CHAPTER 1

The Scientific Endeavour

Introduction

In this chapter, we will learn about science and how it helps us to understand and explore the natural physical world. Scientific knowledge is obtained through making observations, carrying out experiments and analysing results. It can also be obtained through one's imagination and creativity. This knowledge is open to changes when new evidence surfaces. Lastly, the application of scientific knowledge can have beneficial and harmful effects.

1.1 Overview of Science

Learning Outcomes

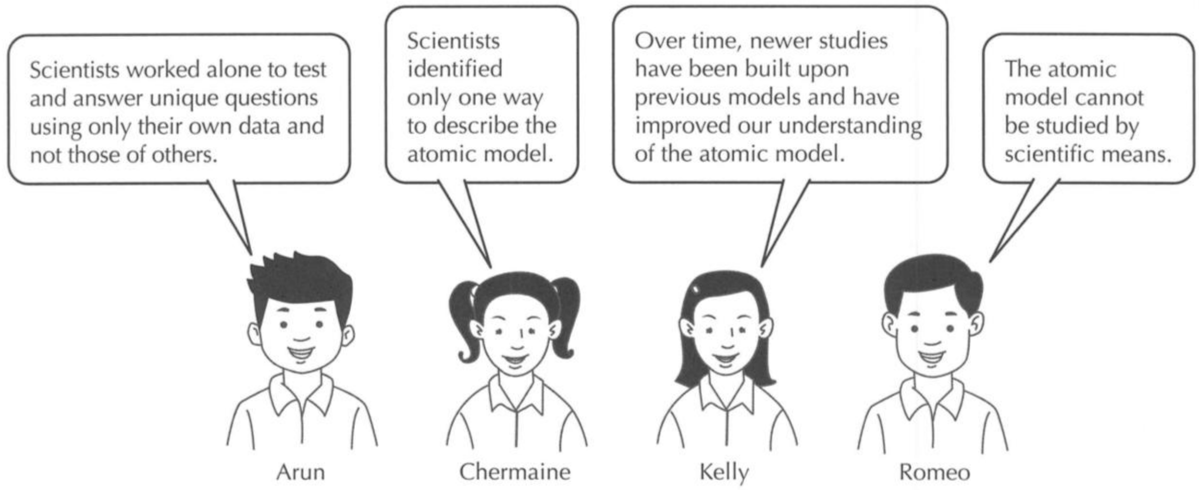
You should be able to:

- understand that science can be observed in the laboratory and in daily life
- explore the natural phenomena in the world with curiosity
- appreciate science being a human endeavour, and scientific knowledge being built up by different civilisations
- understand the nature of scientific evidence and how scientific evidence can be obtained using one's senses or instruments
- understand that scientific evidence can be interpreted differently
- understand how scientific knowledge is built by collecting, analysing and justifying evidence

- In science, we explore and study the natural phenomena in the world.
- The world refers to the components of the universe around us, such as atoms and molecules (units that make up matter), living things, environments, and the natural forces at work.
- Branches of science include social science and natural science. Natural science can be further branched into physical sciences and life sciences.
  (a) Examples of physical sciences: Astronomy, chemistry, physics, earth science
  (b) Examples of social science: Economics, anthropology
- Science can be observed in the laboratory. It can also be observed in our daily lives. Some examples are shown below:
  (a) Electricity powers the water heater to heat up water.
  (b) Technology allows our smartphones to measure blood pressure.
  (c) Light that is absorbed or reflected off objects allows us to see the objects and their colours.
- Science is a human endeavour with knowledge built up by individuals and civilisations over time.
- An example is the atomic model. It is developed over many years. It is used to understand the formation of new substances and the chemical behaviour of substances such as their chemical properties.
- The current atomic model is still subjected to revision in the light of new evidence in future and development of technology.
  *(**Note:** You can refer to Chapter 8 in Revision Guide 1B for an introduction to the atomic model.)*

Worked Example 1

Four students discussed the development of the atomic model as shown below.



Whose comment best describes how the atomic model is understood? Explain your answer.

Answer

Kelly's comment best describes how the atomic model is understood. Scientists build on the work of others to create scientific knowledge. The current atomic model is a result of many years of scientific research using different methods and experiments. Newer research methods and future technology may lead scientists to modify the atomic model.

Tips

- Arun's comment is incorrect. Scientists do not work alone. They work in teams to collect data and compare it with data from other scientists.
- Chermaine's comment is incorrect. The way to describe the atomic model had been changing over many years. The current atomic model is in fact built upon and modified from the previous atomic models.
- Romeo's comment is incorrect. The atomic model had been developed based on experimental data from scientists over many years.

Nature of Scientific Knowledge

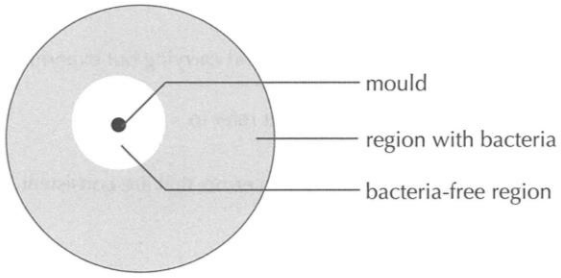
- Scientific knowledge has these characteristics:
  - **(a)** It is contributed by different civilisations over time.
  - **(b)** It is built upon the organised collection and analysis of evidence, and careful reasoning based on the evidence.
  - **(c)** It arises from scientific investigations that use a variety of methods.
  - **(d)** It is open to revision when new evidence arises.
  - **(e)** It is based on the assumption that there is order and consistency in the world.
  - **(f)** It can be used to answer questions about the world, or explain natural phenomena in the form of scientific models, laws and theories.
- Evidence can be obtained by collecting data using our five senses or scientific instruments.

- Data can be classified as qualitative and quantitative data.

Qualitative Data	Quantitative Data
• descriptive (e.g., yellow gas with a pungent smell, colourless liquid with a sweet taste, heavy solid with a smooth surface) • requires the use of one or more of our five senses	• numerical and usually contains units (e.g., 1.75 m, 24.56 s, 74 kg) • requires the use of our senses and scientific instruments to take measurements

Worked Example 2

In 1928, Sir Alexander Fleming, a scientist, returned to his laboratory after a holiday. He noticed something unusual in the Petri dishes that contained a kind of bacteria. A kind of mould called penicillium was growing in some of the Petri dishes. A clear area was found around the penicillium mould, which showed that the bacteria in that area had died.



Sir Alexander came up with an idea that penicillium produces a chemical that kills bacteria. He tested his hypothesis with several experiments and eventually discovered the first naturally occurring antibiotic.

(a) Sir Alexander observed that the bacteria died in the Petri dishes containing penicillin. State the sense that was used to make this observation.

Answer
Sight

Tip
Sir Alexander used his sense of sight to notice the clear areas in the Petri dishes, which showed that bacteria had died.

(b) Based on the passage above, suggest one type of possible qualitative data and one type of possible quantitative data that could be collected by Sir Alexander.

Answer
One type of qualitative data is the observation of whether clear areas were present in the Petri dishes. One type of quantitative data is the number of groups of bacteria left in the Petri dishes. This data could be obtained by using a microscope.

Tips
- The sense of sight could be used to describe whether there were clear areas in the Petri dishes. No measurement is made to obtain qualitative data.
- A measurement is made to obtain quantitative data. A microscope could allow Sir Alexander to count the number of groups of bacteria which are too small to be seen with the naked eye.

(c) Sir Alexander carried out several experiments before he concluded that the chemical from the penicillium mould killed bacteria. Suggest why.

Answer
The bacteria could have died due to other factors such as insufficient food.

Tip
Sir Alexander had to gather evidence to prove what caused the bacteria in the Petri dishes to die. This can be seen as a practice of science.

1.2 Practices of Science

Learning Outcomes

You should be able to:

- carry out scientific inquiry by asking questions, planning and carrying out experiments, and evaluating and communicating experimental results
- understand what accuracy and precision of measurement refer to
- identify zero error and parallax error
- *understand that errors may exist in measurements due to errors that are consistent and/or unpredictable

Ways of Practising Science

- Asking questions about the natural phenomena in the world around us
- Investigating the natural phenomena by making observations and gathering evidence
- Developing explanations and solutions to problems
- Analysing results from experiments
- Communicating findings based on evidence to the scientific community or the public using evidence as support
- Evaluating the findings by the scientific community

Hypothesis and Variables

- Before scientific research is conducted, scientists need to craft research questions.
- A research question is usually accompanied by a hypothesis.
- A hypothesis is a proposed explanation for a natural phenomenon or a proposed solution to a scientific problem.
- We should be able to test a hypothesis and measure both what is changed and what changes as a result in the hypothesis.
- A hypothesis should include a variable to be changed during an experiment (independent variable) and a variable to be measured (dependent variable).
- When designing an experiment, only one variable (independent variable) should be changed. The remaining variables should be kept constant (control variables).
- When scientists conduct experiments, they may obtain results that do not support their hypotheses.
- The process of disproving a hypothesis can provide scientists with important information to make their next hypothesis better.

** denotes "Optional for N(A)"*

Enrichment

- Scientific data usually either supports or does not support a hypothesis. It does not prove that a hypothesis is correct or wrong.
- For example, Janet came up with a hypothesis that earthworms cannot live in places with very cold winters. She predicted that she would be able to find earthworms in the soil in Singapore but not in Alaska, which is near the North Pole and has very cold winters.
- She found earthworms in a hole that is one metre deep and one metre long by one metre wide in the soil in Singapore. Meanwhile, her friend who lives in Alaska did not find any earthworms in a hole with the same dimensions in the soil there.
- Janet's and her friend's findings supported her hypothesis, but they are not based on a large soil area. Thus, Janet cannot claim that there are no earthworms in Alaska.

Worked Example 3

The statements below are possible examples of hypotheses. Identify the variable to be changed and the variable to be measured in each hypothesis.

(a) If the time spent on washing hands increases, the number of microorganisms found on the hands will increase.

(b) If the temperature of a cup of water increases, the mass of sugar that dissolves in the water will increase.

(c) If fertiliser brand **X** is added to a plant, the plant will grow to be bigger than another plant that has fertiliser brand **Y** added to it.

Tip

When identifying the respective variables, ensure that they can be changed and measured respectively.

Answer

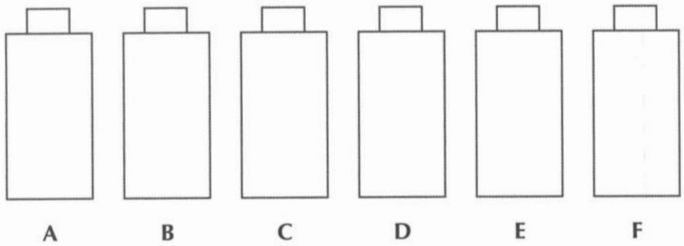
	Variable to be Changed	Variable to be Measured
(a)	amount of time spent on washing hands	number of microorganisms on the hands
(b)	temperature of water in the cup	mass of sugar that dissolves in the water
(c)	brand or type of fertiliser	height of the plant

Tip

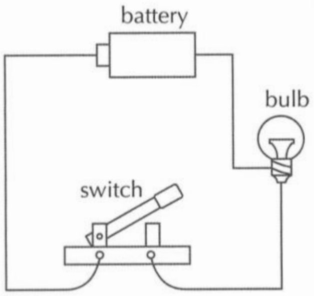
For **(c)**, it is not specific enough to state "size of the plant" as the variable to be measured. It is better to state "height of the plant" as the height of a plant can be measured.

Worked Example 4

Ashley was curious whether a more expensive brand of battery lasted longer than a cheaper brand of battery. She carried out an experiment using the following brands of battery.



Ashley purchased batteries that had similar expiry dates (at least within the same year), and noted the price of each brand of battery. She connected each battery to a bulb in an electric circuit separately as shown below. She then closed the switch and recorded the time taken for the bulb to stop lighting up.



(a) Suggest a hypothesis for Ashley's experiment.

Answer
If the price of a battery is higher, the battery will last for a longer time.

Tip
A hypothesis should include a variable to be changed and a variable to be measured.

(b) State the variable to be changed and the variable to be measured in the experiment.

Answer
The variable to be changed is the brand of battery. The variable to be measured is the time taken for the bulb to stop lighting up.

Tip
The variables to be changed and measured can be inferred from the hypothesis.

(c) State two variables that should be kept the same to ensure that the experiment is fair.

Answer

- The batteries used should have similar expiry dates.
- The batteries used should be of the same size, e.g., AA size.
- The switches in all circuits should be closed at the same time.
- The same type of wires and light bulbs should be used in all circuits.

(Any two acceptable answers)

Tip

The rest of the variables in the experiment needs to be kept constant, so that the effect of changing the brand of battery on the time taken for a bulb to stop lighting up can be observed.

(d) Suggest how the results of Ashley's experiment would be affected if the variables in **(c)** were not kept constant.

Answer

If the expiry dates of the batteries were different, the initial condition of the batteries would be different. The experiment would not be a fair one.

If different battery sizes were used, the initial condition of the batteries would be different as they would contain different amounts of chemical potential energy. The experiment would not be a fair one.

If the switches were closed at different timings, it would be inaccurate to conclude that a brand of battery lasts for the shortest time based on the observations.

If different types of wires and light bulbs were used in the electric circuits, the rate at which the battery used up energy may be affected. The experiment would not be a fair one.

Tip

The variable to be measured in an experiment should change only due to the variable that is changed.

Worked Example 5

Which of the following is not a component of all scientific research methods?

A Conducting experiments
B Being open-minded to other possible results
C Communicating findings for other scientists to evaluate findings
D Gathering data using our five senses or instruments

Answer

A

Tip

Not all scientific research methods involve experimentation. For example, a scientist wants to investigate if smoking increases the risk of lung cancer in men. He cannot conduct experiments by asking a man to smoke and then observe if he develops lung cancer. That would be unethical. The scientist may have to examine the medical records and smoking habits of lung cancer patients instead.

Physical Quantities and SI Units

- A physical quantity is a quantity that can be measured.
- It consists of a numerical value and a unit.
- SI units are widely used to ensure a common standard for measurements.
- The table below shows some physical quantities that we will learn in Lower Secondary Science.

Physical Quantity	SI Unit and Symbol	Commonly Used Unit(s)	Measuring Instrument(s)
length	metre (m)	mm, cm, km	metre rule, measuring tape, digital calipers
mass	kilogram (kg)	g, mg	electronic balance, beam balance
time	second (s)	min, h	digital stopwatch, clock
temperature	kelvin (K)	°C, °F	thermometer
electric current	ampere (A)	mA	ammeter

Enrichment

Base Quantities and Derived Quantities

- There are seven basic physical quantities, which are also known as base quantities.
- Examples of base quantities are length, mass, time and temperature.
- Physical quantities that are obtained from the multiplication and/or division of two or more base quantities are called derived quantities.
- The table below shows some examples of derived quantities.

Derived Quantity	How the Physical Quantity Is Derived	Base Quantity Involved	SI Unit
area	length × width	length	m^2
volume	length × width × height	length	m^3
density	$\frac{\text{mass}}{\text{volume}}$	mass and length	kg/m^3

Prefixes and Conversion

- The magnitudes of physical quantities can range from very big to very small.
- For example, the width of a hair is between 0.00002 m and 0.0002 m. The mass of a large truck can be 5 000 000 g.
- Writing many zeros is inconvenient. It also carries a risk of counting or writing the number of zeroes in a number wrongly.

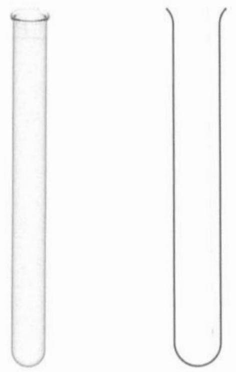
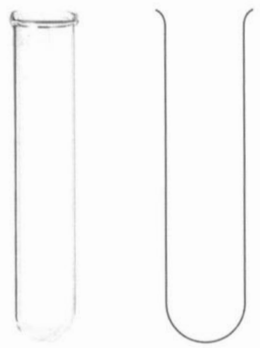
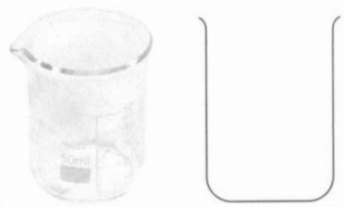
- Prefixes are used to denote multiples or submultiples of an SI unit.

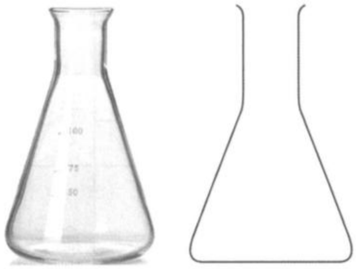
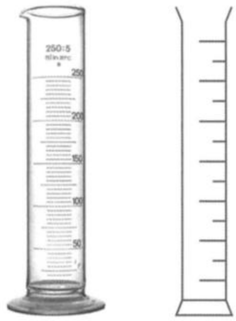
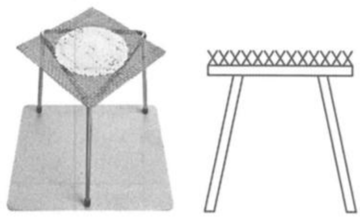
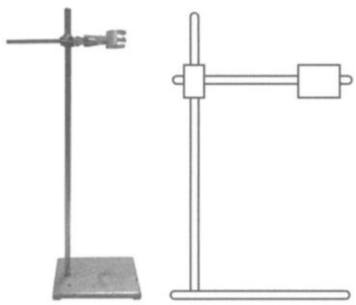
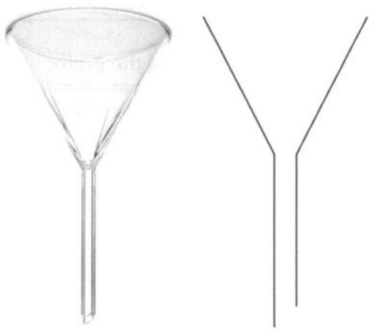
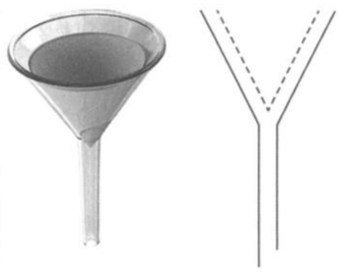
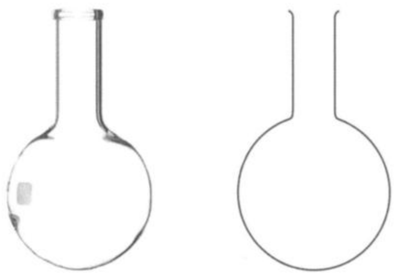
Prefix	Symbol	What It Stands for	Value	Example(s) of Usage	
giga	G	10^9	1 000 000 000	Gg, Gm	multiples of a unit
mega	M	10^6	1 000 000	Mg, Mm	
kilo	k	10^3	1000	km	
deci	d	10^{-1}	$\frac{1}{10} = 0.1$	dm	submultiples of a unit
centi	c	10^{-2}	$\frac{1}{10^2} = 0.01$	cm	
milli	m	10^{-3}	$\frac{1}{10^3} = 0.001$	mm, ms	
micro	µ	10^{-6}	$\frac{1}{10^6} = 0.000001$	µm, µs	
nano	n	10^{-9}	$\frac{1}{10^9} = 0.000000001$	nm, ns	

- Conversion: Unit with prefix ⇄ Base unit (MULTIPLY by the value of the prefix → ; ← DIVIDE by the value of the prefix)
- Examples of conversion:
  (a) 725 µm = 725×10^{-6} = 0.000725 m
  (b) 12.4 s = $12.4 \div 10^{-3}$ = 12 400 ms

Laboratory Apparatus

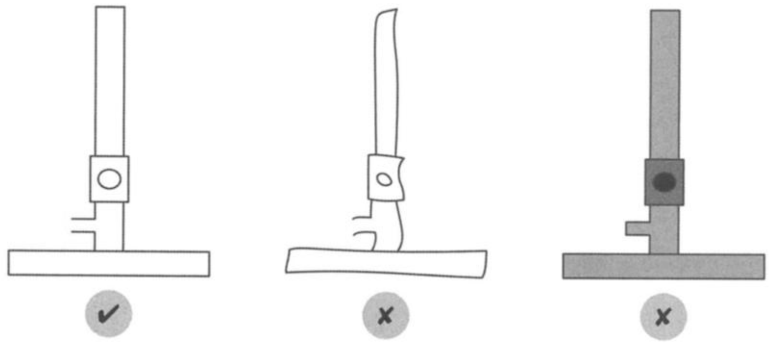
Some common laboratory apparatus and their scientific diagrams and uses:

Test tube	Boiling tube	Beaker
		
• Used for holding a small amount of substance • Also used for heating of chemicals	• Used for holding a large amount of substance • Also used for strong heating of chemicals	• Used for holding a large amount of liquid • Can be used for estimating the volume of a liquid

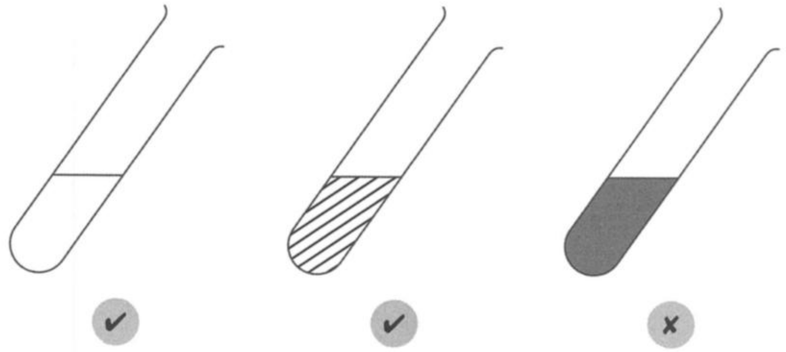
Conical flask  • Has a narrow mouth that allows a rubber stopper or a filter funnel to fit into it • Can be used for the mixing of liquids	Measuring cylinder  • Used for measuring the volume of liquids	Tripod stand with wire gauze  • Used for supporting the apparatus that is heated by a Bunsen burner
Retort stand  • Has a clamp for supporting and holding other apparatus	Filter funnel  • Used for transferring liquids from one container to another	Filter funnel with filter paper  • Used for separating an insoluble solid from a liquid with the help of filter paper
Evaporating dish  • Used for evaporating a liquid from a solution	Round-bottomed flask  • Has a round bottom that allows for even heating of a liquid	

Drawing Scientific Diagrams

- Take note of the following when drawing diagrams of laboratory apparatus:
  (a) Draw the outline of the apparatus, i.e., two-dimensional diagrams.
  (b) Ensure that the diagrams are drawn in proportion.
  (c) Use a pencil.
  (d) Use a ruler to draw straight lines.
  (e) Do not shade the diagrams (unless specified).

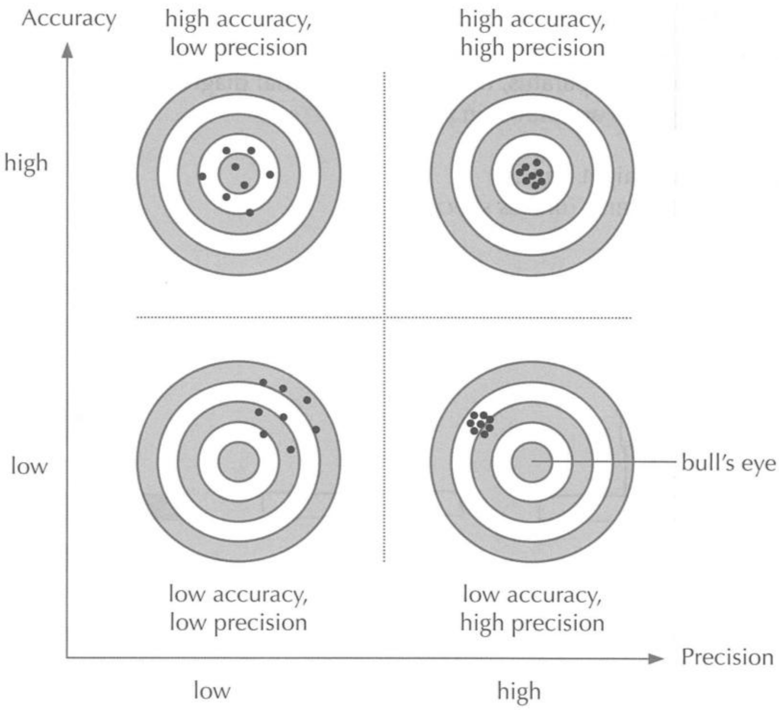


(f) Do not shade a liquid (unless specified). Use diagonal lines when asked to shade a liquid.



Accurate and Precise Measurements

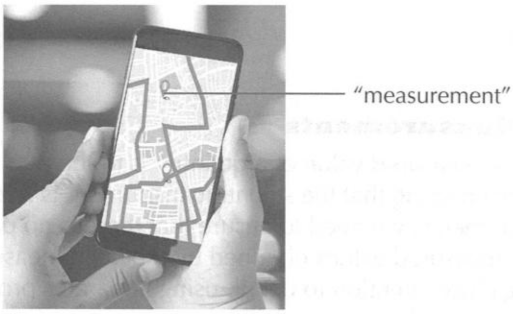
- Accuracy refers to how close a measured value of a quantity is to the true value of the quantity.
- Accuracy can be improved by ensuring that the scientific instrument is free from zero error. When using the instrument to take measurements, we need to ensure that there is no parallax error.
- Precision refers to how close measured values obtained by repeated measurements are to one another.
- It can be improved by paying close attention to detail, using apparatus properly and increasing the number of repeated measurements taken.
- When taking and recording measurements, the best measurement is one that is both accurate and precise.



(**Note:** *Each black dot represents a measured reading and each bull's eye represents the true value.*)

Enrichment

Imagine that a Global Positioning System (GPS) is used to locate a shopping centre. It makes several "measurements" for the actual location of the shopping centre. Let us look at the accuracy and precision of the "measurements" made.



If the "measurements" made by the GPS are quite close to the actual location of the shopping centre, it means that they have high accuracy. However, if they are far away from the actual location of the shopping centre, it means that they have low accuracy.

The "measurements" made by the GPS are considered to have high precision if they are close to one another. Conversely, if they are spread out and quite far apart from one another, it means that they have low precision.

Optional for N(A)

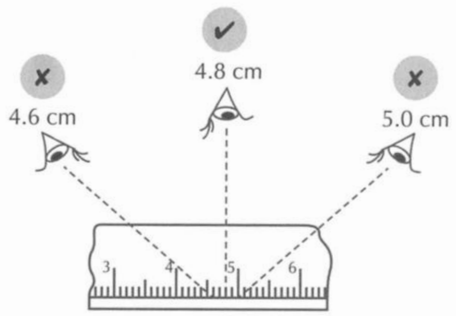
Types of Errors in Measurements

- Two common types of errors in measurements are unpredictable errors and consistent errors.
- Causes of unpredictable errors:
  - **(a)** Environmental conditions such as fluctuating outdoor temperatures and wind speed
  - **(b)** Human reaction time when using instruments such as a digital stopwatch
- Consistent errors cause measurements to be consistently inaccurate.
- Examples of consistent errors:
  - **(a)** Zero error
  - **(b)** Parallax error

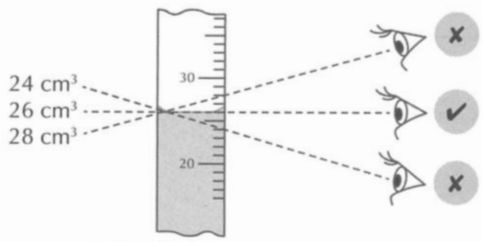
Zero Error and Parallax Error

- Zero error is the error in which an instrument gives a non-zero reading when the measured quantity should be zero.
- Parallax error is the error that is introduced into a measurement when the marking on the instrument is viewed from the wrong angle.

<table>
<tr><th>Type of Error</th><th>How to Reduce the Error</th></tr>
<tr><td>zero error</td><td>
• Replace the instrument with another instrument without zero error or that has been calibrated to account for zero error.
• If a digital instrument is used, reset it by pressing the ‘tare’ button.
</td></tr>
<tr><td>parallax error</td><td>
• View the marking on the instrument from the correct angle.
• The position of the eye should be perpendicular to the marking on a ruler.



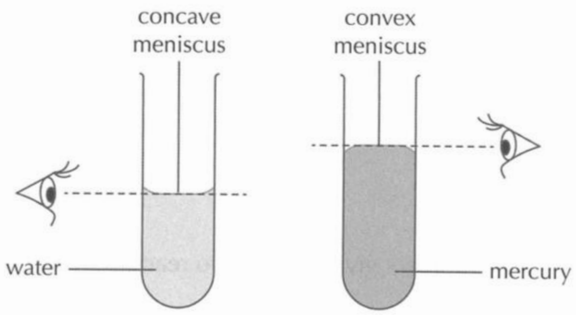
• The position of the eye should be level with the bottom of the meniscus of the liquid when measuring volume.



</td></tr>
</table>

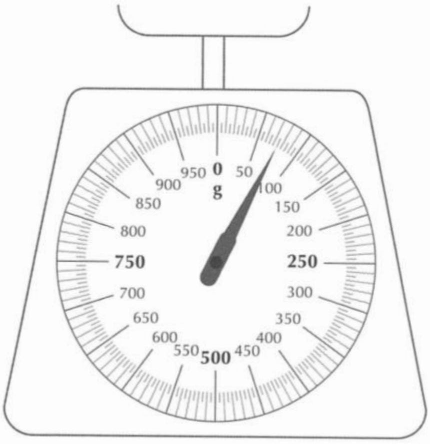
Tip

Some liquids such as mercury do not stick to the walls of their containers. The meniscus of the liquid will thus be convex. In such cases, the eye should be positioned at the same level as the top of the meniscus.



Worked Example 6

The figure below shows the reading on a kitchen scale when nothing is placed on it.



(a) What type of error is shown by the kitchen scale?

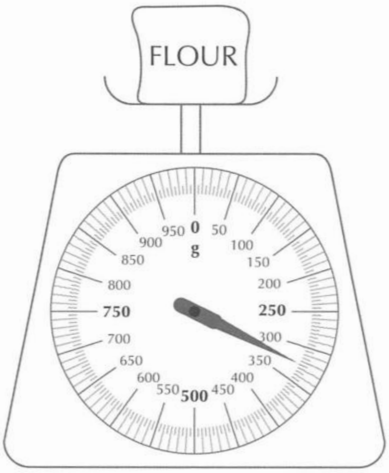
Answer

Zero error is shown by the kitchen scale.

Tip

The kitchen scale shows a non-zero reading of 75 g instead of 0 g when nothing is placed on it.

(b) A packet of flour is placed on the same kitchen scale. The reading on the scale is shown below.



What should be the correct mass of the packet of flour?

Answer

Mass of packet of flour = 325 – 75
= 250 g

Tip

The kitchen scale consistently gives a reading of an additional 75 g. To find the true mass of the packet of flour, we need to subtract 75 g from the measured mass of 325 g.

Worked Example 7

Three students, Jack, Katie and Leonard, each measured the volume of a liquid four times. They recorded their readings in a table as shown below. The actual volume of the liquid is 25.0 cm³.

	Measured Volume of Liquid / cm³				
Student	V_1	V_2	V_3	V_4	$V_{Average}$
Jack	27.2	27.1	26.9	27.0	27.1
Katie	23.6	22.8	24.6	22.2	23.3
Lucy	25.2	25.4	25.3	25.1	25.3

(a) Are Jack's measurements accurate or precise? Explain your answer.

Tip

Recall the definitions of accuracy and precision.

Answer

Jack's measurements are precise but not accurate.

Difference between the highest measured value and the lowest measured value
= 27.2 – 26.9
= 0.3 cm³

The measurements are close to one another. Thus, they are precise. However, the average volume is 27.1 cm^3, which is 2.1 cm^3 greater than the actual volume of 25.0 cm^3. Thus, the measurements are not accurate.

Tip
To check if measurements are precise, we can calculate the difference between the highest measured value and the lowest measured value.

(b) Whose measurements are both accurate and precise, Katie's or Lucy's? Explain your answer.

Answer
Lucy's measurements are both accurate and precise.

Difference between the highest measured value and the lowest measured value
= 25.4 – 25.1
= 0.3 cm^3

The measurements are close to one another. Thus, they are precise. The average volume and each of Lucy's measurements are also close to the actual volume of 25.0 cm^3. Thus, the measurements are accurate.

1.3 Considerations for Practising Science

Learning Outcomes

You should be able to:
- display attitudes such as creativity, objectivity, integrity, open-mindedness and perseverance when carrying out scientific inquiry
- carry out scientific investigations by following safe practices

Values, Ethics and Attitudes

- Values, ethics and attitudes determine how scientific knowledge is applied and the nature of scientific investigations conducted.
- Some examples of desired values, ethics or attitudes when practising science are shown below.

Value, Ethic or Attitude	What It Involves	Example
creativity	• coming up with new ideas to approach and solve problems • figuring out how to collect meaningful data and exploring what those data mean	Dudley R. Herschbach was awarded the Nobel Prize for Chemistry for pioneering the use of molecular beams to analyse chemical reactions. This was made possible as he had learnt the relevant technique from fellow physicists and then creatively applied the technique to his own research.

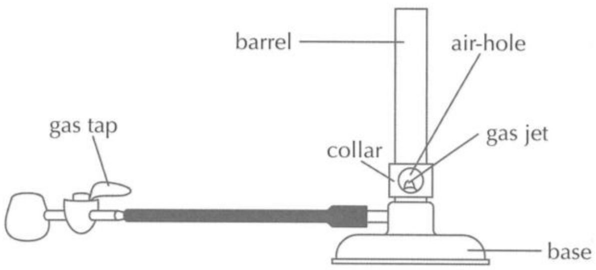
Value, Ethic or Attitude	What It Involves	Example
objectivity	• ensuring that scientific claims, methods and results are based on facts and free from personal opinion or bias • designing experiments to achieve a purpose	James Watson and Francis Crick discovered the structure of DNA. Two other scientists, Rosalind Franklin and Erwin Chargaff, contributed to this discovery. Rosalind Franklin's experimental results revealed that the structure of DNA was a double helix and not a triple helix. Erwin Chargaff's experiments showed how the different molecules in DNA strands pair together. If Watson and Crick had not been objective about their results, they may not have discovered the real structure of DNA.
integrity	• promoting the pursuit of knowledge and truth, and avoidance of error • recording research data as observed • promoting compliance with the law, health and safety	A former university immunology professor A. Melendez was accused of committing serious acts of dishonesty. He was alleged to have created false research data, copied data and edited images from other experiments. More than 10 of his research papers were withdrawn from being published.
open-mindedness	• having the ability to suspend judgment • listening to other people's viewpoints before coming to one's own conclusion • observing what is happening and the patterns that emerge, even when these differ from one's predictions	Scientists studied past pandemics such as MERS, SARS and H1N1 to learn how to treat and manage the COVID-19 pandemic. They shared and published research data online for fellow scientists to analyse and find a cure for the pandemic from as many perspectives as possible.
perseverance	• having the determination to keep trying to achieve something in spite of difficulties	In 1960s, a Tanzanian student, Erasto Mpemba, discovered that warm milk froze faster than cool milk. When he shared his findings with his teacher and classmates, they did not believe him. Some even scorned him. However, Mpemba persevered and shared his observations with a university professor. This professor went on to research, and publish and share this discovery with the scientific community.

Safety Rules for the Laboratory

Dos	Don'ts
• Handle all apparatus and chemicals carefully and correctly. • Wear safety goggles when heating. • Tie up your long hair (for female students). • Work tidily to prevent fire hazards and dispose of toxic waste correctly. • Report all accidents, breakages and spillages to your teacher immediately. • Handle chemicals that give out fumes in the fume cupboard. • Wash your hands thoroughly.	• Do not enter the laboratory without being accompanied by your teacher. • Do not eat, drink or play in the laboratory. • Do not carry out any experiments without your teacher's permission. • Do not taste or smell any chemicals. • Do not remove any apparatus or chemical from the laboratory. • Do not point the mouth of a test tube towards anyone when heating.

Use of the Bunsen Burner

- Parts of the Bunsen burner and their functions:



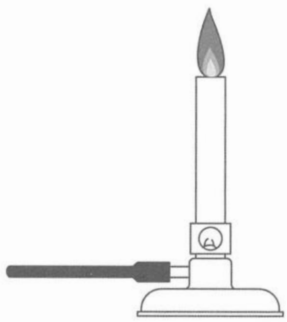
Part of Bunsen Burner	Function
barrel	to raise the flame to a suitable height for heating or burning
air-hole	to allow air to enter the Bunsen burner
collar	to regulate the amount of air entering the Bunsen burner by controlling the size of the air-hole
gas jet	to allow gas to rush out into the barrel
gas tap	to control the amount of gas flowing into the Bunsen burner
base	to support the Bunsen burner so that it does not topple

- Procedure for lighting up a Bunsen burner:
  - **(a)** Turn the collar to close the air-hole.
  - **(b)** Bring a lighter near the top of the barrel.
  - **(c)** Use one hand to turn on the gas tap and light the lighter with the other hand. This produces a luminous flame.
  - **(d)** Turn the gas tap to adjust the size of the flame.
  - **(e)** Turn the collar to open the air-hole. This produces a non-luminous flame.
- A strike back occurs when a flame burns in the barrel of the Bunsen burner. As a result, the Bunsen burner makes a sound and a flame appears at the gas jet. To prevent a strike back, always ensure that the air-hole is closed before lighting the Bunsen burner.
- If a strike back occurs, turn off the gas tap immediately. Do not touch the Bunsen burner as it can be very hot. Let the Bunsen burner cool down first before lighting it again.
- Types of flame produced by a Bunsen burner:

	Luminous Flame	Non-luminous Flame
Colour of Flame	yellow or orange	light blue
Appearance of Flame	tall, flickering flame	short, steady flame
Amount of Soot Produced	a lot (due to incomplete combustion of the gas)	very little (due to complete combustion of the gas)
Relative Temperature of Flame	less hot than a non-luminous flame	much hotter than a luminous flame

Worked Example 8

Study the figure below.



(a) Identify the type of flame shown.

Answer
It is a non-luminous flame.

Tip
The non-luminous flame is steady and does not flicker like the luminous flame.

(b) State briefly how you can obtain the flame in **(a)**.

Answer
Close the air-hole of the Bunsen burner. Light the Bunsen burner and open its air-hole.

Tip
When the air-hole of the Bunsen burner is open, there is sufficient oxygen for complete combustion, which results in a non-luminous flame.

Hazard Symbols

Acute toxicity  • Can cause harmful effects if swallowed, breathed in or upon contact with the skin	Carcinogenicity / Aspiration hazard  • Can cause breathing difficulties • Can cause damage to organs • Can cause cancer	Corrosives  • Can cause severe damage upon contact with body parts such as the skin and eyes
Environmental toxicity  • Can cause harmful effects to the environment	Explosives  • Can cause an explosion on heating • Can cause fire	Flammable substances  • Can cause fire
Gases under pressure  • Can explode when heated • May cause lack of oxygen if a gas is leaked in an enclosed space	Harmful substances / Irritant  • May cause an allergic reaction to the body • Can cause harmful health effects	Oxidising substances  • Release oxygen easily which can start a fire

Tip
One way to remember the description of each hazard symbol is to relate the drawing of each symbol to what it stands for.

1.4 Applications of Science

Learning Outcomes

You should be able to:

- discuss the beneficial and harmful effects of science and technology on society
- relate the applications of science to some social and ethical issues
- identify some limitations of science and technology in solving problems in society
- understand the need to use technology and scientific knowledge responsibly

- The application of science and technology can be harmful and beneficial to society.
- Scientific knowledge helps us to make informed decisions and be responsible towards the society and the environment.
- Example: During the COVID-19 pandemic, many incorrect claims about the disease arose. One such claim is that wearing a face mask does not prevent transmission of the disease. At the same time, scientists and doctors shared scientific research and medical data to help the government, the scientific community and the public to safeguard lives and search for a cure.
- Science has its limitations and cannot be used to solve all the problems in the world.
- Example: Science can be used to predict the effects of global warming and climate change. It can also be used to predict an earthquake. However, issues such as global warming and climate change are complex and involve economic, environmental, ethical and social factors. These factors and how they relate to global warming and climate change are discussed in the table below.

Type of Factor	How It Relates to Global Warming and Climate Change
economic	• Extreme weather causes crop yield to decrease. This leads to less income for people living in agricultural countries.
environmental	• Extreme rainfall and huge changes in weather temperatures affect the biodiversity of ecosystems. • For example, the number of disease-carrying insects may increase due to the deaths of natural predators.
ethical	• A debate on whether developed countries should take the lead to help poorer countries reduce the emission of greenhouse gases may arise. Greenhouse gases contribute to global warming and climate change.
social	• Natural disasters and diseases caused by climate change can worsen health issues among the more vulnerable populations such as the elderly, children and low-income communities.

- Science can only be used to answer questions in terms of natural phenomena and natural processes.

Worked Example 9

Smallpox is a very infectious and deadly disease. It caused millions of deaths before it was eradicated (or got rid of) completely in 1980. Smallpox is the only infectious disease to have been completely eradicated through a global vaccination programme led by World Health Organisation in the 1960s and 1970s.

The smallpox vaccine was first created by Edward Jenner. He tested the smallpox vaccine on himself and on more than twenty other people. Jenner had observed that milkmaids who had been infected with cowpox did not catch smallpox. In 1796, he tried to infect a young boy with cowpox by obtaining pus (yellow liquid formed in an infected area of the skin) from a blister of a milkmaid suffering from cowpox. He then tried to infect the same boy with smallpox. The boy was found to be immune to smallpox, or protected against the disease.

It was later discovered that cowpox is caused by a virus similar to the smallpox virus. The antibodies produced in the human body in response to cowpox makes the body immune to smallpox.

(a) What is the main benefit of Jenner infecting the young boy with cowpox instead of smallpox?

Tip
This question requires comprehension skills. There is a need to read and understand the text.

Answer
Cowpox is not as dangerous and deadly as smallpox. When the young boy recovers from cowpox, he becomes immune to both cowpox and smallpox.

(b) Why do you think Jenner tested his vaccine on more than 20 other people?

Answer
Jenner tested his vaccine on more than twenty other people to check the consistency of the results of his experiment. If these people consistently showed that they were immune to smallpox, there would be a high chance of his experiment having similar results on a larger human population.

Tip
To ensure that a science experiment is reliable and accurate, more than one set of data is needed.

(c) In today's context, Jenner's experiments would be considered ethically unacceptable. Why is this so?

Answer
Jenner did not conduct enough tests to check if the cowpox vaccine had any harmful side effects on the human body. The boy involved was too young to understand the dangers involved. He could have died from being infected with both cowpox and smallpox.

Tip
Science is a complex subject and has ethical considerations. Jenner did not have the right to infect another human with cowpox as all living things should be treated with care.