Theme 1

Elementary Physics

Physics is the study of matter and energy as well as phenomena happening around us.

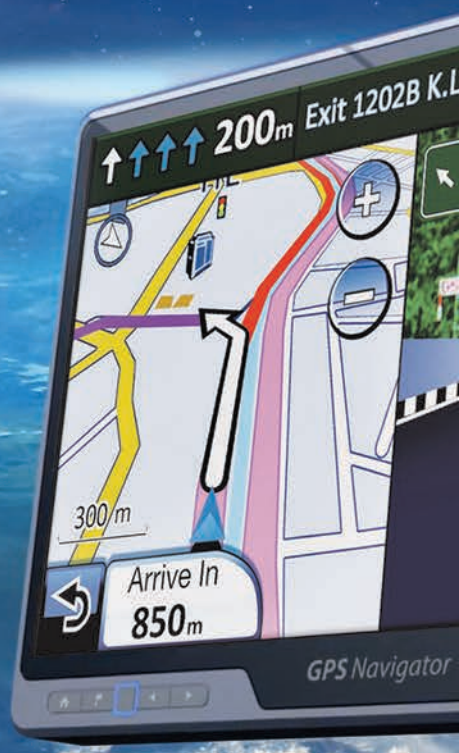
The topics in this theme focuses on the base quantities and their units that are needed to derive other physical quantities. Attention is also given to the scientific method in aspects such as the interpretation of graphs and scientific investigation.

CHAPTER 1 MEASUREMENT

What are physical quantities?

How are base quantities and their respective units used to form derived quantities?

Why are the skills in interpreting and analysing graphs important?



Let's Study

1.1 Physical Quantities
1.2 Scientific Investigation

Information Page

Measurement plays an important role in investigating natural phenomena and inventing modern equipment to solve problems in our lives. The invention of sophisticated modern equipment such as *Global Positioning System* (GPS), seismometers, computers, smartphones and others has helped us in various fields.

GPS determines the location of a person or a place by measuring time and distance using satellites. Accuracy in the measurement of time and distance is very important in GPS to determine exact locations.

How does GPS work?

http://bt.sasbadi.com/p4003a

Learning Standards and List of Formulae

1.1 Physical Quantities

Measurement is a method to determine the value of a physical quantity. **Physical quantities** consist of base quantities and derived quantities.

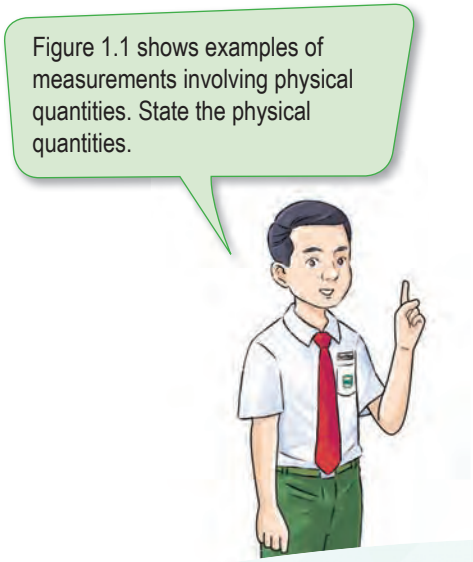
The results of accurate measurements enable us to make right decisions.

Height of Mount Kinabalu is 4 095 m.

National Paralympic athlete, Mohamad Ridzuan Puzi created a world record with a recorded time of 11.87 s in the 100 m sprint event (T36 category) in the 2018 Asian Para Games.

Speed of the tiger, *Panthera tigris* is 49 km h^{-1} to 65 km h^{-1}.

Figure 1.1 *Examples of measurements of physical quantities*



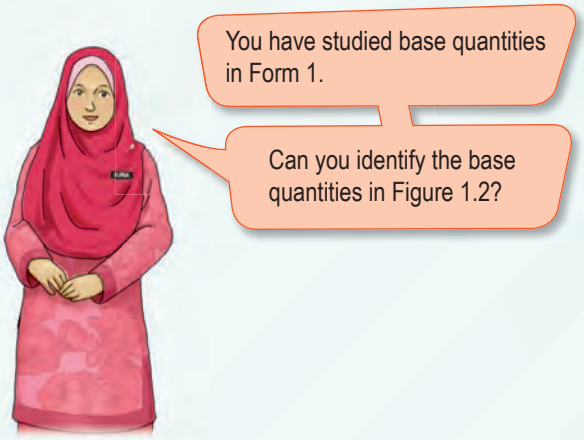


Figure 1.2 *Physical quantities*

Time, length, electric current, thermodynamic temperature, mass, luminous intensity and amount of substance are **base quantities**. The rest of the quantities in Figure 1.2 are **derived quantities**.

Recall

Physical quantities and their units

1.1.1

A physical quantity must be stated in **magnitude** with its **unit**. Observe Figure 1.3.

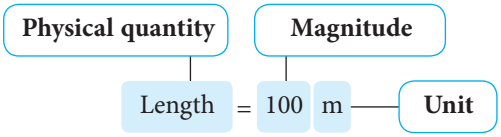


Figure 1.3 *Example of measurement of a physical quantity*

Look at your ruler. Can you see the units in centimetres and inches on the ruler? Centimetre is an example of a **metric unit** while inch is an example of an **imperial unit**. Observe Photograph 1.1.

Photograph 1.1 *Metric unit and imperial unit on a ruler*

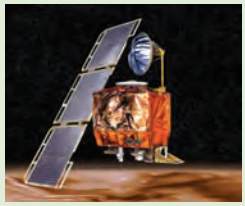
Nowadays we are more familiar with the metric units. The imperial units are seldom used. Photograph 1.2 shows a tyre pressure gauge which displays both the metric unit and the imperial unit.

Photograph 1.2 *Metric unit and imperial unit on a tyre pressure gauge*

Other examples of imperial units are gallons, miles, feet and yards. Do you know that imperial units can be converted to metric units and vice versa?

INTEGRATION OF HISTORY

In 1999, the spaceship *Mars Climate Orbiter* suddenly disappeared in outer space. This was caused by a mistake in the units of measurement used by the engineers. One group of engineers used the imperial unit while the other used the metric unit. This caused the spaceship to crash onto the surface of Mars.



Base Quantities and Derived Quantities

Base quantity is a physical quantity which cannot be derived from another physical quantity. Table 1.1 shows seven base quantities.

Table 1.1 *Base quantities and their respective S.I. units and symbols*

Base quantity and its symbol		S.I. unit and its symbol	
Length	l	metre	m
Mass	m	kilogram	kg
Time	t	second	s
Thermodynamic temperature	T	kelvin	K
Electric current	I	ampere	A
Luminous intensity	I_v	candela	cd
Amount of substance	n	mole	mol

Other physical quantities as shown in Table 1.2 can be described in terms of base quantities. These physical quantities are known as **derived quantities**.

Table 1.2 *Examples of derived quantities and their respective symbols*

Derived quantity and its symbol		Formula
Volume	V	$V = l^3$
Density	ρ	$\rho = \frac{m}{V}$
Velocity	v	$v = \frac{l}{t}$
Charge	Q	$Q = I \times t$

Info File

Amount of substance normally used in Chemistry refers to the quantity of an element or a compound.

Info File

In 1960, International System of Units known as S.I. was agreed upon at the 11th General Conference on Weights and Measures (*Conférence Générale des Poids et Mesures, CGPM*) in Paris, France. This system has facilitated works in the fields of science, sports, trade, medicine and others.

Describing Derived Quantities in Terms of Base Quantities and S.I. Base Units

A derived quantity is related to the base quantities through a **formula**. The derived unit is related to the base units in a similar manner. Study the example shown in Figure 1.4 on page 7.

Derived quantity	Formula	In terms of base quantities	S.I. unit
Density	$\rho = \frac{m}{V}$	$\frac{m}{l \times l \times l}$	kg m^{-3}

Figure 1.4 Example of describing a derived quantity

Activity 1.1

CPS ISS

Aim: To discuss derived quantities in terms of base quantities and S.I. base units

Instructions:

1. Carry out a Think-Pair-Share activity.
2. Scan the QR code to download and print Table 1.3.
3. Discuss and complete the table.

Download Table 1.3

http://bt.sasbadi.com/p4007

Table 1.3

Derived quantity and its symbol		Formula	In terms of base quantities	In terms of S.I. base units	S.I. unit (Specific unit) if any
Area	A	$A = l^2$			–
Volume	V	$V = l^3$			–
Density	ρ	$\rho = \frac{m}{V}$	$\frac{m}{l \times l \times l} = \frac{m}{l^3}$		–
Velocity	v	$v = \frac{l}{t}$		m s^{-1}	–
Acceleration	a	$a = \frac{v}{t}$	$\frac{l}{t \times t} = \frac{l}{t^2}$		–
Force	F	$F = m \times a$		kg m s^{-2}	newton (N)
Momentum	p	$p = m \times v$	$m \times \frac{l}{t} = \frac{ml}{t}$		–
Pressure	P	$P = \frac{F}{A}$		kg m^{-1} s^{-2}	pascal (Pa)
Energy or Work	W	$W = F \times l$	$\frac{ml}{t^2} \times l = \frac{ml^2}{t^2}$		joule (J)
Charge	Q	$Q = I \times t$		A s	coulomb (C)

Scalar Quantities and Vector Quantities

Figure 1.5 shows two situations during a Physical Education lesson. In both situations, the teacher instructs his pupils to run a distance of 50 metres. What is the difference between situation 1 and situation 2?

CAREER INFO

Metrology is a scientific study of measurements and standards. Many scientists apply advanced technologies of measurements to determine the standards of fundamental units. In Malaysia, Standard and Industrial Research Institute of Malaysia (SIRIM) is responsible to prepare the standards of all measurements.

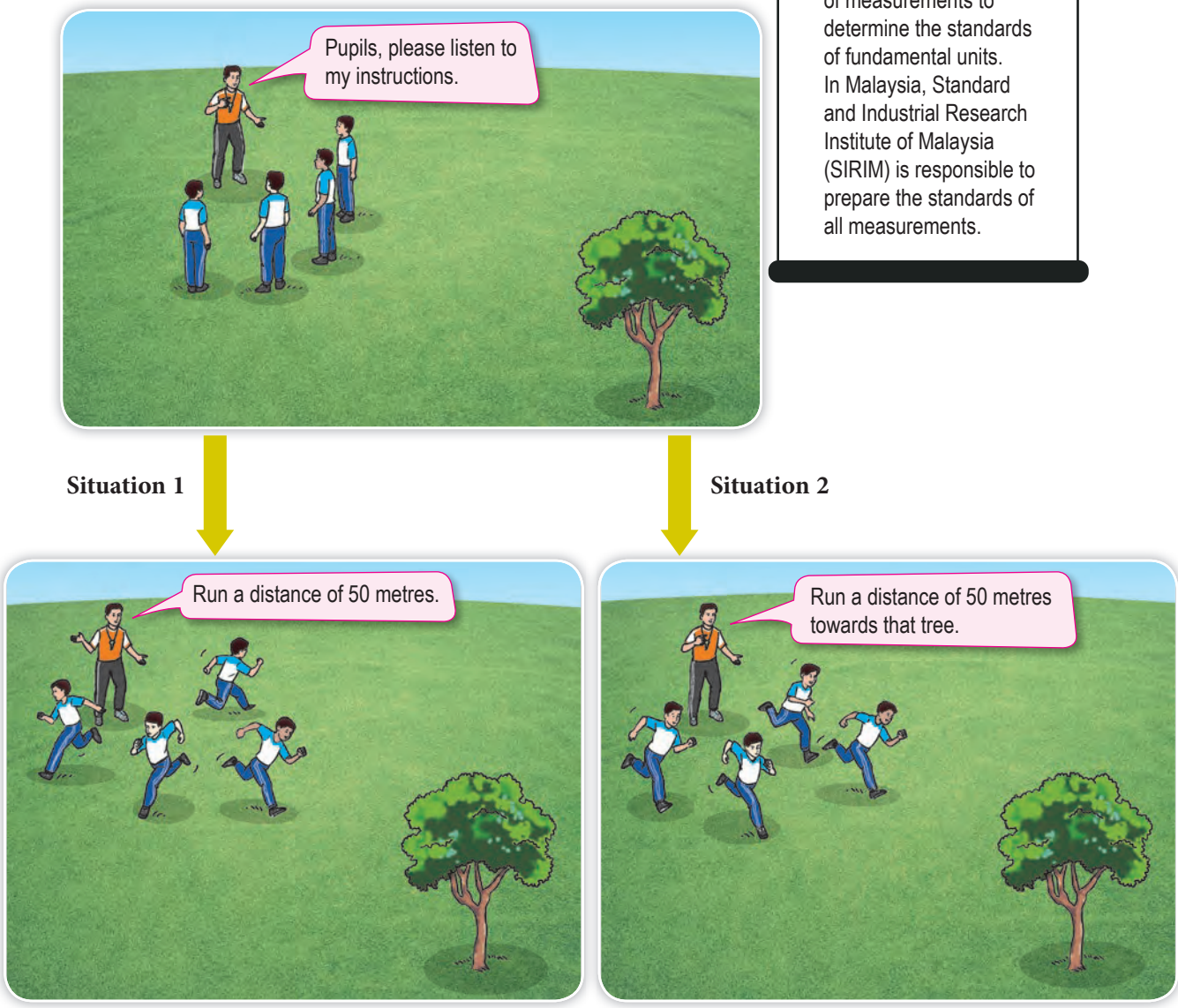


Figure 1.5 *Two situations during a Physical Education lesson*

Scalar quantities are physical quantities that have magnitude only while **vector quantities** are physical quantities that have both magnitude and direction. Identify the situations that involve scalar and vector quantities in Figure 1.5 above.

Table 1.4 shows examples of scalar and vector quantities. What other examples of scalar and vector quantities do you know?

Table 1.4 *Examples of scalar and vector quantities*

Scalar quantities		Vector quantities
Distance	Time	Displacement
Area	Volume	Velocity
Length	Speed	Force
Work	Energy	Acceleration
Temperature	Density	Momentum

Video of scalar and vector quantities

http://bt.sasbadi.com/p4009

Formative Practice 1.1

1. Figure 1.6 shows Encik Fendi taking a measurement of Wei Li.

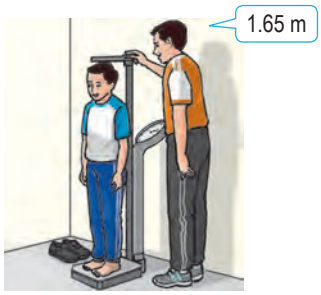


Figure 1.6

(a) State the measured physical quantity.

(b) What is the measured base unit, symbol of the unit, magnitude of the physical quantity and symbol of the physical quantity in the situation shown in Figure 1.6?

2. (a) What is the difference between scalar quantity and vector quantity?

(b) Read the following passage.

> Puan Aishah wants to travel to Kota Kinabalu. The distance from her house to Kota Kinabalu is 333 km. She drives her car at a speed of 80 km h^{-1} along a highway. She wants to reach Kota Kinabalu in 3 hours. Therefore, she increases the speed of her car with an acceleration of 1.2 m s^{-2}.

Identify the scalar quantities and vector quantities involved in the situation described above.

3. Rina and her friends took part in a Treasure Hunt held in conjunction with Science Day in their school. Each group had to find several objects hidden in the school compound within 30 minutes as listed in Figure 1.7.

- ☐ Container filled with 500 mℓ of pond water
- ☐ A unique piece of rock of mass 950 g
- ☐ Rope of length 1.5 m
- ☐ Camping canvas of area 7.2 m^2

Figure 1.7

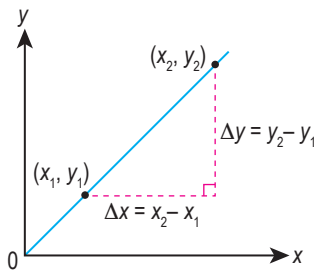
Identify the base quantities and derived quantities in the above situation.

1.2 Scientific Investigation

We can plot graphs using data from scientific investigation and interpret the shapes of the graphs to determine the relationship between two physical quantities.

Interpretation of Graphs of Different Shapes

1

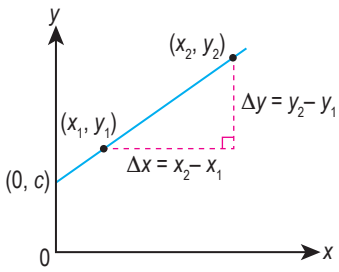


Type of graph:
A straight line that passes through the origin

Interpretation of graph:
- y is directly proportional to x
- Gradient of graph, $m = \dfrac{\Delta y}{\Delta x}$

  $m = \dfrac{y_2 - y_1}{x_2 - x_1}$
- Linear equation, $y = mx$

2

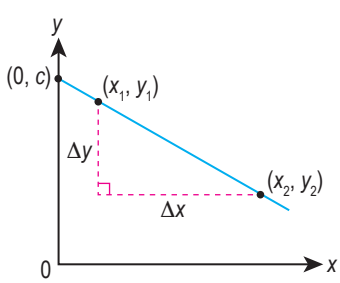


Type of graph:
A straight line with a positive gradient that does not pass through the origin

Interpretation of graph:
- y increases linearly with x
- Gradient of graph, $m = \dfrac{\Delta y}{\Delta x}$

  $m = \dfrac{y_2 - y_1}{x_2 - x_1}$
- y-intercept $= c$
- Linear equation, $y = mx + c$

3

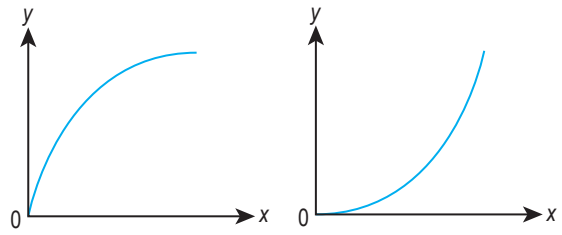


Type of graph:
A straight line with a negative gradient that does not pass through the origin

Interpretation of graph:
- y decreases linearly with x
- Gradient of graph, $m = \dfrac{\Delta y}{\Delta x}$

  $m = \dfrac{y_2 - y_1}{x_2 - x_1}$
- y-intercept $= c$
- Linear equation, $y = mx + c$

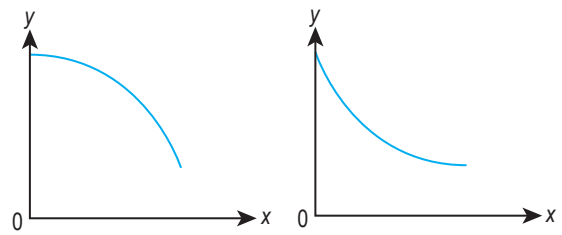
4



Type of graph:
A curve with a positive gradient that passes through the origin

Interpretation of graph:
- y increases with x

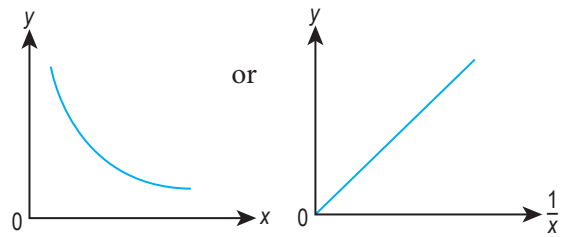
5



Type of graph:
A curve with a negative gradient that does not pass through the origin

Interpretation of graph:
- y decreases with x

6



Type of graph:
- A curve with a negative gradient that does not cut both axes
- A straight line y against $\frac{1}{x}$ with a positive gradient that passes through the origin

Interpretation of graph:
- y is inversely proportional to x

Figure 1.8 *Examples of shapes of graphs showing the relationship between two physical quantities*

Activity 1.2

ISS CPS

Aim: To discuss the shapes of graphs showing the relationship between two physical quantities

Instructions:
1. Carry out a Think-Pair-Share activity.
2. Scan the QR code to download and print Activity 1.2 worksheet. Complete the worksheet.

Download Activity 1.2 worksheet

http://bt.sasbadi.com/p4011

Analysing Graphs to Summarise an Investigation

In general, there are five important aspects in analysing graphs.

1

The **relationship** between two variables.

Method:
Interpret the shape of graph obtained.

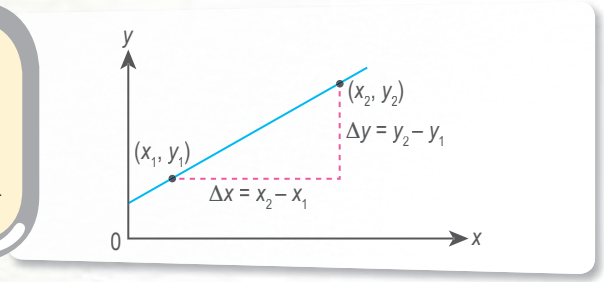
Recall
Gradient and intercept

2

The **gradient** of the graph.

Method:
Calculate the gradient of the graph, $m = \frac{\Delta y}{\Delta x}$

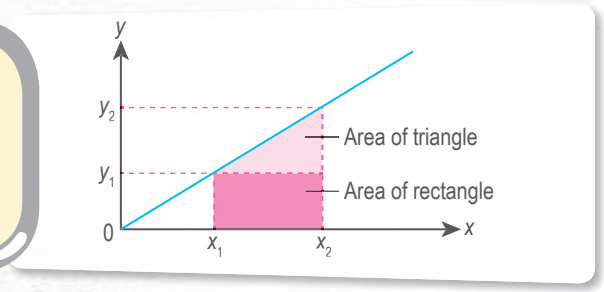
$$= \frac{y_2 - y_1}{x_2 - x_1}$$



3

The **area under the graph**.

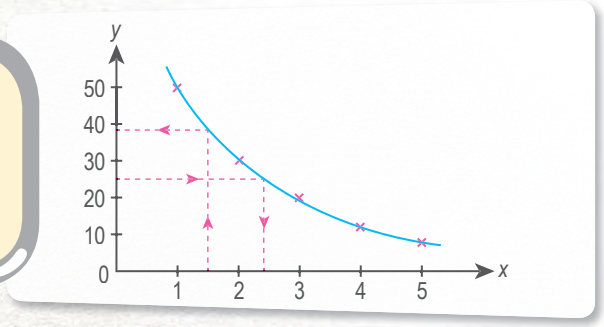
Method:
Calculate the area under the graph using the relevant formula for the area.



4

The **interpolation** to determine the value of a physical quantity.

Method:
If the value of x is given, determine the value of y using interpolation and vice versa.



5

The **extrapolation** to make a prediction.

Method:
1. Extrapolate the graph.
2. Determine the value of x or y concerned.

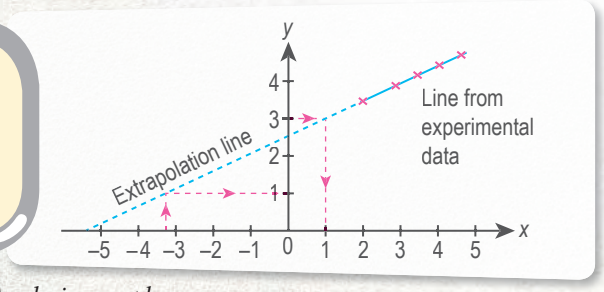


Figure 1.9 *Analysing graphs*

Activity 1.3

Abstraction CPS ISS

Aim: To plot and analyse a graph using a set of given data

Farah carried out an experiment to investigate the relationship between force, F and extension of a spring, x using the apparatus set up as shown in Figure 1.10. The results of the experiment are shown in Table 1.5. Assist Farah to analyse the graph and summarise the investigation.

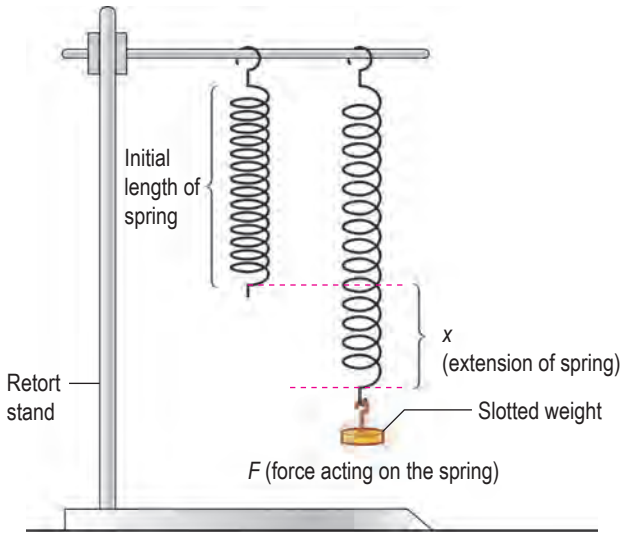


Figure 1.10

Table 1.5

Force, F / N	Extension of spring, x / cm
0.5	0.8
1.0	1.6
1.5	2.4
2.0	3.2
2.5	4.0
3.0	4.8
3.5	5.6
4.0	6.4

Instructions:

1. Work in groups.
2. Plot a graph of F against x.
3. Analyse your graph based on the following aspects:
   (a) State the relationship between F and x.
   (b) Calculate the gradient of graph, k. Show on the graph, how you determine the value of k.
   (c) The equation that relates F and x is $F = kx$, where k is the spring constant. Determine the value of k in S.I. unit.
   (d) Area under the graph represents the work done in stretching a spring. Determine the work needed to stretch the spring by 5 cm.
   (e) Determine the value of F when x = 3.5 cm.
   (f) Predict the value of x when F = 5.0 N.
4. Present your graph and the analysis of the graph.

Scientific Investigation and Complete Experimental Report

Recall
Scientific method and complete experimental report

Figure 1.11 shows a situation in a playground. Read the conversations below.

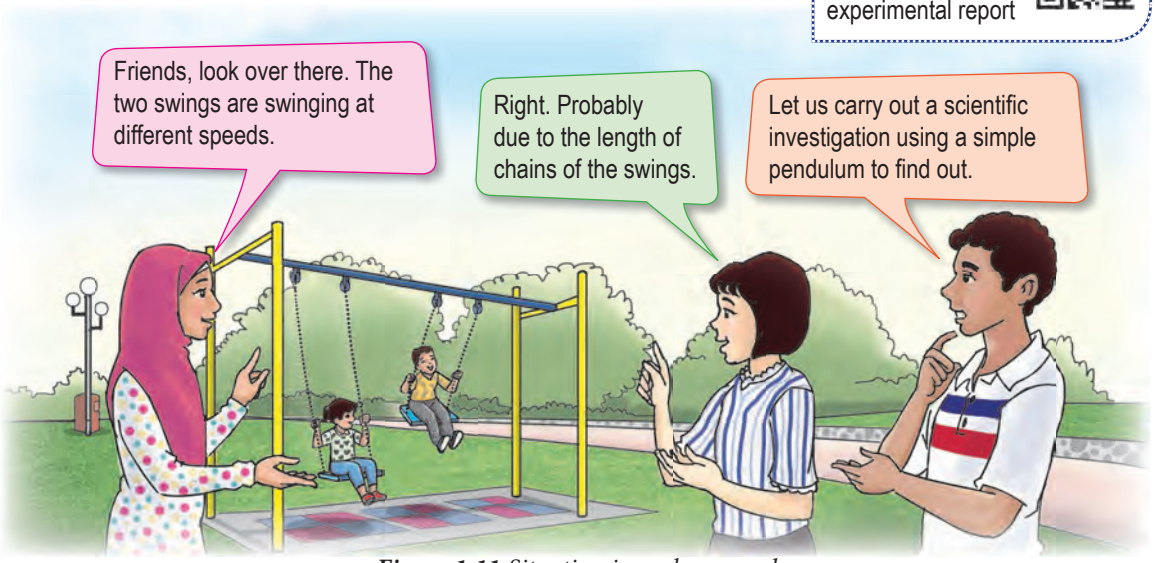


Figure 1.11 *Situation in a playground*

Experiment 1.1

Inference: The period of oscillation of a simple pendulum depends on its length.

Hypothesis: The longer the length of the simple pendulum, the longer its period of oscillation.

Aim: To investigate the relationship between the length of a simple pendulum, l and the period of oscillation of the simple pendulum, T.

Variables:
(a) Manipulated variable: Length of pendulum, l
(b) Responding variable: Period of oscillation of pendulum, T
(c) Constant variable: Mass of pendulum bob

Apparatus: Retort stand, protractor, pendulum bob, stopwatch, metre rule and G-clamp

Materials: 100 cm thread and two small pieces of plywood

Procedure:

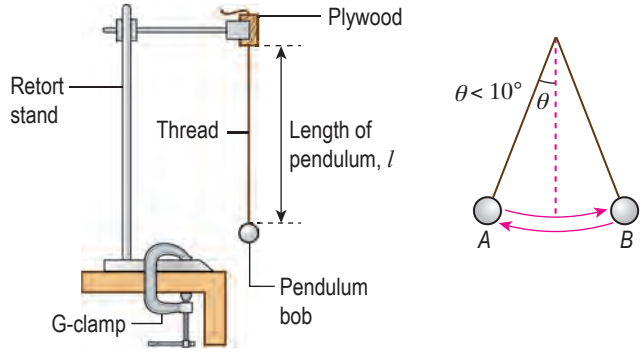


Figure 1.12

1. Set up the apparatus as shown in Figure 1.12.
2. Adjust the length of pendulum, l = 20.0 cm.
3. Displace the pendulum bob at an angle of less than 10° from the vertical and release it.
4. Measure and record the time, t_1 taken for 20 complete oscillations.
5. Repeat step 4 and record the time as t_2.
6. Calculate the average time, $t_{average} = \frac{(t_1 + t_2)}{2}$.
7. Calculate the period of oscillation, $T = \frac{t_{average}}{20}$ and the value of T^2.
8. Repeat steps 2 to 6 with length of pendulum, l = 30.0 cm, 40.0 cm, 50.0 cm, 60.0 cm and 70.0 cm.
9. Record the data in Table 1.6.

Results:

Table 1.6

Length of pendulum, l / cm	Time for 20 complete oscillations, t / s			T / s	T^2 / s^2
	t_1	t_2	$t_{average}$		
20.0					
30.0					
40.0					
50.0					
60.0					
70.0					

Analysis of data:

1. Plot a graph of T against l and a graph of T^2 against l on separate sheets of graph paper.
2. State the shape of the graph and the relationship between the variables in each graph.
3. Determine the gradient, m of the graph of T^2 against l. State the value of m in S.I. unit. Show clearly how you obtain the answer.
4. Given $T^2 = 4\pi^2\frac{l}{g}$ where g is the Earth's gravitational acceleration.

   Relate gradient, m to the value of g and then determine the value of g in this experiment.

Conclusion:

What conclusion can you make in this experiment?

Prepare a complete report on this experiment.

Discussion:

1. Why does the time for 20 complete oscillations need to be taken in this experiment?
2. Why is the measurement of time taken for 20 complete oscillations repeated?
3. State one precaution that should be taken to increase the accuracy of the results of this experiment.
4. Compare the value of g obtained from this experiment with the standard value of g, that is 9.81 m s^{-2}. Justify the difference in the values of g.

Formative Practice 1.2

1. Graphs play an important role in scientific investigations.
   (a) What are the uses of graphs?
   (b) Explain the main steps taken in the process of plotting a graph.

2. Figure 1.13 shows a graph obtained from a study to investigate the relationship between volume, V and temperature, θ of a fixed mass of gas. Based on the graph given in Figure 1.13, answer the following questions.

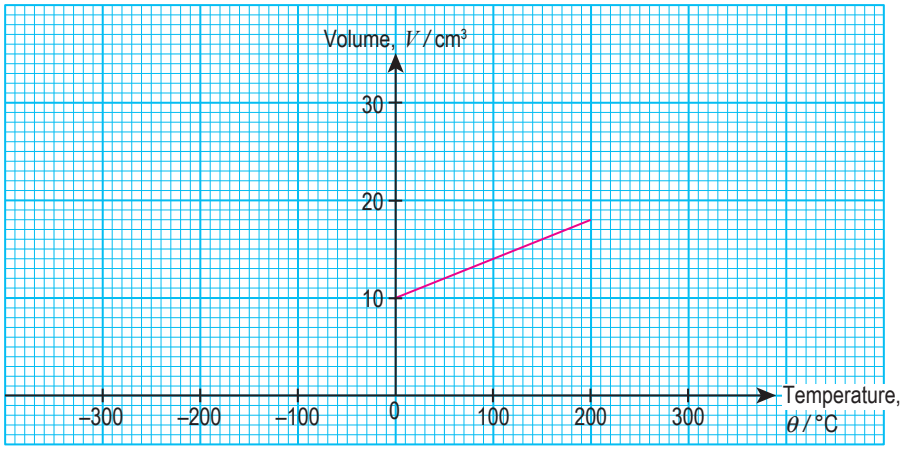


Figure 1.13

   (a) What happens to V when θ increases?
   (b) Determine the value of θ when the volume is zero. Show on the graph, how you determine the value of θ.
   (c) Determine the value of V when $\theta = 300°C$. Show on the graph, how you determine the value of V.

Conceptual Framework

Measurement

- Physical quantities
  - Base quantities
    - Length, l
    - Mass, m
    - Time, t
    - Electric current, I
    - Thermodynamic temperature, T
    - Luminous intensity, I_v
    - Amount of substance, n
  - Derived quantities
    - Examples
      - Area, $A = l \times l$
      - Volume, $V = l \times l \times l$
      - Density, $\rho = \frac{m}{l \times l \times l} = \frac{m}{V}$
      - Velocity, $v = \frac{l}{t}$
      - Acceleration, $a = \frac{l}{t \times t} = \frac{v}{t}$
      - Force, $F = ma = m \times \frac{l}{t \times t}$
  - Scalar quantities
  - Vector quantities
- Scientific investigations
  - Interpreting graphs of different shapes
  - Analysing graphs to summarise an investigation
  - Writing a complete experimental report
    - Relationship between two physical quantities
    - Gradient of graph
    - Area under the graph
    - Interpolation of graph
    - Extrapolation of graph

Interactive Quiz

http://bt.sasbadi.com/p4017

SELF-REFLECTION

1. New things I learnt in this chapter on measurement are _____.
2. The most interesting thing I learnt in this chapter on measurement is _____.
3. Things I still do not fully understand or comprehend are _____.
4. My performance in this chapter,

   Poor | 1 | 2 | 3 | 4 | 5 | Excellent

5. I need to _____ to improve my performance in this chapter.

Download and print Self-reflection Chapter 1

http://bt.sasbadi.com/p4018

Performance Evaluation

1. (a) State seven base quantities and their S.I. units.

   (b) Power, P can be defined using the formula, $P = \frac{\text{Force} \times \text{Length}}{\text{Time}}$. Derive the unit for P in terms of S.I. base units.

2. Figure 1 shows a graph of speed, v against time, t obtained from the speed test of a car.

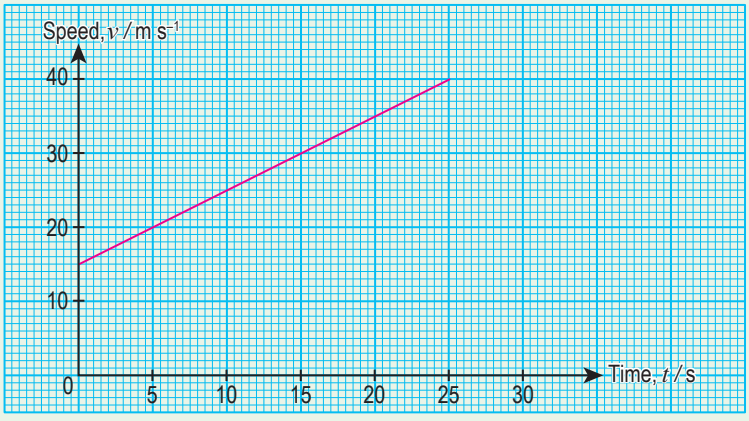


Figure 1

   (a) Determine the gradient of the graph v against t.

   (b) Determine the y-intercept of the graph when $t = 0$.

   (c) State the relationship between speed, v and time, t.

3. Hashim carried out an experiment to investigate the relationship between the mass of slotted weights and the period of oscillation, T of a spring as shown in Figure 2.

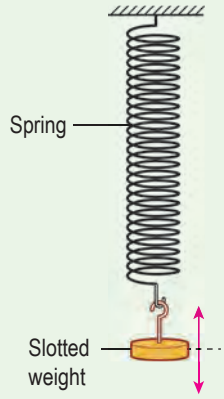


Figure 2

Hashim measured the time, t for 20 complete oscillations for different masses of slotted weights. The data obtained is shown in Table 1.

Table 1

Mass of slotted weights, m /g	20	40	60	80	100
Time for 20 oscillations, t / s	26.0	36.0	44.4	51.0	57.2
Period of oscillation, T					
T^2					

(a) Complete Table 1 by calculating the values of derived data T and T^2. State the appropriate units for both the physical quantities.

(b) Plot a graph of T^2 against m with appropriate scales. Draw the best fit line.

(c) Determine the gradient of the graph. Show clearly how it is done.

(d) If the experiment is done on the Moon, what is likely to happen to the gradient of the graph?

(e) How can an oscillating spring with slotted weights be used as a time measuring device with unit of measurement in seconds? ($T^2 = 4\pi^2\frac{m}{k}$)

4. Encik Ahmad measured the time taken by five pupils in a 400 m run. Table 2 shows the recorded time.

Table 2

Pupil	Time, t / s	Speed, v / m s^{-1}
A	58.79	
B	60.06	
C	57.68	
D	59.87	
E	57.99	

(a) Complete the table by calculating the speed of the five pupils.

(b) Suggest an appropriate device that Encik Ahmad can use in this situation.

(c) Based on the data in Table 2, which pupil is the fastest runner?

(d) State one way to increase the accuracy of the recorded time.

5. Table 3 shows the formula for three physical quantities.

Table 3

Physical quantity	Formula
Force, F	$F = m \times a$
Area, A	$A = l \times l$
Time, T	–

(a) If force, F, area, A and time, T are chosen as new base quantities, then the mass, m and length, l become new derived quantities. State the mass, m and length, l in terms of F, A and T.

(b) What are the constraints faced by physicists if *FAT* is made as a new basic physical quantity?

6. Figure 3 shows graphs obtained from several experiments. Based on the shape of each graph, determine the relationship between the two physical quantities, p and q.

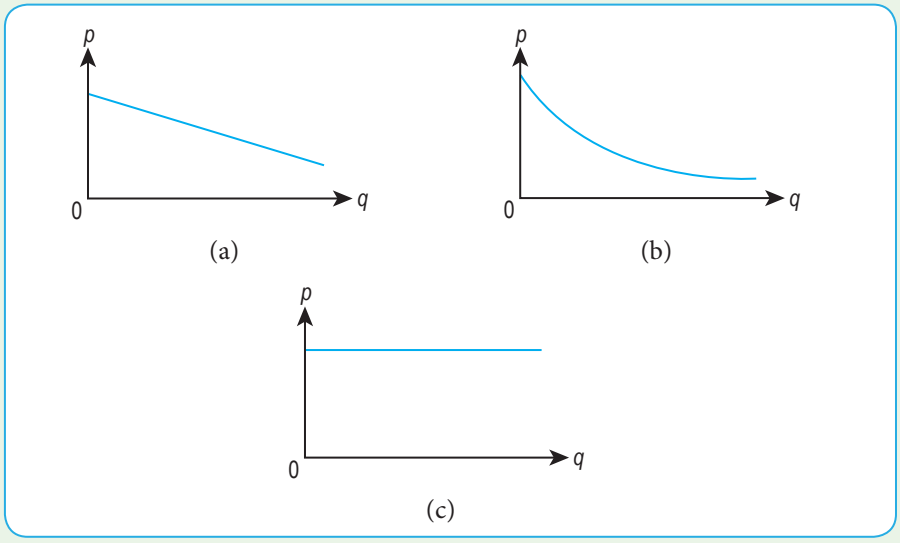


Figure 3

7. Figure 4 shows the reading on a mechanical stopwatch at the start and the end of an experiment. The mechanical stopwatch is used to measure the time taken for 20 complete oscillations of a simple pendulum of length, l.

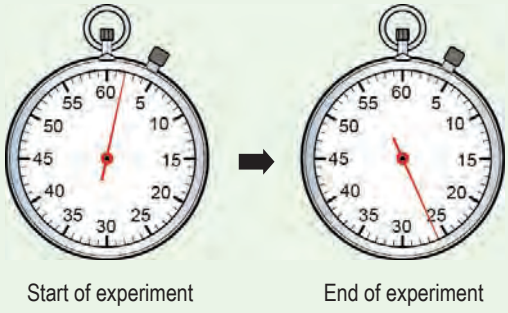


Figure 4

(a) (i) What is the time taken for the pendulum to make 20 complete oscillations?

(ii) Why is it necessary to take the time for 20 complete oscillations?

(iii) Suggest two ways to improve the experiment.

(b) (i) Determine the period of oscillation, T of this pendulum.

(ii) The relationship between length, l and period, T, of a simple pendulum is given by the equation, $l = \left(\frac{g}{4\pi^2}\right)T^2$.

Using the value of T in (b)(i), calculate the length of the pendulum, l.

[$g = 10$ m s^{-2}]

8. Newton's Law of Gravitation can be expressed as follows:

$$F = \frac{GMm}{r^2}$$

F is the force
G is the gravitational constant
M and m are the masses
r is the distance between two bodies

(a) Based on the equation, give an example for each of the following:
(i) base quantity (ii) derived quantity (iii) vector quantity

(b) Derive the unit of G in terms of S.I. base units.

Enrichment Corner

9. A driver wants to know the petrol consumption per km of a car in a journey of 300 km at constant speed. He installed a measuring device to record the remaining volume of petrol at every 50 km interval from the starting point. Table 4 shows the readings obtained.

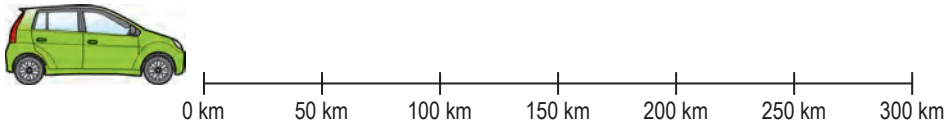


Figure 5

Table 4

Distance, s / km	50	100	150	200	250	300
Volume of petrol, V / ℓ	40	34	28	23	16	9

(a) The driver forgot to record the volume of petrol at the starting point of the journey. How can the driver estimate the volume of petrol at the start of the journey?

(b) Determine the petrol consumption of the car for the first 80 km. Show how you obtain the answer.

(c) If the petrol consumption of the car for every 50 km travelled can be saved by 10%, show the new values of V for every corresponding s in a table.

(d) Plot a graph of the new V against s.