass to the same length as the line.



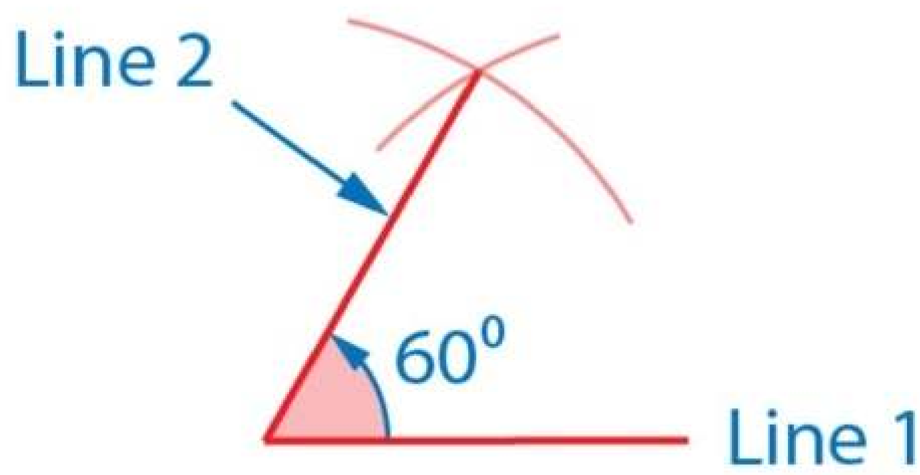
Place the point of the compass at one end of the line and then scribe an arc, as shown below:



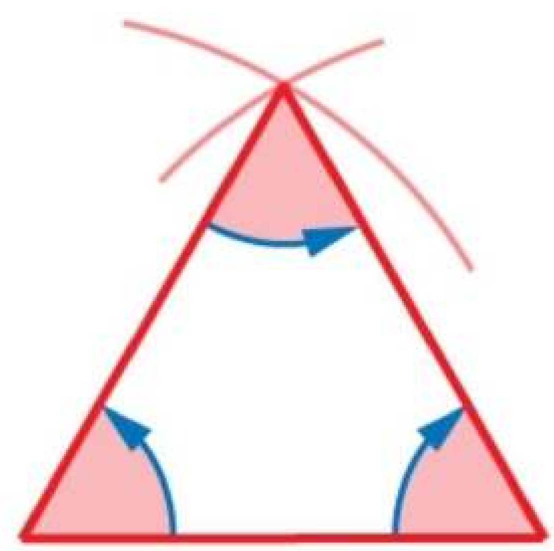
Then scribe an arc with the point of the compass at the other end of the line, as shown below:



If you then draw a second line, from one end of the first line to where the two arcs intersect, you will have created a precise 60^0 angle.

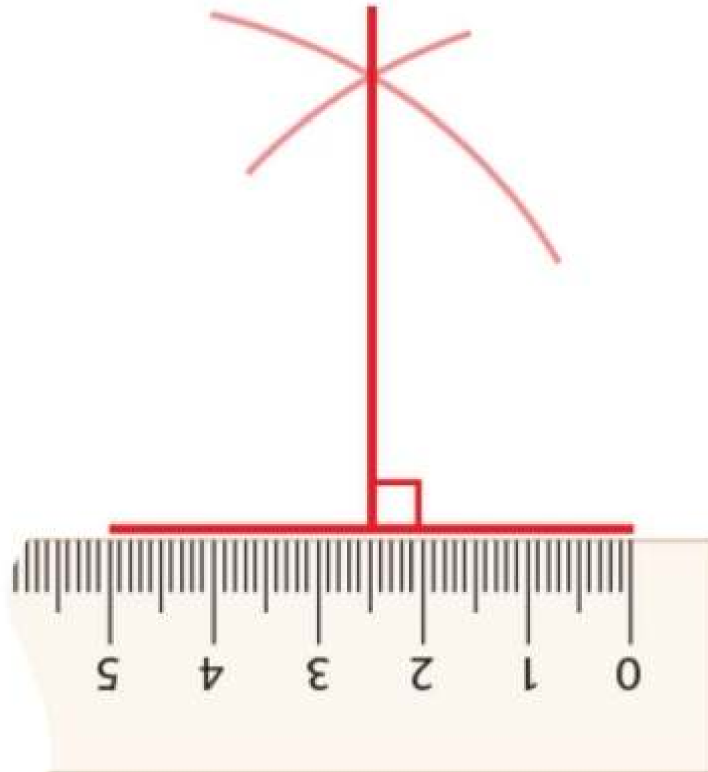


*Note: from here, you can easily create an equilateral triangle by drawing one more line!



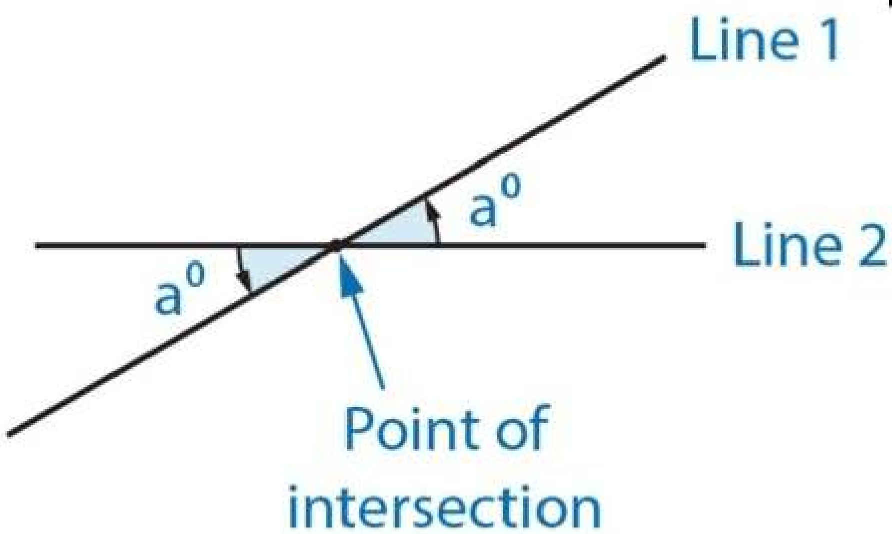
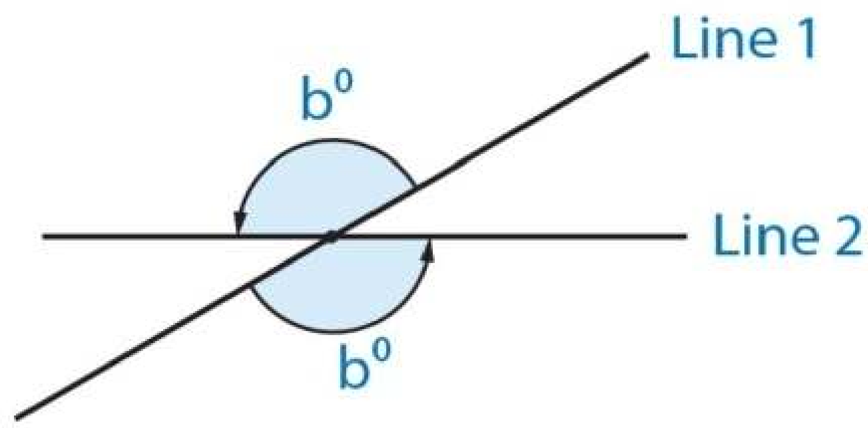
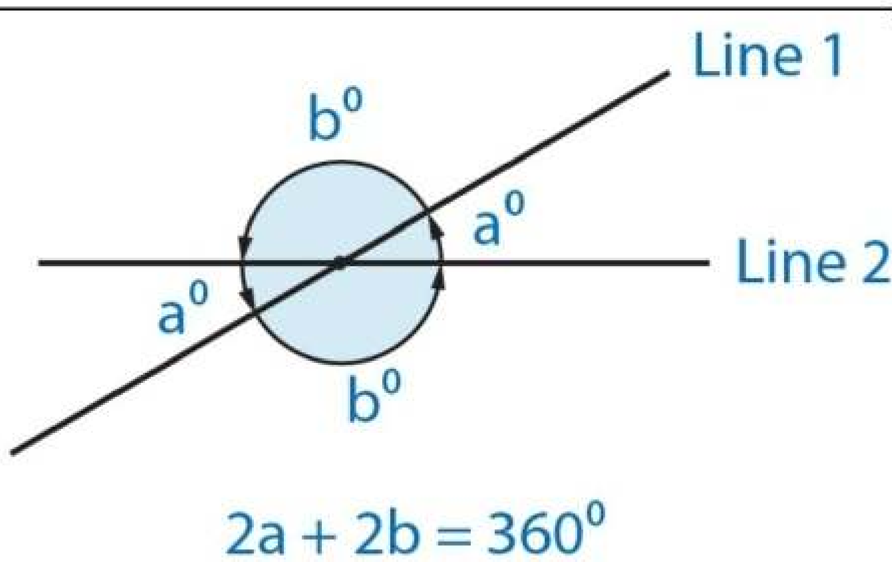
Constructing 90^0 Angles

To construct a 90^0 angle, draw your first line at a specific length, adjust the width of the compass to the same length as the line, and scribe the two arcs as above. This time, locate the centre of your first line, and draw your second line straight up from this point to where the two arcs meet. This will create a 90^0 angle as shown below:



Helpful Geometry Tips

The following diagrams show the angles produced when two straight lines intersect one another. Some basic tips that can be helpful for identifying these angles are stated in the following table.

<table>
<tr><th colspan="2">Helpful Geometry Tips</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">The laws of geometry state that (provided the two lines are straight) the opposite angles will always be equal</td></tr>
<tr><td>
</td><td>It is also helpful to remember that adding all the angles will produce a full circle/revolution, i.e. 360^0.

So in this case: $2a + 2b = 360^0$</td></tr>
</table>

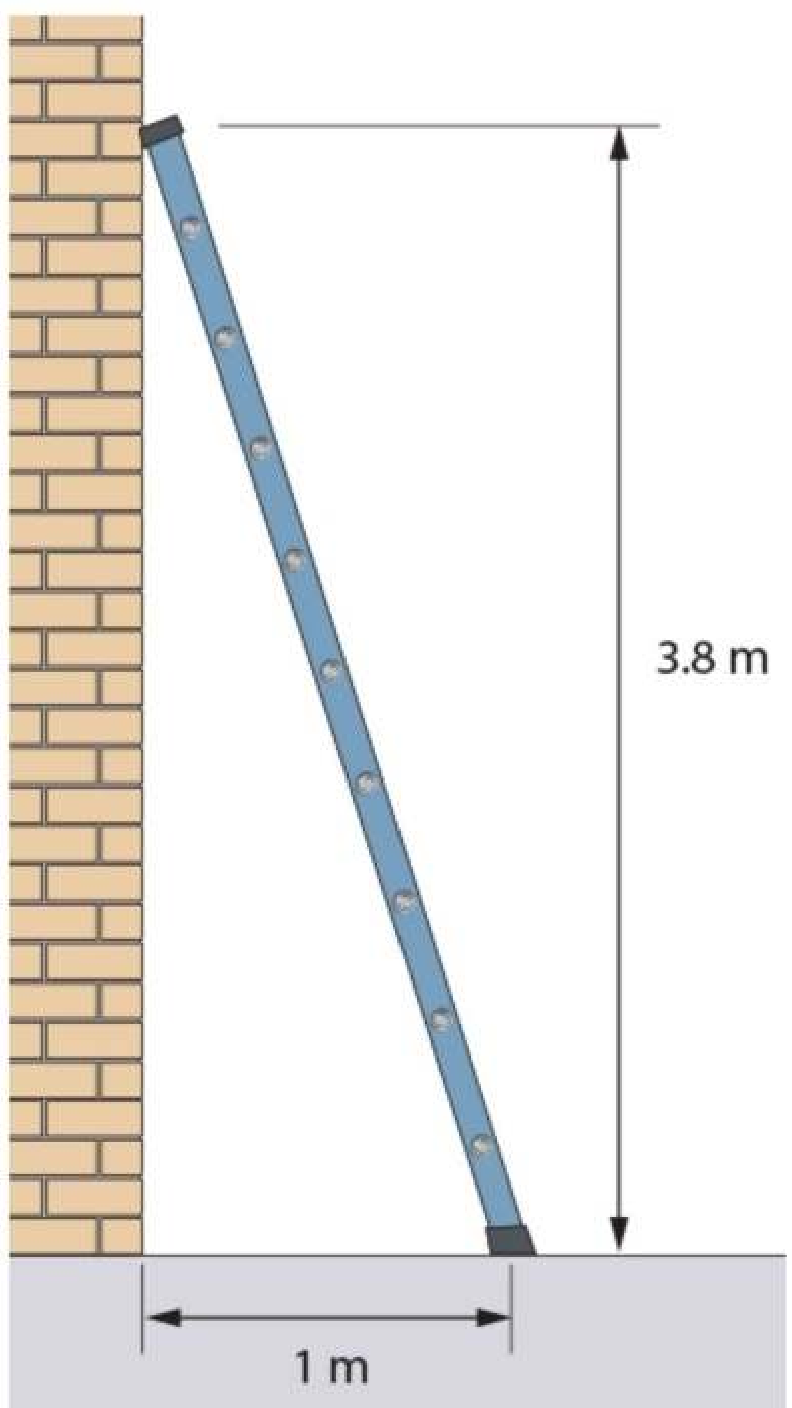
This learning activity consists of 6 parts designed to develop your understanding of where and how angles are important to electrotechnology work, and the methods of constructing angles to solve problems.

Triangles in Electrotechnology Work

Right angle triangles can be used to represent various parameters in electrical circuits. If these triangles are drawn to scale, the sides and angles will accurately represent these circuit characteristics, which can even be measured and identified from the triangle! These triangles can actually be used to solve circuit problems that would otherwise need to be calculated, so being able to construct and draw triangles accurately is a very useful skill indeed.

Using Scales

Angles and triangles used for electrotechnology work are usually drawn using a scale. This means that the *proportions* of the drawing are the same as the 'real world' proportions, but the *size* of the drawing can be made to fit conveniently on a page as needed. For example, consider that we want to draw a triangle to represent the following:



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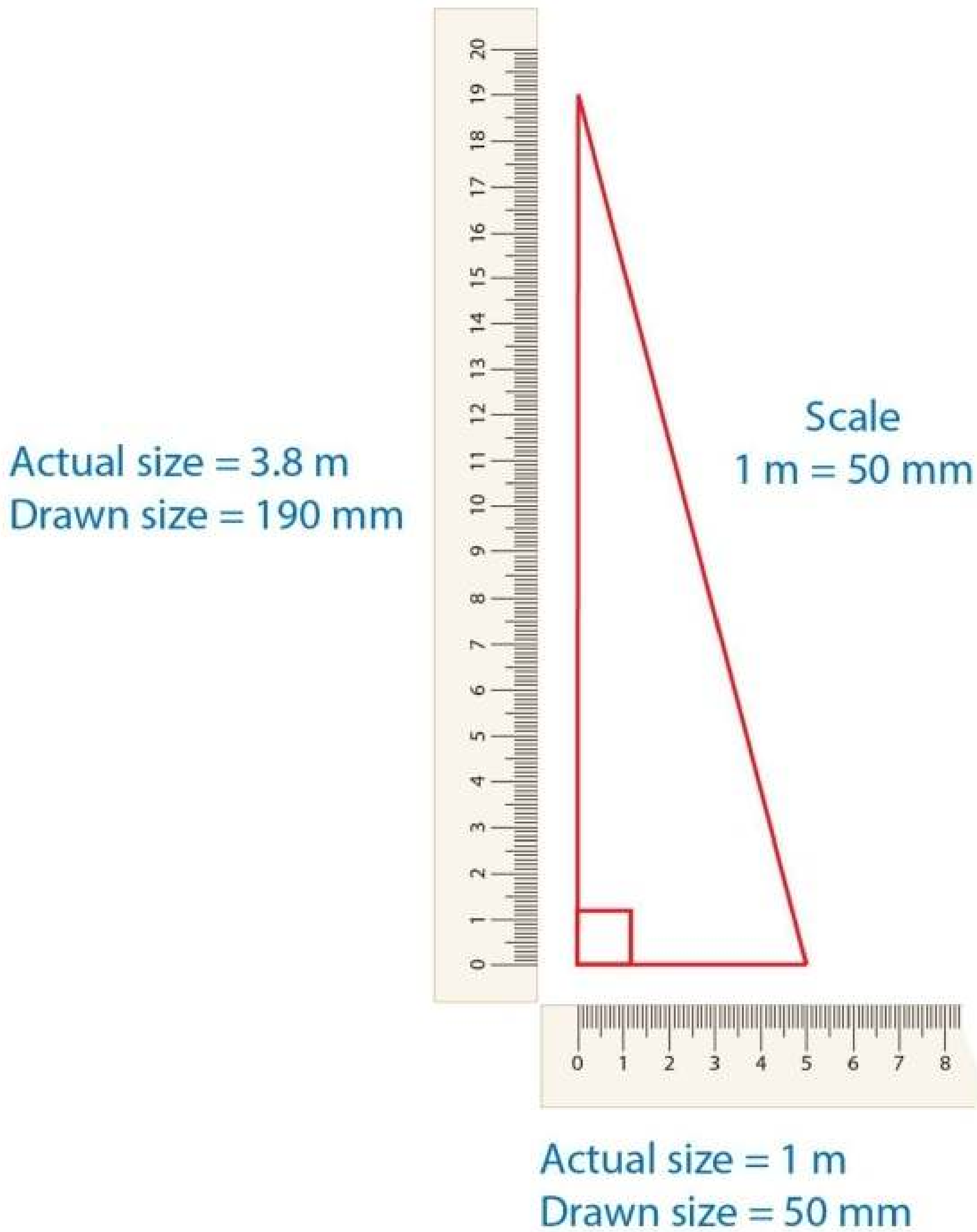
It’s impractical to draw a life-size triangle, so a suitable scale must be selected, for example:

1 metre = 10 millimetres

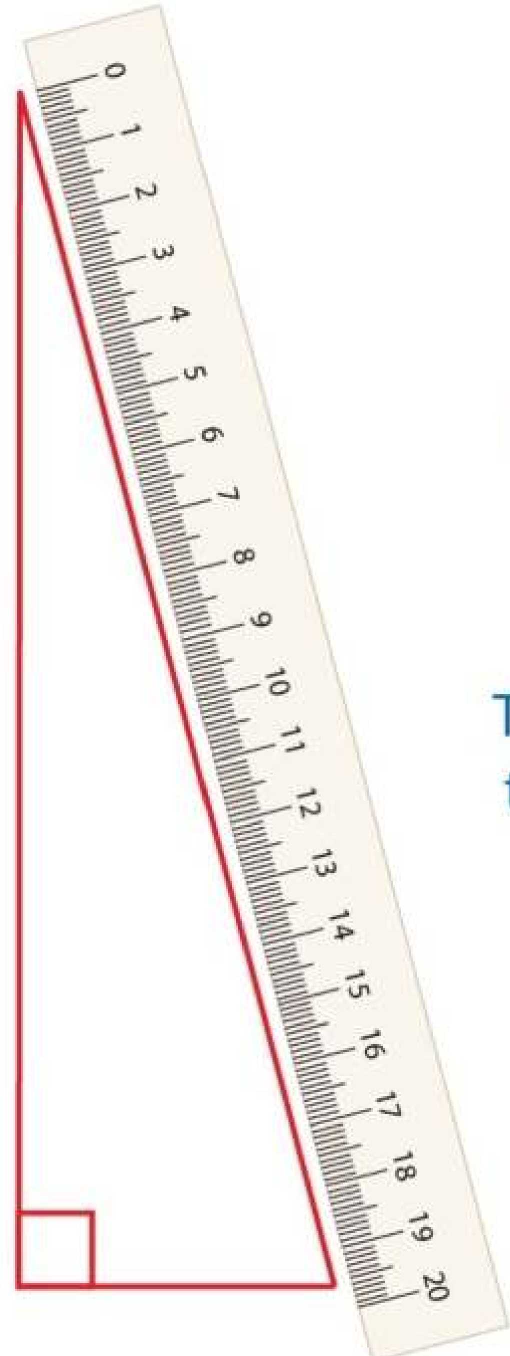
This would result in the diagram of the triangle being 10 mm across and 38 mm from top to bottom. If this was going to be too small, we could choose a different scale, such as:

1 metre = 50 millimetres

This would result in the diagram of the triangle being 50 mm across and 190 mm from top to bottom, as shown below:



If we draw the triangle accurately, we can take measurements to identify unknown values. In this case, for example, we could measure the length of the hypotenuse and then apply the scale to determine the actual length of the ladder.



Measured size = 196 mm

196 / 50 = 3.92

Therefore the actual size of the hypotensuse is 3.92 m

When drawing triangles and angles for the purpose of measuring unknown sides or angles, it's essential to draw all lines accurately, and to the same scale – otherwise any measured values will be incorrect.

Constructing a Right-Angle Triangle

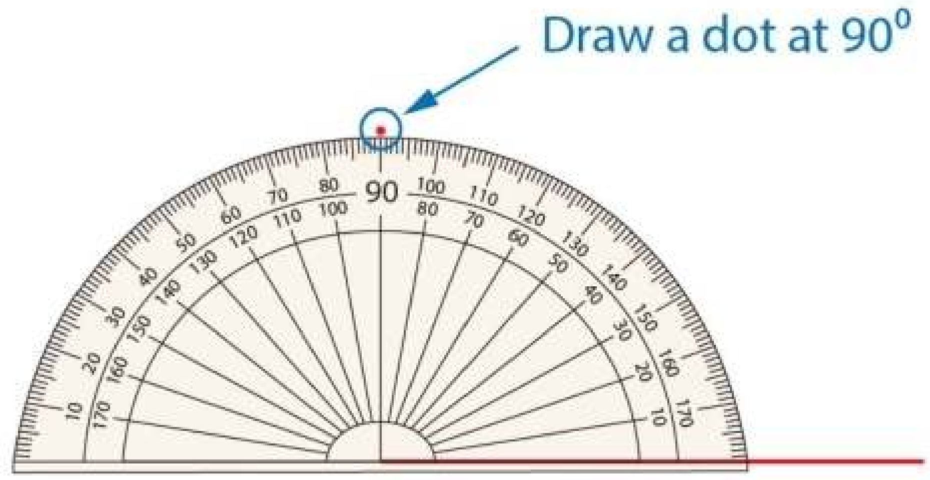
Consider that you need to draw a right-angle with a base of 10 metres and a height of 5 metres.

1) The first step is to choose an appropriate scale – in this case, a simple scale would be:

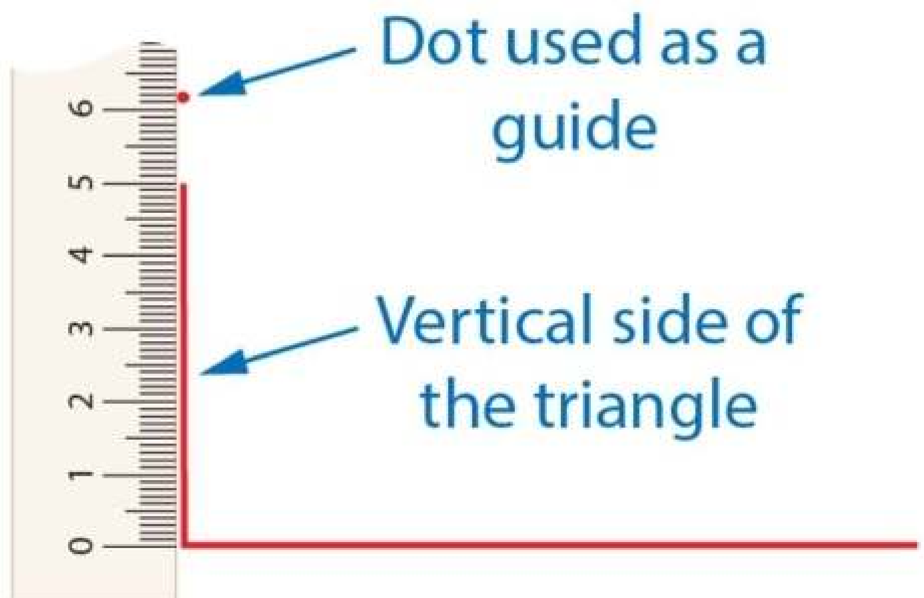
1 m = 10 mm

2) The second step is to draw the base of the triangle, which is 10 metres in length, therefore we need to draw a 100 mm line (10 x 10 mm = 100 mm):

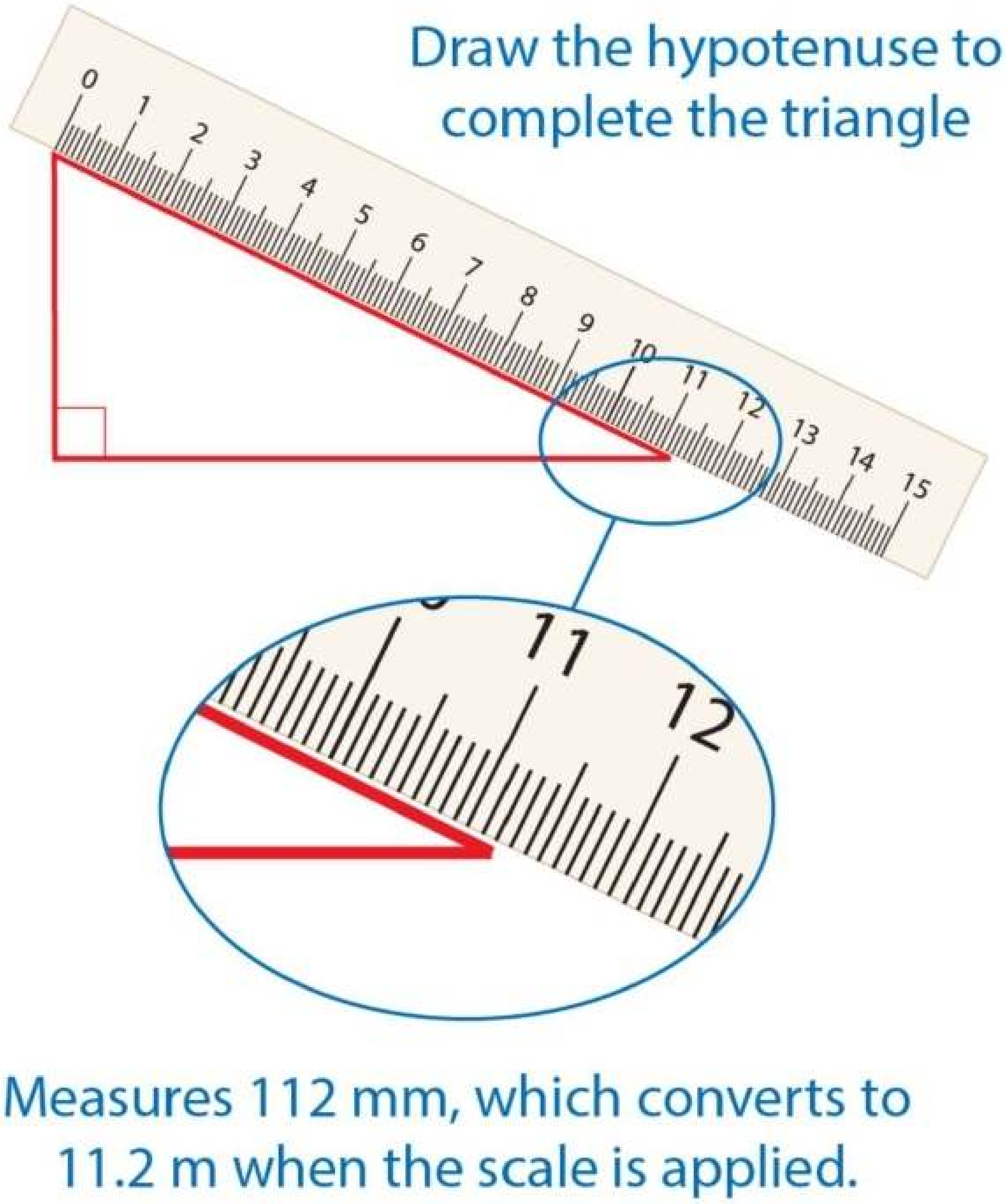
3) Next we can use a protractor to draw a dot at 90^0 to the base:



4) The next step is to draw the vertical side of the triangle using the dot marked at 90^0 as a guide. The height of the triangle is 5 metres, therefore the line needs to be 50 mm in length (5 x 10 mm = 50 mm):



5) Finally, join the two open ends of the triangle to complete the hypotenuse, which can now be measured to determine the unknown value:



To apply the scale, we need to find out how many lots of 10 mm are in the answer, as 10 mm = 1 m. We do this by dividing the measured value by 10:

112 mm ÷ 10 = 11.2 m

The answer can also be confirmed by applying Pythagoras' Theorem (method 1):

$$c^2 = a^2 + b^2$$

$$\text{c} = \sqrt{a^2 + b^2}$$

$$\text{c} = \sqrt{10^2 + 5^2}$$

$$\text{c} = \sqrt{100 + 25}$$

$$\text{c} = \sqrt{125}$$

$$\text{c} = 11.2 \text{ m}$$

Introduction

Literacy refers to our ability to read, interpret and apply written information. This encompasses reading and understanding passages of text, the interpretation of plans and diagrams, as well as effectively expressing information in written form. In this topic you will learn about the levels of reading comprehension, spelling and sentence construction needed for the electrotechnology work environment.

Literacy Concepts

In order to work effectively with written information, we need to understand the rules governing the structure of words and sentences in the English language. This group of rules is referred to as 'grammar'. The ability of a person to communicate effectively in writing depends heavily on their understanding of grammar.

Grammar can be broken down into two main areas, as described in the following table.

Literacy Concepts		
Concept	**Description**	**Examples**
Spelling	The agreed upon selection and arrangement of letters to produce a word.	Correct spelling: • Apples and oranges Incorrect spelling: • Apels and orunjes
Syntax	The selection and arrangement of words to produce coherent sentences and passages.	Correct syntax: • I like apples a lot. Incorrect syntax: • I liking apples lots.

Literacy for Electrotechnology Work

Minimum literacy levels are needed in the electrotechnology industry, as interpreting and communicating with written information is an integral part of almost every work function.

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Examples of where literacy skills are commonly applied in the electrotechnology industry include:

- Carrying out risk assessments.
- Understanding safety and other signage in the workplace.
- Reading and interpreting job specifications.
- Reading and interpreting Australian Standards.
- Reading and interpreting plans and drawings.
- Filling out job cards and completing maintenance logs.
- Documenting inspection and testing results.
- Filling out timesheets and other employer documents.
- Documenting workplace experience (workplace evidence collection).

Literacy Levels

There are five defined levels of 'reading' and 'writing', as summarised in the following table.

<table>
<tr><th colspan="2">Literacy Levels for Electrotechnology Work</th></tr>
<tr><td>Level 1</td><td>Reading:
Identify letters and basic symbols.
Read and understand short, simple passages of text and graphic instructions.
Writing:
Type own name or single words into a computer.</td></tr>
<tr><td>Level 2</td><td>Reading:
Read and understand short texts related to technology.
Choose basic computer software from written descriptions.
Extract information from a list.
Interpret basic instructions that have text and pictures.
Writing:
Write a short description of an object.
Note down simple, routine information.</td></tr>
<tr><td>Level 3</td><td>Typically needed for Certificate II level (pre-vocational) Electrotechnology qualifications.
Reading:
Read and extract information from technical manuals.
Comprehend short summarised information.
Writing:
Use electronic search engines effectively.
Use word processing software to produce texts.
Write simple instructions and basic reports on technology.
Complete workplace documentation.</td></tr>
</table>

Level 4	*Typically needed for Certificate III level (apprenticeship) Electrotechnology qualifications.* Reading: • Understand technology after reading a brochure/manual. • Compare technologies based on written information. • Read complex diagrams to identify components and procedures. • Interpret and apply health and safety, environmental, ethical and technical guidelines. Writing: • Write a report on the impact of a particular technology. • Type up a hand-drafted report.
Level 5	*Typically needed for Certificate IV and higher level (post-trade) Electrotechnology qualifications.* Reading: • Effectively research new systems/technology. • Define the purpose and objectives for the use of a particular technology. • Use technological principles to reduce environmental impacts or physical constraints. Writing: • Draw on various sources and computer skills to prepare a report. • Prepare written or oral reports that critically evaluate technical texts. • Adapt task instructions to suit changes in technology.

Check your understanding of the content by answering the following questions.

What are some common electrotechnology work tasks that require the use of reading skills?

What are some common electrotechnology work tasks that require the use of writing skills?

(answers at bottom of page)

Introduction

The ability to communicate effectively is an important skill, not just at work, but in all areas of life. A core part of electrotechnology work involves communicating with colleagues, customers and suppliers. Poor communication leads to significant amounts of time and money being wasted, and can cause frustration, stress and even serious injuries. In this topic you will learn about effective communication with suppliers and clients in the electrotechnology industry.

Communicating with Customers

There are many things that may need to be communicated throughout the course of a work day. Work-related issues that commonly need to be discussed with customers include the following:

Communicating with Customers	
What work needs to be done	• Determining what the customer wants. • Confirming the details of the actual work to be performed. • Discussing any technical or safety issues that might affect the work.
When work can be carried out	• Determining times the work can be carried out. • Confirming methods for accessing the site. • Coordinating work to minimise any potential impact on others (e.g. due to loss of power).
Contractual details	• Timelines and staging of work. • Arrangements for invoicing and payments. • Variations to the work due to unforeseen problems.

Communication Methods

In the electrotechnology industry, it's common to communicate with customers through:

- Face to face conversations.
- Telephone conversations.
- Email and text messaging.
- Formal documentation e.g. quotes/tenders.

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Check your understanding of the content by answering the following question.

1. Why would an electrotechnology contractor need to discuss access to a job site with the customer?

2. What types of contractual details might the contractor need to discuss with the customer?

(answers at bottom of page)

Communication Techniques

Effective communication with customers comes from being polite, responsive, and by asking the right questions to find out what they need. It is also about building relationships so that they gain confidence in the service you provide.

To be effective in communicating with customers use your E.A.R.S:

- **E**xplore by asking questions.
- **A**ffirm to show you are listening.
- **R**ecap to show understanding.
- **S**ilence – listen some more.

It's always important to be courteous and show respect. "Please" and "Thank you" are always appreciated.

Check your progress answers.

1. Why would an electrotechnology contractor need to discuss access to a job site with the customer?

Answer: The contractor may need to obtain entry permissions, keys etc. in order to perform work in restricted areas

2. What types of contractual details might the contractor need to discuss with the customer?

Answer: Timelines, staging of work, invoicing, payments and variations

Communicating with Suppliers

Electrotechnology workers need to be able to communicate effectively with suppliers in order to source the parts and materials needed for carrying out work. Issues that commonly need to be discussed with suppliers include the following:

Communicating with Suppliers	
Making enquiries	• Telling the supplier what you need. • Comparing and contrasting alternate parts and materials. • Confirming the technical details and specifications of specific parts and materials.
Purchasing parts and materials	• Confirming pickup/delivery arrangements. • Invoicing and payment. • Arranging the return of unwanted/damaged goods.

Communication Methods

It's common to communicate with electrotechnology suppliers through:

- Face to face conversations.
- Telephone conversations.
- Email.
- Formal documentation e.g. Purchase Orders.

Check your understanding of the content by answering the following questions.

1. What types of things would an electrotechnology contractor enquire about with a supplier?

2. When a contractor purchases materials, what type of formal document does the supplier give to the contractor as a record of the purchase?

(answers at bottom of page)

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Communication Techniques

Some general tips for effective communication are to always:

- Be clear and direct about what you want to say.
- Be friendly, patient and respectful.
- Listen carefully.
- Try to understand where the other person is coming from.

When making enquiries to suppliers, make sure you have any information that may be required close by, such as ratings and parts numbers. It is also a good idea to have a pen and paper ready in-case you need to note down any details.

Check your progress answers.

1. What types of things would an electrotechnology contractor enquire about with a supplier?

Answer: Various types of parts, components and materials needed for jobs

2. When a contractor purchases materials, what type of formal document does the supplier give to the contractor as a record of the purchase?

Answer: An invoice