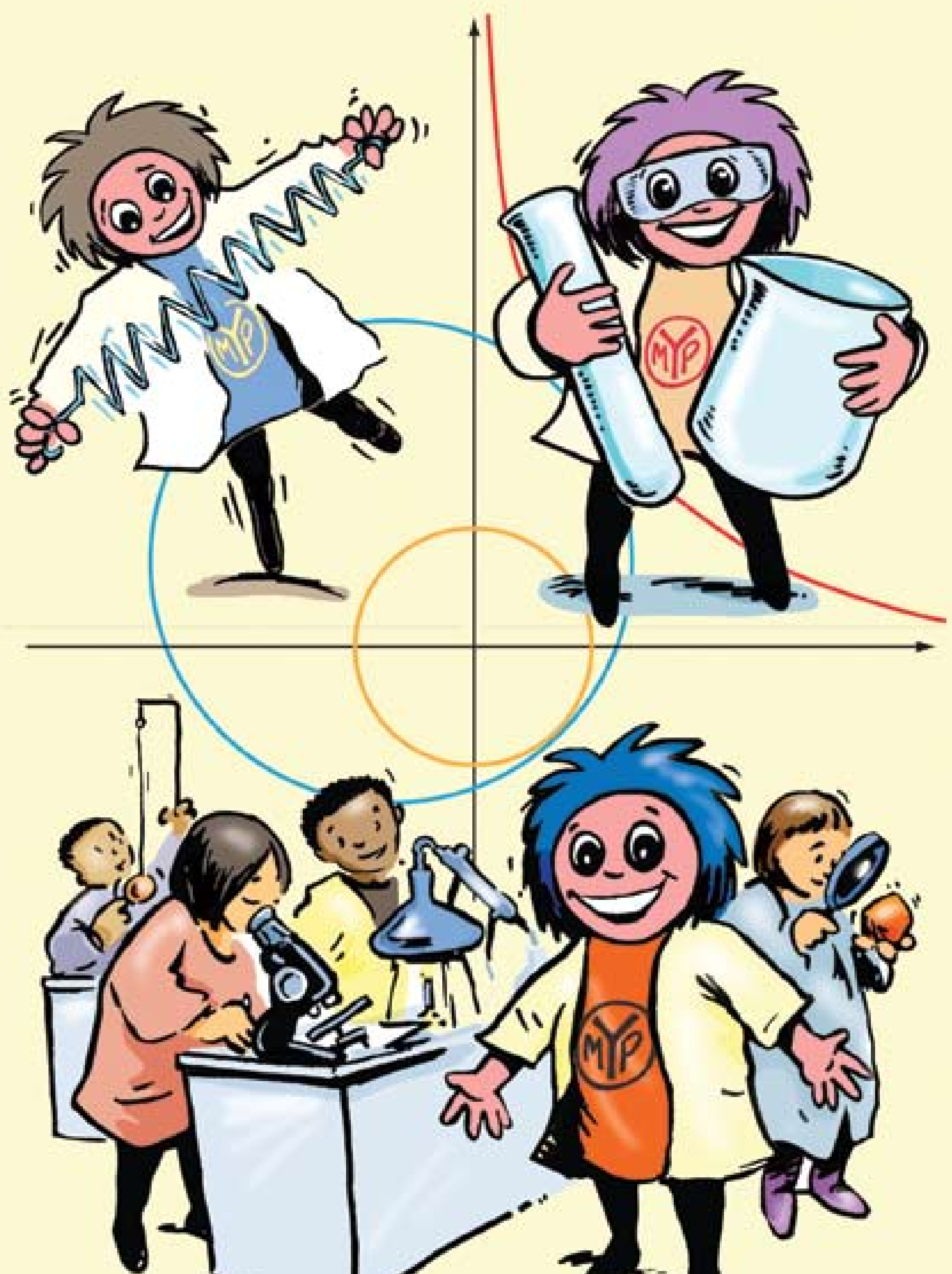
IA Handbook for MYP Sciences

Christopher Talbot, Cesar Reyes, David Fairley

FOR USE WITH THE
I.B. PROGRAMME

2nd EDITION



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INTERNAL ASSESSMENT HANDBOOK FOR MYP SCIENCES

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MYP

SECTION 2.3 MANAGING VARIABLES AND COLLECTING DATA

DESCRIPTORS FOR ACHIEVEMENT BY LEVELS

The student is able to:

1-2 **outline** the variables

3-4 design a **safe method** in which he or she **selects materials and equipment.**

5-6 **describe** how to manipulate the variables, and describe how **sufficient, relevant data** will be collected

7-8 **explain** how to manipulate the variables, and explain how **sufficient, relevant data** will be collected.

2.3.1 VARIABLES

There are four types of variables:

- A **categoric** variable is a variable that is described using words. For example, the colour of hair is a categoric variable, such as red, blond or black hair.
- A **discrete** variable is a variable described in whole numbers. For example, the number of flowers on a leaf or the number of beetles in a quadrat.
- An **ordered** variable is a variable where the data can be placed into order. For example, small, medium and large lumps of calcium carbonate.
- A **continuous** variable is a variable that can be measured and represented by a number. For example, the height of trees.

When designing your MYP investigation you should always plan to measure continuous data whenever possible.

For example, if you were growing seedlings in volumes of water with different salt concentrations then it would be best to measure the heights of all the seedlings. This is more scientific than recording the number that are 'tall' or 'short'.

Proximate and ultimate variables

A proximate dependent variable is the variable that is directly measured in an experiment, e.g. in a calorimetry experiment this would be a temperature change. The ultimate dependent variable in this case would be an enthalpy change, which requires processing of the proximate variable in order to determine it (by using the specific heat capacity of water to calculate the heat released and dividing this by the number of moles of fuel burnt). In short, the proximate variable is determined directly by experimental measurement, the ultimate variable is obtained by processing the proximate variable in some way. Another example would be an electrical investigation where we wish to determine the resistance of a particular material - the voltage and current would be proximate variables and the resistance (calculated using Ohm's Law) would be the ultimate variable. In an investigation of reaction rate a student would first measure reaction time in seconds (proximate) before taking the reciprocal to obtain a value proportional to rate, in seconds^{-1} (ultimate). It is important that your method indicates clearly what data processing will be performed with your raw data (see **Chapter 3: Criterion C: Processing and Evaluating**).

EXERCISE 2.5

Classify the following variables:

- Internal body temperatures of people
- Lengths of tree snakes (compared with each other)
- Eye colour in domestic cats
- Number of toes on the left foot of people

2.3.2 DESIGNING AN INVESTIGATION

METHOD

Fair Testing

When conducting a scientific investigation, it is possible that there are other variables, aside from the selected independent variable, which could affect the dependent variables. If this is the case, then it is important that these other variables must not change.

A fair test is one in which there is one independent variable that affects the dependent variable. All other variables are controlled and kept constant.

Consider an investigation studying the variables that affect the rate of reaction between marble chips (calcium carbonate) and dilute hydrochloric acid. Possible independent variables include: concentration of acid, temperature of acid and surface area of the calcium carbonate. Three investigations are possible, each involving the changing of one of these variables and making the other two controlled (*Figure 212*).

Independent variable	Controlled variables
Concentration of acid	Temperature of hydrochloric acid and surface area of calcium carbonate
Temperature of acid	Surface area of calcium carbonate and concentration of hydrochloric acid
Surface area of calcium carbonate	Temperature of hydrochloric acid and concentration of hydrochloric acid

Figure 212 Possible investigations into the reaction between calcium carbonate and hydrochloric acid

If the MYP Science investigation is a Biology investigation, perhaps involving fieldwork, then additional issues should be considered. Plants and animals live in complex environments whose variables are complex and difficult to control. You should aim to ensure that the controlled variables change in the same way, except for the variable you are investigating. For example, if you are studying a small section of woodland then you must take measurements to see whether all parts are receiving the same rainfall and sunlight.

If you are investigating two variables in a large population of animals or plants then you will need to carry out a survey of the population. A random sample of the population needs to be studied.

Controls are used in MYP Chemistry and Biology investigations to allow comparison of observations in the presence and absence of the independent variable (i.e. the variable being changed).

EXERCISE 2.6

An MYP Science student proposes the following hypothesis: leaves in the light need carbon dioxide to synthesize starch. Outline the test and the control. Explain the need for a control in the investigation.

For example, you might be studying the effect of a phosphate fertiliser on the growth of plants. A control group should be included. For example, ten plants may receive the fertiliser and the other group of ten plants will be a control and not be treated with fertiliser.

The three test tubes shown below in *Figure 213* summarise a simple investigation to determine whether air and water are required for rusting. Test tubes A and B are the controls since they exclude water and air, which are both hypothesized to be necessary for rusting.

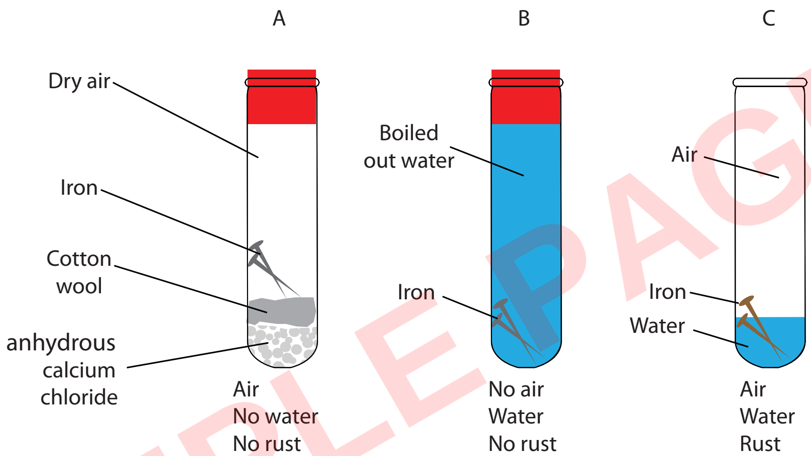

Figure 213 Factors affecting the rusting of iron

2.3.3 CHOOSING VALUES OF A VARIABLE

A trial run may be very useful before you perform your MYP Science investigation. A trial run is performed to establish the upper and lower limits (the range) of your independent variable. An absolute minimum of five trials should be performed.

Do you have the correct conditions?

CHEMISTRY

For example: An investigation into the reaction between magnesium and hydrochloric acid produces gas too quickly to measure at 30 second intervals in a 100 cm^3 gas syringe.

This could be improved by one or more of the following:

- lower the temperature of the acid
- lower the concentration of the acid
- use a gas syringe with a larger volume

BIOLOGY

For example: An investigation into photosynthesis that produces insufficient amounts of oxygen-enriched air.

This could be improved by one or more of the following:

- light of high enough intensity
- sufficient pondweed (*Elodea*)
- sufficient dissolved carbon dioxide
- raising or lowering the temperature
- using water with a lower concentration of chlorine

PHYSICS

For example: An investigation into the evaporation of volatile liquids resulted in a mass loss too small to accurately measure.

This could be achieved by one or more of the following:

- use larger amounts of the liquid
- raise the temperature of the surroundings
- increase the surface area of the evaporating liquid
- use an electronic balance with a greater sensitivity, i.e. more decimal places

Have you chosen a sensible range?

CHEMISTRY

For example: Burning alcohols investigation (*Figure 214*)

There is sufficient alcohol for a reasonable burn length, but only small amounts of alcohol are combusted. Type of alcohol or, preferably, number of carbon atoms is the independent variable.

- You might need to move the spirit burner closer to the calorimeter.

BIOLOGY

For example: Photosynthesis investigation

There is sufficient oxygen to measure, but the results are all very similar. Light intensity is the independent variable.

- You may not have chosen a wide enough range of light intensities. You might need to move the lamp further away from and closer to the photosynthesising plant.

Figure 214 Apparatus required for burning alcohols

PHYSICS

For example: Strength of an electromagnet (operated using a small battery and a variable resistor)

The electromagnet picks up a small mass of iron filings, but the results are all very similar. Electric current is the independent variable.

- You may not have chosen a wide enough range of electric currents. You might need to replace the battery and variable resistor with a power pack.

Have you got enough readings that are close together?

If the results are very different from each other you might not see a pattern because you have large gaps between readings over the important part of the range. This is especially important for investigations that aim to find the optimum pH or temperature for enzyme activity.

2.3.4 ACCURACY AND PRECISION

Accuracy

Accurate results are very close to the true values. Your investigation should provide data that is accurate enough to validate or invalidate your hypothesis. However, it is not always possible to know what the true values are.

How do I obtain accurate data?

- Repeat the investigation and average the results obtained.

Try repeating the measurements with a different measuring instrument and see if you obtain the same readings. For example, if you are measuring temperature changes then use another thermometer of the same type.

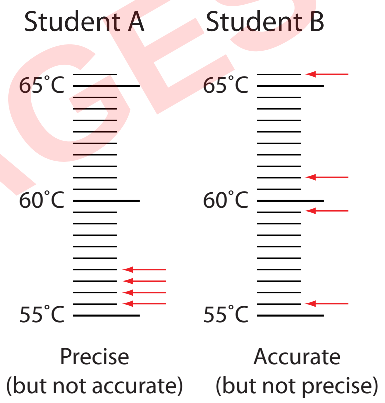

Figure 215 Accuracy and precision

- Use high quality instruments that measure accurately.

For example, use a burette which measure volumes more accurately than a measuring cylinder. A mercury thermometer is more accurate than an alcohol thermometer.

- Use the instruments properly and carefully.

For example, you should read to the bottom of the meniscus (curved liquid surface) when measuring volumes of liquids.

Precision

If your repeated results are closely grouped together then the results are said to be precise. Your MYP investigation must provide data with sufficient precision. If there are large differences within sets of repeat readings then you will not be able to draw a valid conclusion.

How do I get precise data?

- You have to repeat your tests.
- You have to repeat your tests in exactly the same way.

For example, you might be assessing the rate of reaction between sodium thiosulfate and dilute acid in a flask by observing a cross on a piece of paper. The same or identical cross and conical flask must be used. The same person must record the observation.

However, note that results may be precise but inaccurate. For example, consider a digital balance, it is very precise and measures masses to 4 decimal places. However, when there is no mass on the pan, the balance gives a reading of 0.0050 g. This means that every mass is inaccurate by a factor of 0.0050 g, for example, a mass of 50.055 g is actually 50.05 g.

The difference between accurate and precise results is illustrated in *Figure 215*. A spirit burner with ethanol is used to heat 100 cm^3 of water at room temperature for 5 minutes. Two MYP Science students repeated this experiment, four times each. Their results are marked on the thermometer scales in *Figure 215*.

Precise results are grouped together closely. Accurate results will have a mean or average close to the true value (60°C).

Method

The method for your investigation should be written in a distinctive style. It is meant to be factual, functional and objective (impersonal). Since the investigation has not been completed, the method should be written in the future tense. However, you will not be penalised if you write a formal method in the past tense after carrying out your planned method.

Many MYP students number the steps of their method. This is not necessary, but may be helpful so you do not miss out any steps when you come to perform the investigation.

However, the guiding principle when you write your method for your MYP Science investigation is that another MYP Science student could perform the investigation and obtain results within experimental error. It is very important that you emphasise which part of the method is the test and which, if relevant, is the control.

If something you did not expect happened, you may have to describe it and explain why it occurred. You may then have to repeat that part of the investigation. Any changes that you make to your planned method while implementing it should be included, highlighted and justified. The method must indicate which steps will be repeated and how many times.

Do not hide your mistakes or problems. The IBO strongly encourages academic honesty.

Examples

CHEMISTRY

Some of the copper(II) sulfate crystals from the third crystallisation experiment were spilt.

BIOLOGY

Two of the thirty germinating pea seeds grew fungus and died.

PHYSICS

The resistance wire became hot and melted, breaking the circuit.

A list of materials and equipment should also be included at the beginning of the method. A poor (left column) and a good list (right hand column) of material and equipment are shown in *Figure 216*.

Materials or equipment	Materials or equipment
Amylase	*Beta*-amylase from barley grains
Magnesium	Cleaned magnesium ribbon (1 cm diameter)
Gas syringe	Gas syringe (250 cm^3)
Flask	Conical flask (250 cm^3)
Thermometer	Mercury thermometer (0 - 100 °C) ± 0.5 °C
Spatula	Plastic spatula
Methanoic acid	1.00 mol dm^{-3} methanoic acid, HCOOH(aq)
Clock	Manually operated electronic stop watch (± 1 s)
Data logger	pH data logger sensor (manufacturer: Vernier Logger Pro 3.1: ± 0.02 pH units)
Voltmeter	Analogue voltmeter 0 – 6V (±4%)
Wire	Constantan (copper/zinc) wire; diameter 1.62 mm

Figure 216 Poor (left) and good (right) lists of material and equipment for MYP Science Investigations

Many pieces of glassware and other apparatus in the laboratory will have the manufacturer's error printed on them. This information should be recorded in the method of your plan.

A method should be more than just a 'recipe' that another student can follow. You should try to give scientific reasons for anything you plan to do. *Figure 217* shows three measuring cylinders. If, for example, the measuring cylinder on the far right was going to be used then it should be described as a glass measuring cylinder, capacity 100.0 mL ± 0.8 mL. This means that a measurement of 100 mL will lie within the range 100.8 mL and 99.2 mL. The plus-or-minus 0.8 mL is the error or random uncertainty. It is an example of a random error.

Figure 217 Three measuring cylinders

For example, if during an investigation into osmosis you are surface drying potato chips that have been placed in a solution, explain why you are doing this e.g. to remove surface solution which could vary and make the chips appear heavier.

If you are investigating a chemical or biochemical reaction, then make it quite clear what the end point of the reaction is. For example, if investigating the enzyme rennin then the end point could be the time taken for the milk to coagulate so that it will not run when the tube is placed horizontally. Or, alternatively, when catalase reacts with hydrogen peroxide, measure the time taken for an amount such as 10 cm^3 of oxygen to be produced.

Write down the range and number of readings you are going to take. You should aim for at least 5 different measurements of a variable for an investigation. Also give reasons why you have chosen this range. For example, for an enzyme investigation you may obtain data between 20 and 70 ^{0}C but not between 0 and 100 ^{0}C. This is because enzymes are expected to be denatured at the extremes of the second range and be inactive. The first range is expected to include the optimum temperature of the enzyme.

Always make it clear that you are going to repeat your results at least three times and obtain an average (mean) of each measurement. You must explain why this is necessary, for example, to give an indication as to how reliable the results are - if the readings are close to each other then the data is reliable. *Figure 218* shows an example of the outline of a plan of a method from a relatively simple investigation into the solubility of sodium chloride. A detailed description of the chemicals and apparatus has not been included, but note how the outline of the method relates to the requirements of Criterion B: Inquiring and Designing. Include a cross-section diagram with labels and dimensions.

Identifying all the relevant variables and explaining how to manipulate them.	In this investigation, the independent variable is the temperature of water. I will use a Bunsen burner to raise the temperature of the water and ice to lower the temperature of the water. The dependent variable is the time it takes to dissolve powdered sodium chloride. I will use 3.00 g of sodium chloride so that I will not have to wait a long time for it to dissolve. The electronic balance will be used to measure out 3.00 g. To make my experiment a fair test, I will use the same volume of water, same mass of sodium chloride powder and the same size and shape container as this can affect the rate of heat lost to the environment. I will monitor the temperature with a thermometer. I will stir five times after the sodium chloride has been added.
Include precise values	The temperature of the water will be varied from 40 °C to 90 °C at intervals of 10°C. The volume of the water used will be kept at 100 cm^3.
Rationale for the method is provided	I will use sodium chloride powder instead of crystals so that the time it will take to dissolve is shorter. If time is measured, it is good practice to have at least three trials.

Figure 218 An outline for a plan into an investigation of the solubility of sodium chloride

Two examples of parts of detailed methods are given, one for a Biology investigation involving enzymes and one for a Physics investigation involving resistance. Note the detail and precision in the method.

BIOLOGY

For example: From an investigation into the activity of salivary amylase

5 cm^3 of the 2% (by volume) salivary amylase solution will be added to a labelled test tube containing 5 cm^3 of 2% (by volume) starch solution. The tube containing this reaction mixture will be placed in a water bath thermostatted at 37 °C. An electronic stop clock will be immediately started.

Figure 219 A spotting tile

After 4 minutes, 1.0 cm^3 of the reaction mixture will be placed onto a ceramic spotting tile (*Figure 219*). Three drops of dilute iodine solution will be added to this sample and any colour change noted. Immediately after sampling, the reaction mixture will be returned to the water bath. The procedure described will be repeated at three minute intervals and the investigation will be continued for a total of fifteen minutes.

PHYSICS

For example: From an investigation into how the resistance of a nichrome wire varies with length

A potential difference of 6.0 volts will be applied to a 70 cm length of 0.28 mm diameter nichrome wire. This voltage will be measured with a 0 – 15 V D.C. analogue voltmeter. The current will be measured with a 0 – 3 A analogue ammeter but a more sensitive ammeter may be needed once I start performing some trial runs. The resistance can then be calculated from the ammeter and voltmeter readings. Values of resistance will be calculated by dividing voltage readings (in volts) by current readings (in amps).

The potential difference will be maintained at 6.0 volts, but the procedure above will be repeated and the nichrome wire shortened by 5.0 cm each time until it is only 10.0 cm long. The wire will be measured with a steel rule whose smallest divisions are 0.5 mm. I will view the wire and rule from directly above a flat table. The experiment described will then be repeated three times and average values calculated for each length. *Figure 220* shows part of the circuit the student intends to construct.

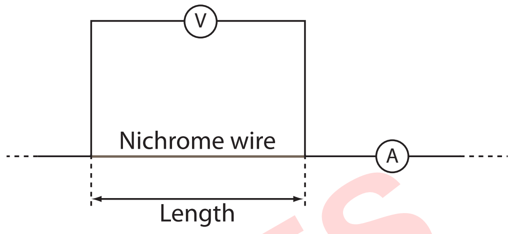

Figure 220 A possible circuit for investigating the resistance of a wire

However, since electrical resistance varies with temperature I plan to use a large beaker of cold water to keep the temperature of the nichrome wire constant and compensate for the heating effect of an electrical current. The resistance of a wire also varies with diameter and so, to ensure that I have the same diameter, I will use lengths of nichrome wire taken from the same reel.

I will use a micrometer screw gauge (with an accuracy of 0.01 mm) to check the diameter of each piece before using it. I will use a thermometer to monitor the temperature of the water bath to ensure that it does not change during the investigation. *Figure 221* shows an improved circuit.

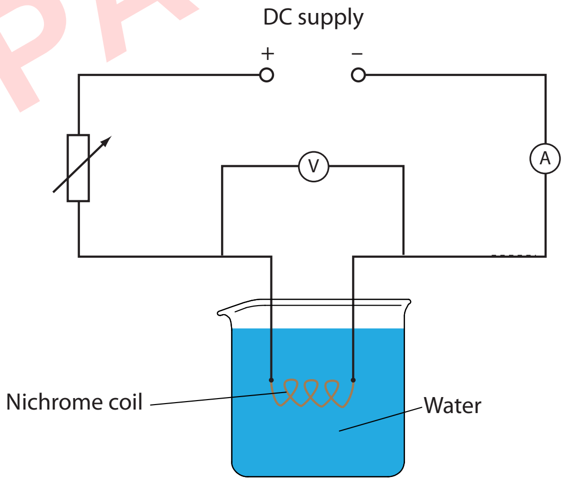

Figure 221 A more suitable circuit for investigating the resistance of a wire

2.3.5 DRAWINGS OF APPARATUS

A drawing of apparatus is also necessary for many MYP Science Investigations. It is very important that relevant information not included in the diagram is included in the method.

Examples

CHEMISTRY

The aspirin was dried for 4 hours in an oven maintained at 60 degrees Celsius.

BIOLOGY

The plant (*Tradescantia*) used in the experiment had first been de-starched by keeping it in a dark cupboard for 48 hours.

Drawing Apparatus

- Draw diagrams in cross section, not as three-dimensional pictures.
- Start at the top of your page and work downwards, so that you are less likely to run out of space.
- Make drawings sufficiently large so the detail can be seen.
- Do not draw Bunsen burners (use an arrow labelled 'heat'), the bench, gas taps or clamps.
- A water bath should be shown if used.
- Label important points on the diagram or unusual items.
- If you name the glassware, then use the correct names.
- Include relevant measurements or dimensions that would allow another student to set up the same apparatus in an identical way.

You may have to design and build an electrical or electronic circuit as part of an MYP Physics investigation. Circuit diagrams show the connections as clearly as possible with all wires drawn neatly as straight lines. The actual layout of the components is usually quite different from the circuit diagram and this can be confusing for the beginner. You should concentrate on the connections, not the actual positions of components.

Criterion B: Inquiring and Designing also requires you to suggest in your plan and method how you will process and analyse the raw data you are collecting.

For example, if you were investigating the stretching of a spring then you would plot a line graph of extension (y axis) against load (x axis). The extension is the increase in length compared to the unstretched spring. The spring constant is obtained from the reciprocal of the slope or gradient of the straight line. If the "load" force is being plotted then it is correct to plot load on the x-axis and extension on the y-axis.

However, Hooke's Law is usually given in the form $F = kx$ (or more correctly $F = -kx$) where x is the extension and also the x-axis variable. The force is no longer the "load" force, but rather the "elastic restoring force" in the spring (which equals the load by Newton's third law of motion and is dependent on the extension). The reason for doing this is that the gradient of the graph then directly gives the force constant of the spring in Newtons per metre. If extension is plotted vs load the force constant is then the reciprocal of the gradient.

If you were measuring times for magnesium to completely react with the same volume of different concentrations of hydrochloric acid then you would want to calculate the reciprocal of times (1/time or time^{-1}) as a measure of the rate of the reaction. A line graph of rate versus concentration could then be drawn.

If you were investigating the effect of sucrose solution on the mass and length of potato cylinders then you would probably want to calculate the increases and decreases and plot them on the same graph: length or mass on the y axis and concentration of sucrose on the x axis.