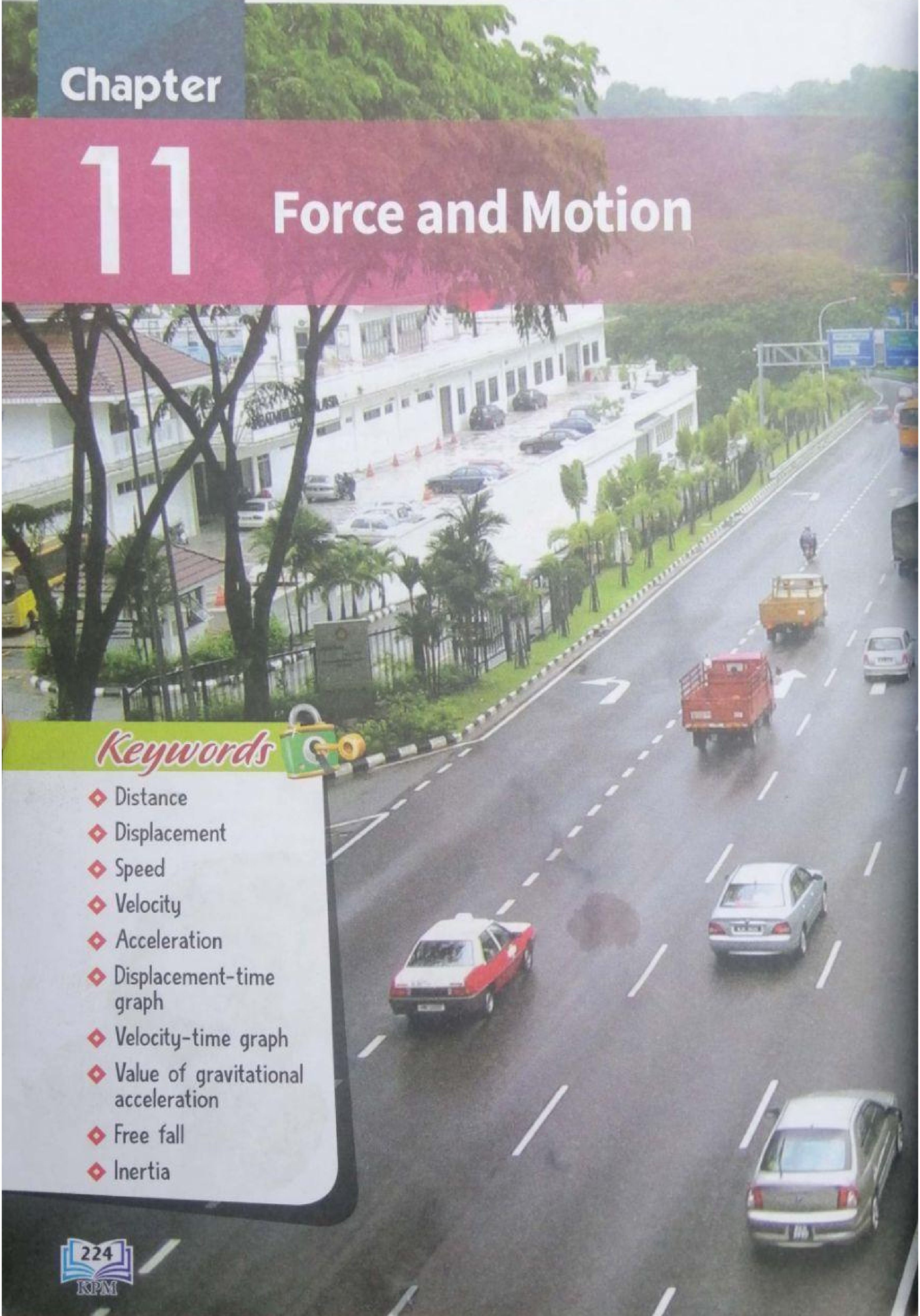
THEME 4 Energy and Sustainability of Life

- What is the velocity of a racing car?
- Have you heard of the term inertia?
- What is your opinion on the use of nuclear energy to generate electricity in Malaysia?

Chapter

11 Force and Motion



Keywords

- Distance
- Displacement
- Speed
- Velocity
- Acceleration
- Displacement-time graph
- Velocity-time graph
- Value of gravitational acceleration
- Free fall
- Inertia

What is the difference between distance and displacement?

How do we determine the speed of an object?

What will happen to a parachutist if the gravity of Earth suddenly disappears?

Why are we hurled forward when the vehicle we are travelling in suddenly stops?

Science Digest

Electric Trains in Malaysia

The electric train service (ETS) in Malaysia which is operated by Keretapi Tanah Melayu Berhad (KTMB) has revived public interest to again use trains as a means of transport to their respective destinations.

The electric train from Kuala Lumpur arrives at Padang Besar, Perlis in 4 hours 15 minutes compared to 12 hours by diesel train. It can reach a speed of about 160 km h^{-1}. Based on the information from the KTMB website, the ETS has also begun its operation connecting Padang Besar to Gemas.

You will learn about:

- linear motion
- linear motion graphs
- gravitational acceleration and free fall
- mass and inertia

11.1 Linear Motion

Linear motion is the motion of an object in a straight path.

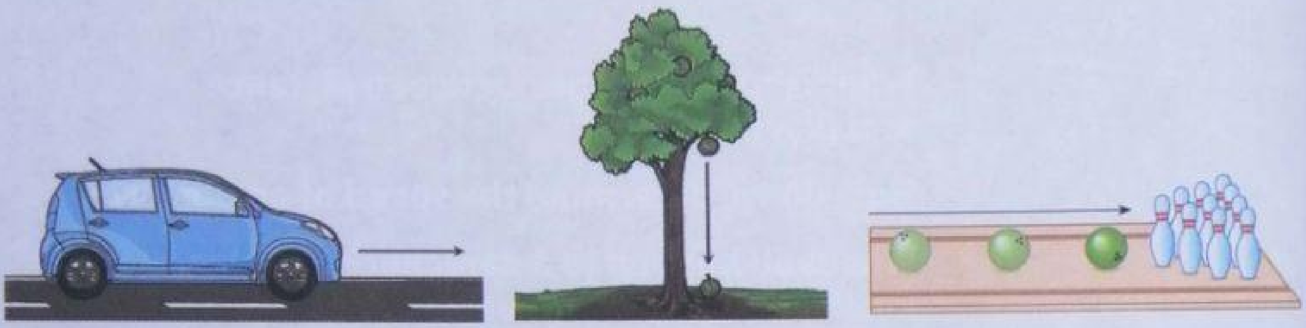


Figure 11.1 *Examples of linear motion of objects*

Distance and Displacement

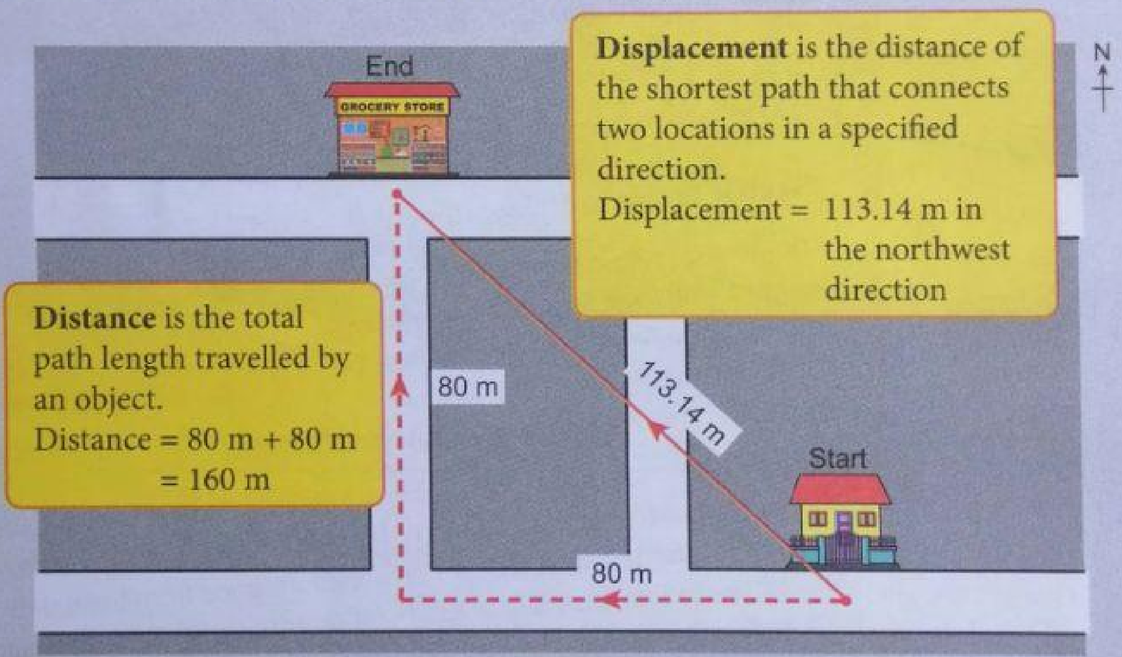
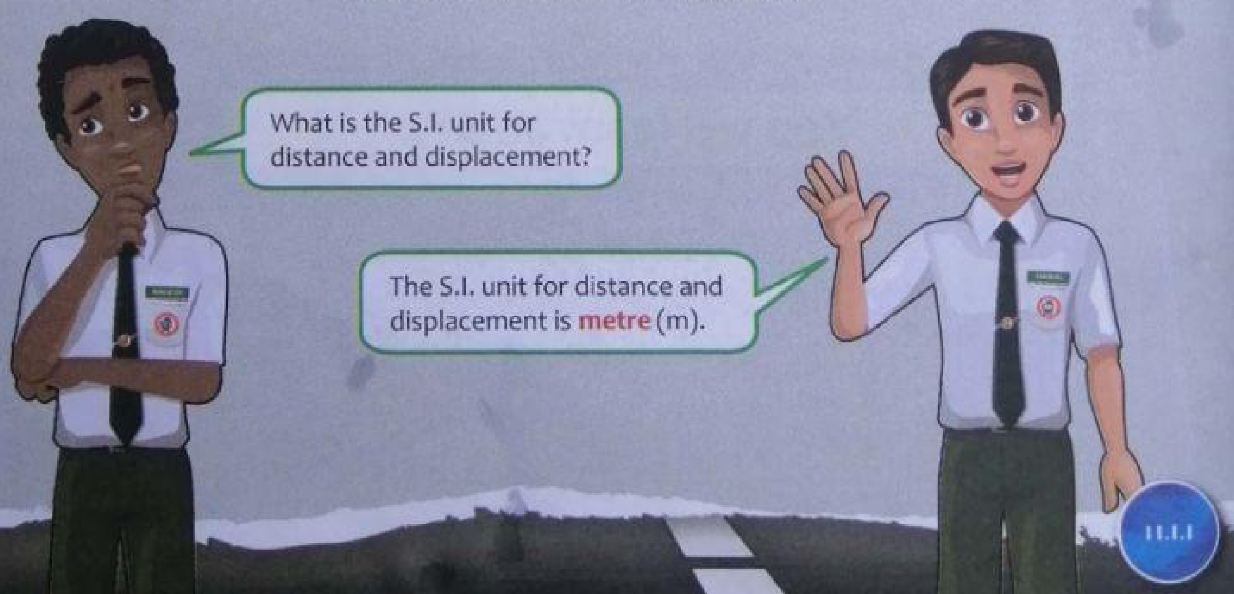


Figure 11.2 *Distance and displacement*



Distance and displacement are quantities that can be measured. What is the method to measure distance and displacement on a map? Let us carry out Activity 11.1.

Activity 11.1

Think-Pair-Share

21st Century Skills

Aim: To measure the distance and displacement between two locations.

Materials: Ruler, sketch map

Instructions:

1. Carry out this activity in pairs.
2. Look at the sketch map given below.

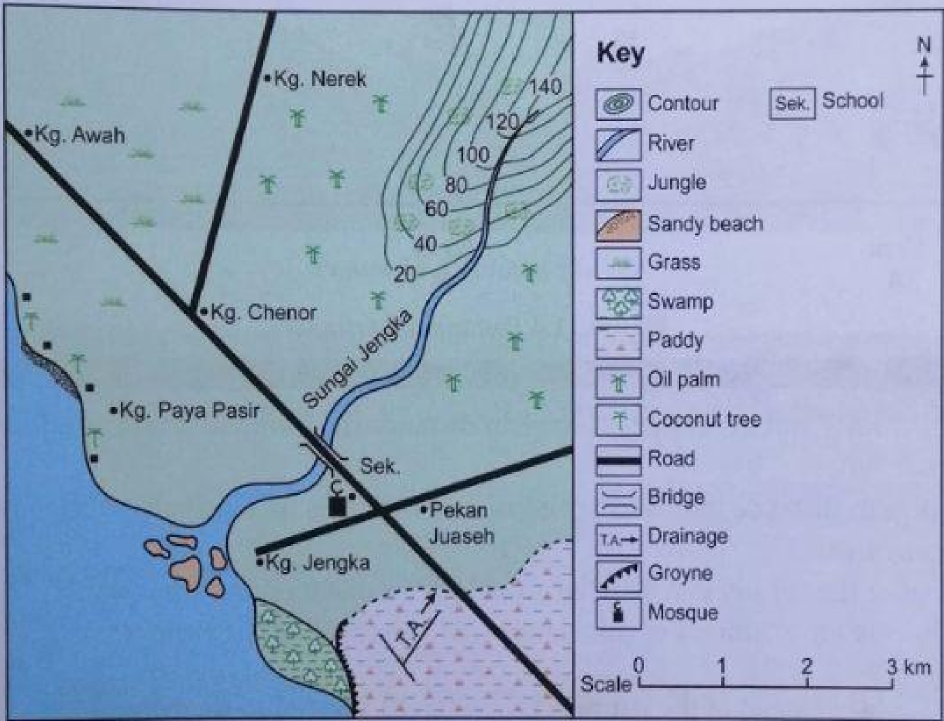


Figure 11.3 *Sketch map*

3. Measure the distance and displacement between the following locations using a ruler:
   (a) Kampung Nerek to Kampung Chenor
   (b) Kampung Awah to the mosque
   (c) Kampung Awah to Kampung Nerek
   (d) Kampung Jengka to Kampung Nerek
4. The distance between two locations on the map can be calculated based on the scale given. Scale is the ratio of distance on the map to actual distance on the surface of Earth. Look at the scale on the map. Use the scale to convert the distance of location on the map to the actual distance.
5. Discuss the difference between the distance and displacement of two locations that you have obtained.

INFORMATION
Device for Measuring Distances
http://bukuteksskssm.my/Science/F4/Pg227_1

INFORMATION
Distance Measuring Wheels
http://bukuteksskssm.my/Science/F4/Pg227_2

11.1.1

Speed

Speed is defined as the rate of change of distance. **Average speed** is the rate of change of total distance travelled.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} \qquad \text{Average speed} = \frac{\text{Total distance}}{\text{Total time}}$$

The S.I. unit for both speed and average speed are **metre per second** ($m\ s^{-1}$).

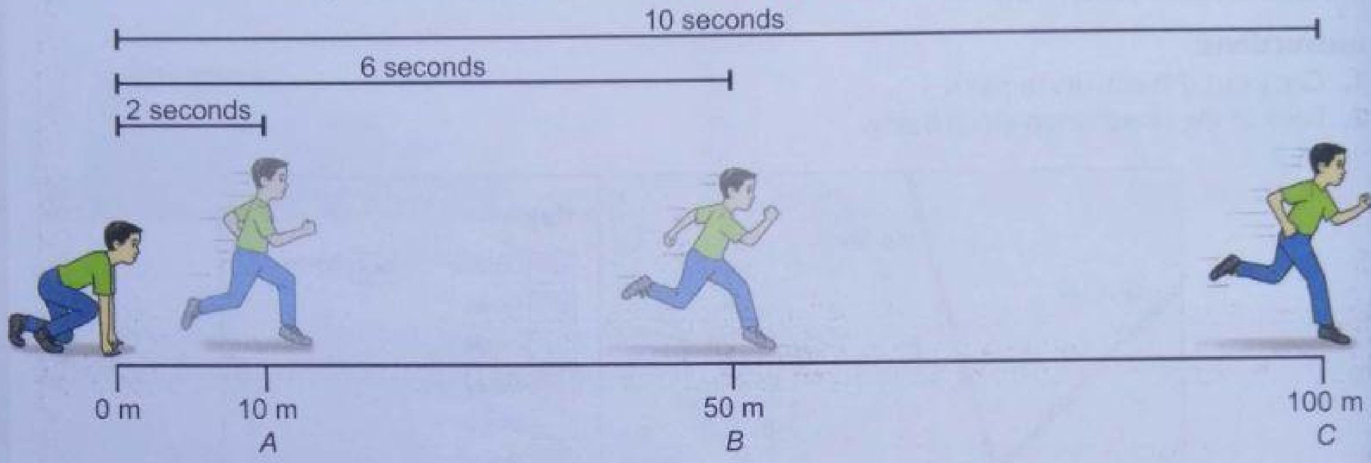


Figure 11.4 *Positions of a runner*

- A 100 m runner will experience change in distance the moment he starts running from the starting line.
- The change in distance increases as the runner becomes increasingly further away from the starting line.
- The speed of the runner can be determined by the distance and time taken.
- The following are examples of calculations for the speed of the runner:

(a) Speed of the runner at position *A*

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} = \frac{10\ \text{m}}{2\ \text{s}} = 5\ \text{m s}^{-1}$$

(b) Speed of the runner at position *B*

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} = \frac{50\ \text{m}}{6\ \text{s}} = 8.33\ \text{m s}^{-1}$$

- The following is an example of calculation for the average speed of the runner:

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}} = \frac{100\ \text{m}}{10\ \text{s}} = 10\ \text{m s}^{-1}$$

Velocity

Velocity is defined as the rate of change of displacement.

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}}$$

The S.I. unit for velocity is the same as speed, which is **metre per second** (m s^{-1}).

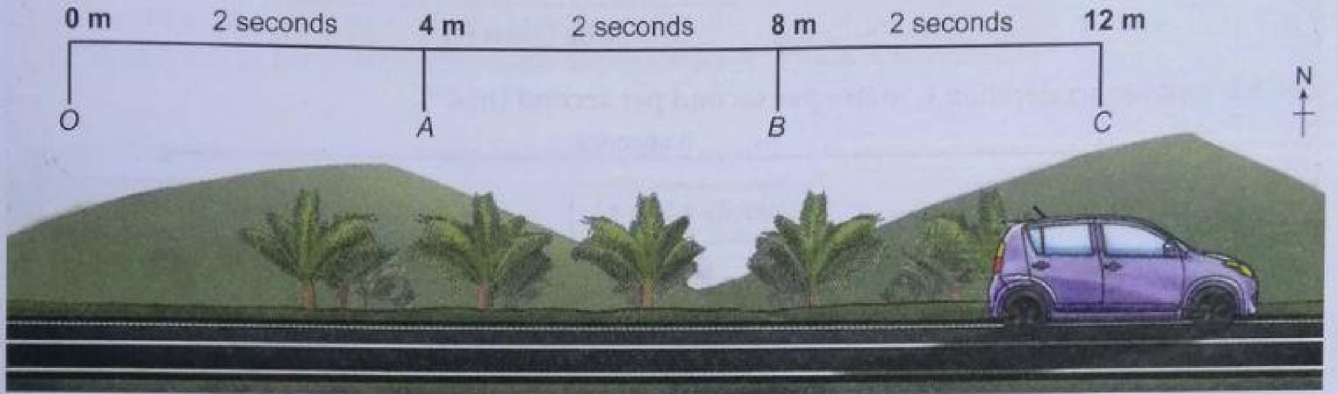


Figure 11.5 *Position of a car*

- The car above starts to move from initial point *O* to final point *C* which has a displacement of 12 m to the east. The car experiences a change in displacement.
- The velocity of the car can be determined by the displacement and time taken by the car to reach point *C*.
- The following is an example of the calculation for velocity of the car:

(a) Velocity of the car from point *O* to *A*

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}} = \frac{4\text{ m}}{2\text{ s}} = 2\text{ m s}^{-1}$$
to the east

(b) Velocity of the car from point *A* to *B*

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}} = \frac{(8\text{ m} - 4\text{ m})}{2\text{ s}} = \frac{4\text{ m}}{2\text{ s}} = 2\text{ m s}^{-1}$$
to the east

(c) Velocity of the car from point *O* to *C*

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}} = \frac{12\text{ m}}{6\text{ s}} = 2\text{ m s}^{-1}$$
to the east

- The positive and negative signs in the value for velocity show the direction of motion of the car.
- Referring to Figure 11.5, when the car travels to the east, its velocity is written with a positive sign. The velocity of the car in the opposite direction would be written with a negative sign.

Acceleration

A body or object which experiences a change in velocity is said to have acceleration. **Acceleration** is defined as the rate of change of velocity.

$$\text{Acceleration, } a = \frac{\text{Change of velocity}}{\text{Time taken}} = \frac{\text{Final velocity } (v) - \text{Initial velocity } (u)}{\text{Time taken } (t)}$$

The S.I. unit for acceleration is **metre per second per second** ($m\ s^{-2}$).

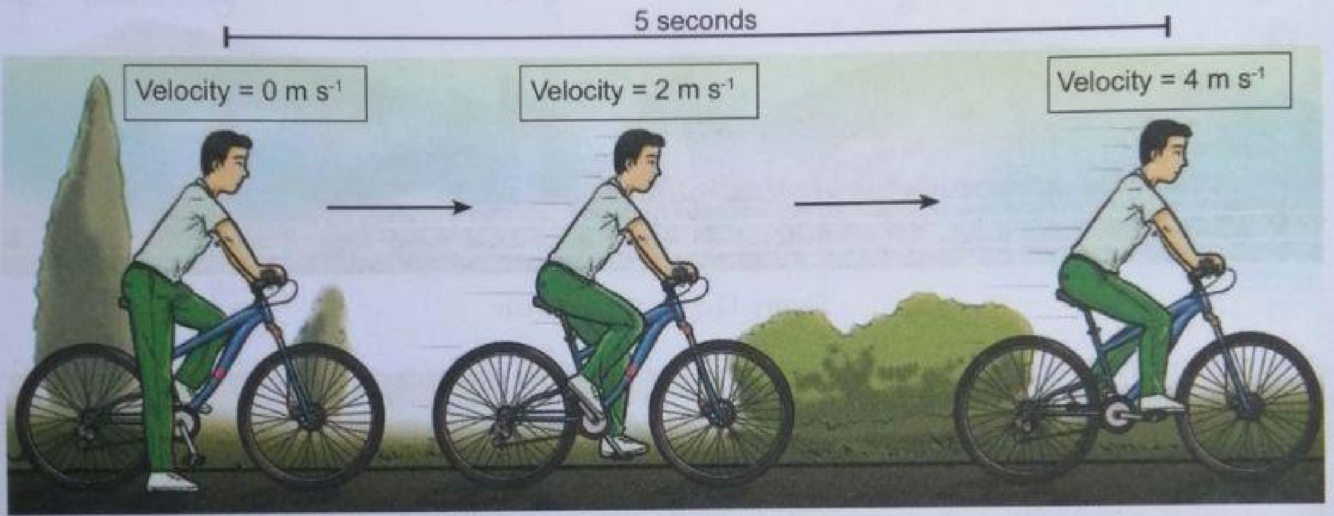


Figure 11.6 *Velocity of a bicycle*

- The bicycle in the figure above which is stationary starts to move with the velocity as stated above. The bicycle is pedalled with increasing velocity.
- This situation shows that the bicycle is experiencing acceleration.
- The following is an example of calculation for acceleration of the bicycle:

$$\text{Acceleration, } a = \frac{\text{Change of velocity}}{\text{Time taken}} = \frac{\text{Final velocity } (v) - \text{Initial velocity } (u)}{\text{Time taken } (t)} = \frac{4\ m\ s^{-1} - 0\ m\ s^{-1}}{5\ s} = 0.8\ m\ s^{-2}$$

- If the brakes are applied, the bicycle will slow down and the velocity of the bicycle will decrease. This situation shows that the bicycle experiences **deceleration**.

Solving Problems involving Speed, Average Speed, Velocity and Acceleration in Daily Life

The change in speed, velocity and acceleration of an object can be shown more clearly using formulae. Problems involving linear motion often occur in our daily life.

Example 1

A student participates in a 100 m race. He recorded 12.58 seconds in the event. What is his average speed?

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}} = \frac{100 \text{ m}}{12.58 \text{ s}} = 7.95 \text{ m s}^{-1}$$

Example 2

Figure 11.7

A car travels 800 m from point A to point B in 65 seconds. Then, the car turns back 350 m from point B to point C in 30 seconds.

(a) What is the speed of the car at point B?
(b) Determine the total displacement of the car.
(c) What is the velocity of the car?

(a) $\text{Car speed} = \frac{\text{Distance}}{\text{Time}} = \frac{800 \text{ m}}{65 \text{ s}} = 12.31 \text{ m s}^{-1}$

(b) $\text{Displacement} = 800 \text{ m} - 350 \text{ m} = 450 \text{ m}$

(c) $\text{Velocity} = \frac{\text{Displacement}}{\text{Time}} = \frac{450 \text{ m}}{95 \text{ s}} = 4.74 \text{ m s}^{-1}$

Example 3

What is the acceleration of Usain Bolt if he starts from rest and attains a velocity of 10.44 m s^{-1} at the 100 m finish line in 9.58 seconds?

$$a = \frac{v - u}{t}$$

$$a = \frac{10.44 \text{ m s}^{-1} - 0 \text{ m s}^{-1}}{9.58 \text{ s}}$$

$$a = 1.09 \text{ m s}^{-2}$$

Example 4

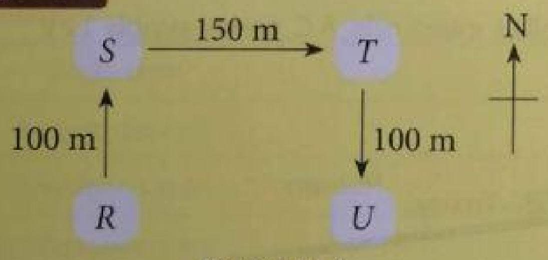


Figure 11.8

Syafiq runs from point R to S which is 100 m to the north of R. He then runs to T, 150 m to the east of S. He continues running to U, 100 m to the south of T. The total time taken is 60 seconds. Calculate the:

(a) distance
(b) average speed
(c) displacement
(d) velocity

(a) Distance
$= 100 \text{ m} + 150 \text{ m} + 100 \text{ m}$
$= 350 \text{ m}$

(b) $\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}} = \frac{350 \text{ m}}{60 \text{ s}} = 5.83 \text{ m s}^{-1}$

(c) Displacement = 150 m to the east

(d) $\text{Velocity} = \frac{\text{Displacement}}{\text{Time}} = \frac{150 \text{ m}}{60 \text{ s}}$ = 2.5 m s^{-1} to the east

Science Gallery

Photogate is a timing device used to measure very fast motion or short time intervals accurately. Photogate is suitable for determining acceleration due to free fall, period of oscillation of pendulum or speed of trolley moving down a track.

The velocity and acceleration of an object in motion can be determined through activities carried out in the laboratory using a ticker timer. The ticker timer vibrates at 50 vibrations per second (50 Hz). One tick is the time interval between two adjacent dots on the ticker tape (Figure 11.9). Therefore, one tick represents $\frac{1}{50}$ seconds or 0.02 seconds.

Figure 11.9 *Ticker tape*

Example

The velocity of the ticker tape which has 5 ticks can be calculated using the following formula:

Displacement
= length of ticker tape
= 10 cm

Time taken
= 5 ticks × 0.02 s
= 0.1 s

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time taken}} = \frac{10 \text{ cm}}{0.1 \text{ s}} = 100 \text{ cm s}^{-1}$$

How can we take measurements on the ticker tape to determine the velocity, displacement and acceleration of an object in motion? Let us carry out Activity 11.2.

Activity 11.2

Inquiry

21st Century Skills

Aim: To determine the velocity and acceleration of an object using a ticker timer.

Material: Ticker tape

Apparatus: Ticker timer, runway, wooden block, trolley, metre rule, A.C. power supply 12 V

Procedure:

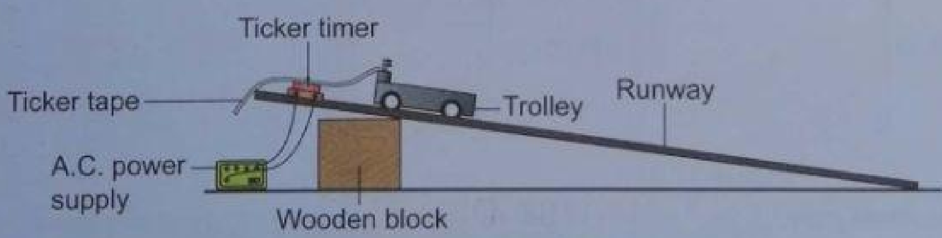


Figure 11.10 *Setup of apparatus*

1. Arrange the apparatus as shown in Figure 11.10.
2. Switch on the ticker timer and let the trolley move down the runway.
3. Collect the ticker tape obtained.

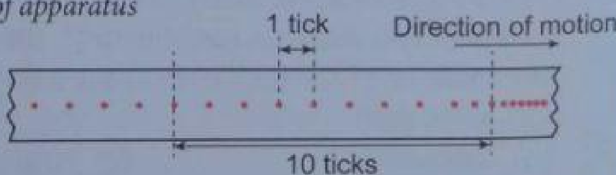


Figure 11.11 *Ticker tape*

4. Cut the ticker tape into 5 strips of 10 ticks each. Paste them side by side to form the chart as shown in Figure 11.12.
5. Record the length of each strip of ticker tape.
6. Calculate the velocity of each strip using the following formula:

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}} = \frac{\text{Length of ticker tape with 10 ticks}}{\text{Time to make 10 ticks}}$$

* Time for 1 tick = 0.02 seconds

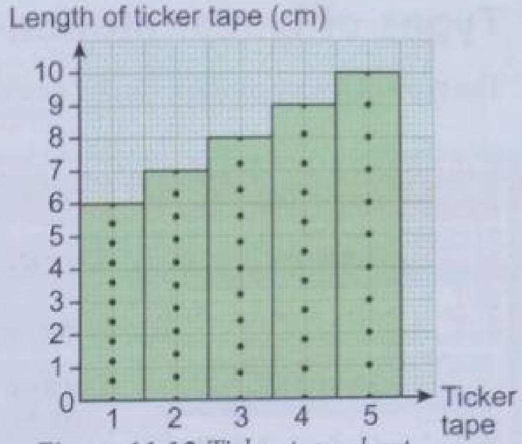


Figure 11.12 *Ticker tape chart*

7. Based on the tape chart in Figure 11.12, calculate the acceleration using the following formula:

Acceleration, $a = \frac{v - u}{t}$

Initial velocity, u = Velocity of ticker tape 1
Final velocity, v = Velocity of ticker tape 5
Time interval, t from ticker tape 1 to ticker tape 5 = $(5 - 1) \times 0.2$ s
**Time for 10 ticks on one strip = 10 ticks × 0.02 s
= 0.2 s

8. Record the results in the table.

Observation:

Velocity

Ticker tape	Time to make 10 ticks (s)	Length of 10 ticks (cm)	Velocity (cm s^{-1})
1	0.2		
2	0.2		
3	0.2		
4	0.2		
5	0.2		

Acceleration

Ticker tape	1	5
Velocity (cm s^{-1})		
Time interval (s)		
Acceleration (cm s^{-2})		

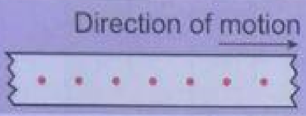
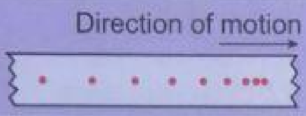
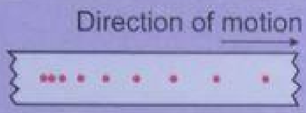
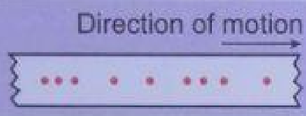
Questions:

1. What can be observed from the ticker tape?
2. Is the length of each 10-tick strip the same? What inference can be made based on your observation?

Types of Linear Motion

The type of linear motion can be determined from the distance between dots on the ticker tape.

Table 11.1

Ticker tape	Distance between dots	Type of motion
	Distance between dots is constant	Uniform velocity
	Distance between 2 consecutive dots increases uniformly	Velocity increases uniformly (Uniform acceleration)
	Distance between 2 consecutive dots decreases uniformly	Velocity decreases uniformly (Uniform deceleration)
	Distance between 2 consecutive dots is not constant	Non-uniform velocity

Activity 11.3

Round Table

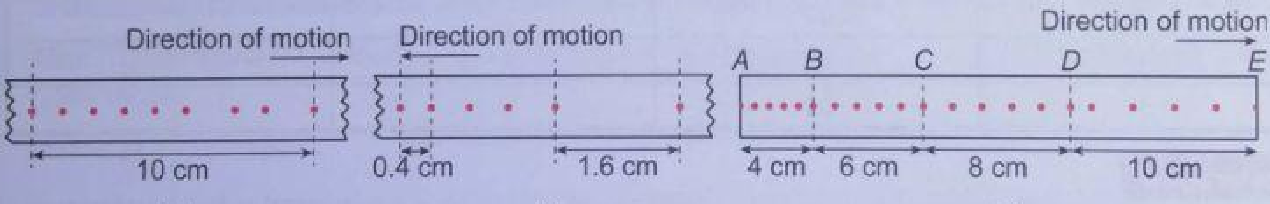
21st Century Skills

Aim: To carry out an activity to study the type of motion and to determine the velocity and acceleration of a motion using a ticker timer.

Material: Flip chart paper

Instructions:

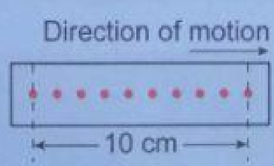
1. Carry out this activity in groups.
2. Observe the figures below which show three strips of ticker tape for three different motions of an object.



3. Discuss the type of motion, velocity and acceleration of each ticker tape above.
4. Present the results of your group's work to the class.

FORMATIVE PRACTICE 11.1

1. State the meaning of the following terms:
   (a) Distance (b) Displacement (c) Velocity (d) Acceleration
2. The figure shows a strip of ticker tape that was pulled through a ticker timer vibrating at 50 ticks per second. What is the displacement and velocity shown by the strip of ticker tape?



11.1.4

11.2 Linear Motion Graphs

Sometimes, it is difficult for us to explain motion in words. Therefore, we can use graphs to explain the motion of an object in detail.

Linear motion graphs are used to present information and data regarding a motion. There are two types of linear motion graphs that you have to learn, which are the **displacement-time graph** and the **velocity-time graph**.

Displacement-time graph

The displacement against time graph is used to show the displacement of an object changing with time. Figure 11.13 shows a displacement against time graph for the motion of a boy. Can you describe the motion of the boy?

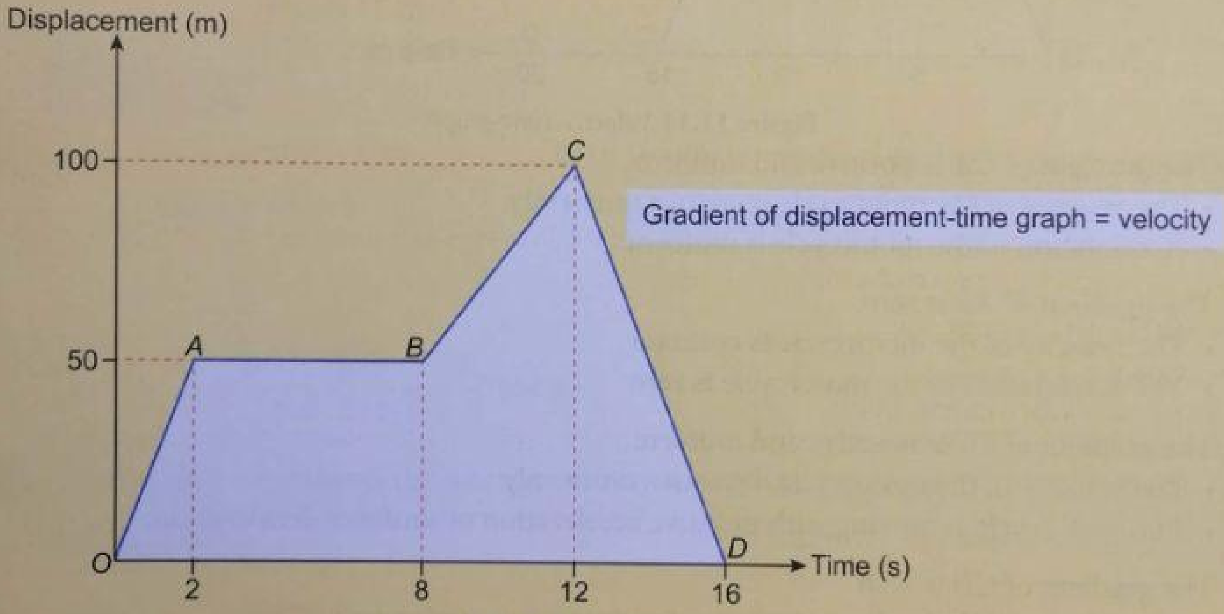


Figure 11.13 *Displacement-time graph*

OA: The gradient of *OA* is positive and uniform.
- Its velocity is uniform.
(The boy moves 50 m from the starting point with uniform speed.)

AB: The gradient of *AB* is zero.
- Its velocity is zero.
(The boy is at rest from the 2^{nd} to the 8^{th} second.)

BC: The gradient of *BC* is positive and uniform.
- Its velocity is uniform.
(The boy moves 50 m with uniform speed.)

CD: The gradient of *CD* is negative and uniform.
- Its velocity is negative and uniform, that is moving in the opposite direction.
(The boy turns back 100 m to the starting point with uniform speed.)

11.2.1

Velocity–time graph

The velocity against time graph allows the displacement, velocity and acceleration of an object in motion to be determined. The velocity against time graph below shows the motion of a motorcycle which starts to move from point *O*. Explain the motion of the motorcycle.

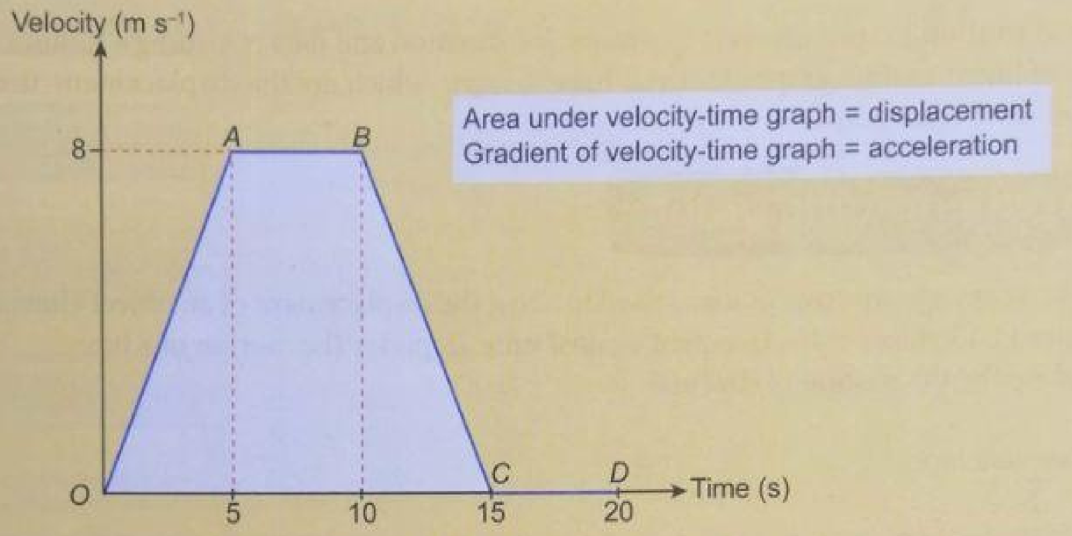


Figure 11.14 *Velocity-time graph*

OA: The gradient of *OA* is positive and uniform.
- The velocity of the motorcycle increases uniformly.
- Acceleration of the motorcycle is uniform.

AB: The gradient of *AB* is zero.
- The velocity of the motorcycle is constant.
- The acceleration of the motorcycle is zero.

BC: The gradient of *BC* is negative and uniform.
- The velocity of the motorcycle decreases uniformly.
- The motorcycle is moving with negative acceleration or uniform deceleration.

CD: The gradient of *CD* is zero.
- The velocity of the motorcycle is zero (motorcycle is stationary).
- The acceleration of the motorcycle is zero.

Activity 11.4

Result Showcase

21st Century Skills

Aim: To draw and interpret the linear motion graphs for:
(a) displacement-time (b) velocity-time

Materials: Pencil and paper

Instructions:
1. Carry out this activity in groups.
2. Choose envelops of different colour provided by your teacher.
3. Discuss and draw a graph based on the situation described in the envelop chosen by your group.
4. Present the results of your work to the class.

Solving Numerical Problems involving Linear Motion Graphs

Displacement-time graph

1 The graph below shows the linear motion of a remote control toy car.

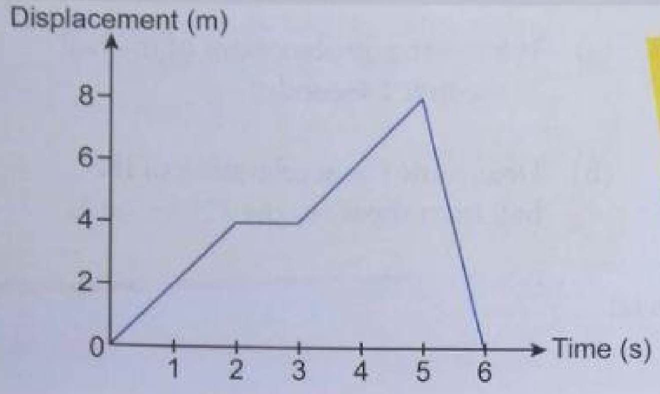


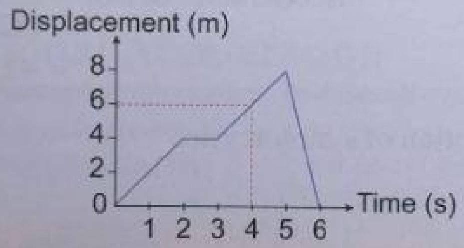
Figure 11.15

(a) What is the displacement of the toy car after the first 4 seconds?

(b) What is the velocity of the toy car from the 3rd to the 5th second?

Solution

(a) Displacement = 6 m



(b) Velocity = gradient of displacement-time graph

$$\text{Velocity of the toy car} = \frac{(8-4)\text{ m}}{(5-3)\text{ s}} = \frac{4\text{ m}}{2\text{ s}} = 2\text{ m s}^{-1}$$

2 The graph below shows the motion of a motorcycle along a straight track.

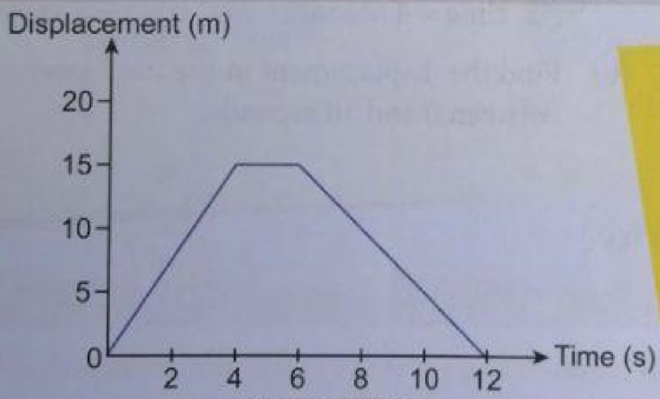


Figure 11.16

(a) What is the displacement of the motorcycle after 4 seconds?

(b) What is the velocity of the motorcycle from the 6th to the 12th second?

Solution

(a) Displacement = 15 m

(b) Velocity = gradient of displacement-time graph

$$\text{Velocity of the motorcycle} = \frac{(0-15)\text{ m}}{(12-6)\text{ s}} = -2.5\text{ m s}^{-1}$$

Velocity-time graph

1 The motion of a ball can be represented by the graph below.

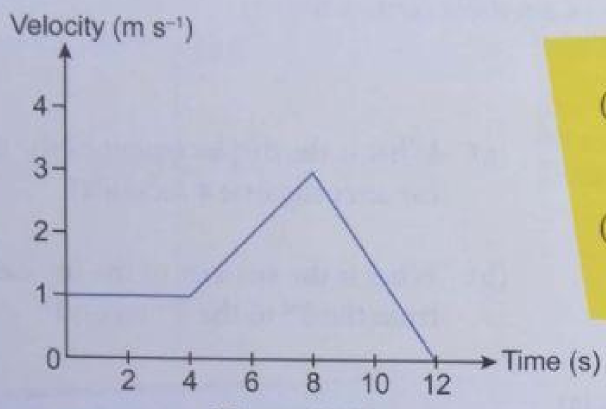


Figure 11.17

(a) What is the displacement of the ball in the first 4 seconds?

(b) Determine the acceleration of the ball from the 8th to the 12th second.

Solution

(a) Displacement = Area under the velocity-time graph

$= 4\text{ s} \times 1\text{ m s}^{-1}$

$= 4\text{ m}$

(b) Acceleration = gradient of velocity-time graph

$$\text{Acceleration of ball} = \frac{(0-3)\text{ m s}^{-1}}{(12-8)\text{ s}}$$

$$= -0.75\text{ m s}^{-2}$$

2 The velocity-time graph below shows the motion of a motorcycle.

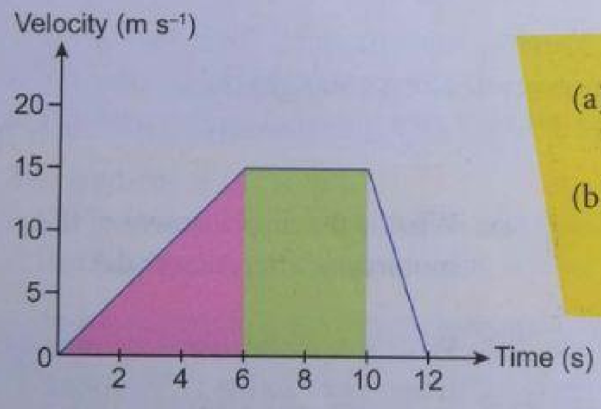


Figure 11.18

(a) Determine the velocity when
(i) time = 4 seconds (ii) time = 8 seconds

(b) Find the displacement in the time interval between 0 and 10 seconds.

Solution

(a) (i) Velocity at 4 seconds $= 10\text{ m s}^{-1}$

(ii) Velocity at 8 seconds $= 15\text{ m s}^{-1}$

(b) Displacement = area under the velocity-time graph
= area of triangle + area of rectangle

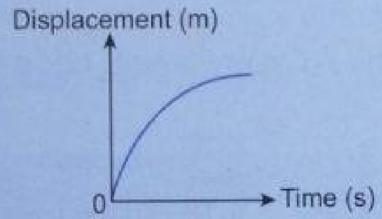
$$= [\frac{1}{2} \times (6\text{ s})(15\text{ m s}^{-1})] + [(10\text{ s} - 6\text{ s})(15\text{ m s}^{-1})]$$

$$= 105\text{ m}$$

FORMATIVE PRACTICE 11.2

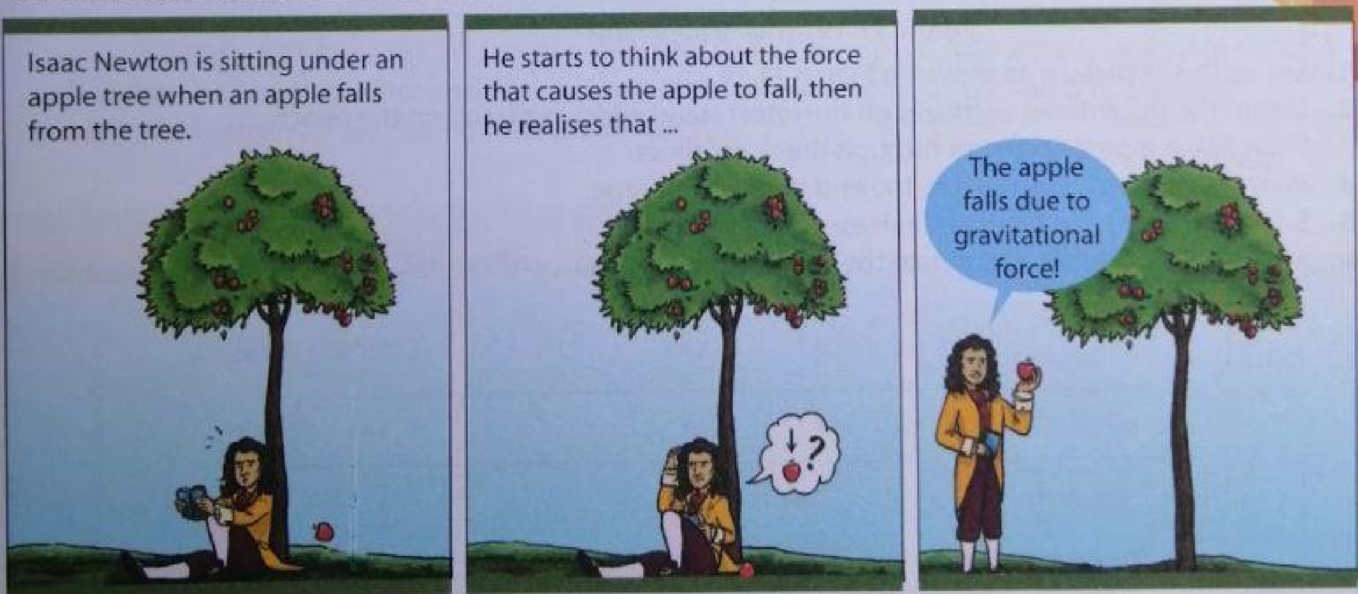
1. What is represented by the gradient of the graph in the displacement-time graph?
2. What is represented by the area under the graph in the velocity-time graph?
3. A toy car moves down a smooth runway and then moves over a rough flat surface until it stops. Sketch the velocity-time graph which describes the motion of the toy car.

4. Interpret the motion of the object based on the graph shown below.



11.3 Gravitational Acceleration and Free Fall

Gravitational Acceleration



You have been introduced to the term gravitational force in Form 2. All objects around us are pulled towards the centre of Earth by **Earth's gravitational force**. Gravitational force causes an object to always fall downwards. An object such as the apple that falls due to Earth's gravitational force will experience **gravitational acceleration**. The symbol used to represent gravitational acceleration is g.

What is the value of g? How can we determine the value of g in the laboratory? Let us carry out Experiment 11.1.

Brain Teaser

What will happen if there is no gravitational force on Earth?

11.3.1

Experiment 11.1

Aim: To determine the value of gravitational acceleration, *g* using a ticker timer.

Problem statement: What is the value of the gravitational acceleration, *g*?

Hypothesis: The value of gravitational acceleration, *g* is 10 m s^{-2}.

Variables:

(a) manipulated: Mass of weight
(b) responding: Value of gravitational acceleration
(c) constant: Height of object released

Materials: Ticker tape, cellophane tape

Apparatus: Ticker timer, weight, G-clamp, A.C. power supply 12 V, soft board, retort stand and clamp

Procedure:

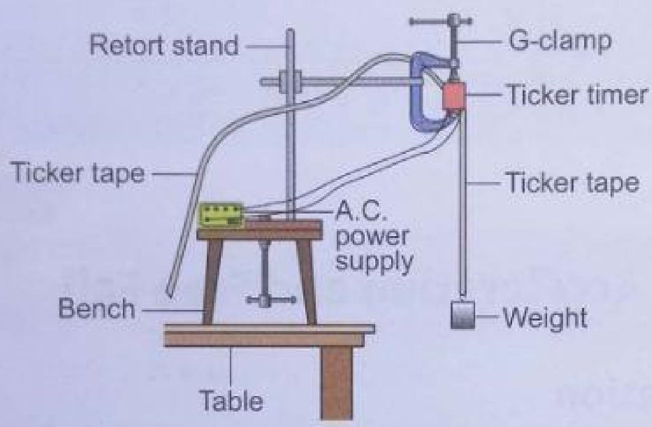
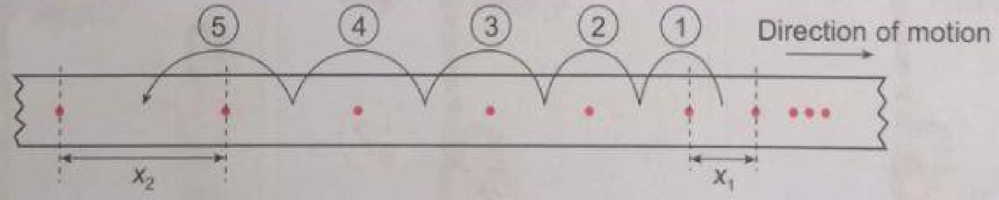


Figure 11.19 *Setup of apparatus*

Precautionary measures:
Place the soft board on the spot where the weight will hit the floor.

1. Set up the apparatus as shown in Figure 11.19.
2. Clamp the ticker timer vertically on the retort stand which is placed on the bench.
3. Put a ticker tape strip of 1 m through the ticker timer.
4. Hang a weight of mass 50 g to the end of the ticker tape.
5. Switch on the ticker timer and release the weight.
6. Analyse the ticker tape to obtain the value of gravitational acceleration, *g* by the following method:



Initial velocity, $u = \dfrac{x_1 \text{ cm}}{0.02 \text{ s}}$

Final velocity, $v = \dfrac{x_2 \text{ cm}}{0.02 \text{ s}}$

Time interval, t = 5 ticks × 0.02 s
= 0.1 s

Gravitational acceleration, $g = \dfrac{v - u}{t}$
= ______ cm s^{-2}
= ______ m s^{-2}

7. Repeat steps 3 to 6 using weights of mass 100 g, 150 g, 200 g and 250 g.

Result:

Mass of weight (g)	50	100	150	200	250
Gravitational acceleration, g (m s^{-2})					

Conclusion:

Is the hypothesis of this experiment accepted? What is the conclusion of this experiment?

The value of gravitational acceleration, g on the surface of Earth is 10 m s^{-2}.

Is the value of the gravitational acceleration obtained in Experiment 11.1 the same as the actual value of g? Explain your answer.

Free Fall

An object is said to experience free fall if it falls due to the effects of gravitational force only. For example, a sheet of paper does not fall freely because its motion is affected by air resistance. Objects falling freely, fall with the same gravitational acceleration no matter what their mass and shape are.

Actually, free fall only occurs in a vacuum, that is in a space with no air. In a vacuum chamber, a chicken feather and a tennis ball that are released from the same height will reach the bottom of the chamber simultaneously.

Brain Teaser

Take a look at Photograph 11.1. Do the parachutists experience free fall?

Photograph 11.1 *Parachutists*

11.3.2

Motion Graphs of Objects Experiencing Free Fall

Now, let us study the free fall in more detail by using linear motion graphs.

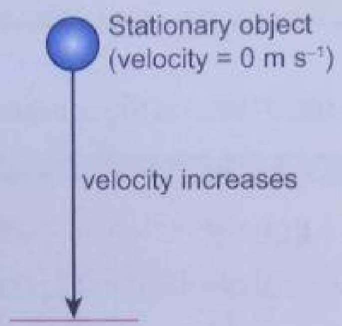
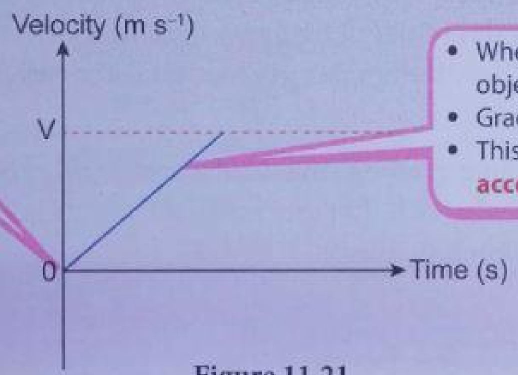


Figure 11.20 *Object released from a certain height*

Velocity-time graph

- Before being released, the velocity of the object is zero.
- The object is stationary.



- When the object is released, the velocity of the object increases uniformly.
- Gradient of velocity-time graph = acceleration
- This acceleration is known as **gravitational acceleration.**

Figure 11.21

Displacement-time graph

③
- During free fall, the object falls with a higher velocity than its initial velocity.
- This can be seen in the greater value of the gradient of the graph.

②
- Once the object is released, it falls with a low velocity.
- This can be seen in the small value of the gradient.

①
- Before being released, the displacement of the object is zero.
- The object is stationary.

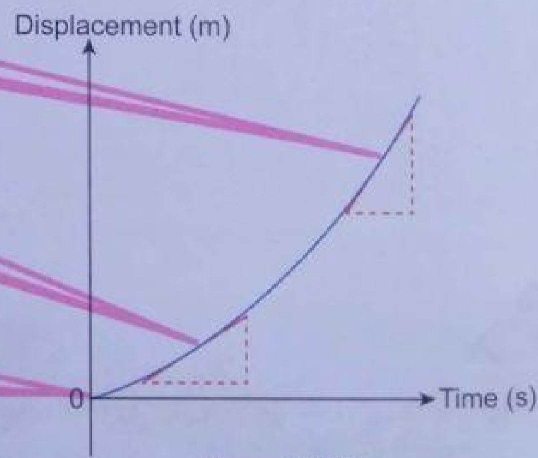


Figure 11.22

Motion Graph of Objects Moving Against Gravitational Force (Antigravity)

What is the shape of the linear motion graph if the object moves against gravity?

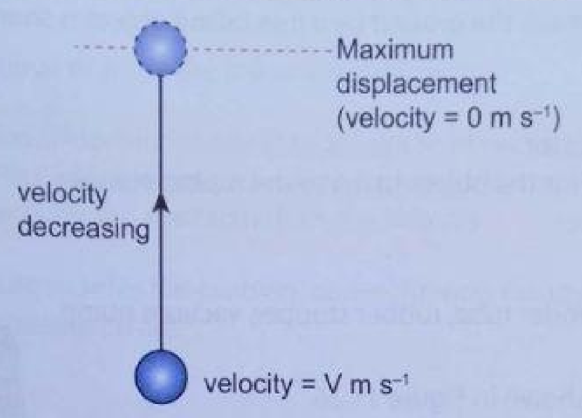
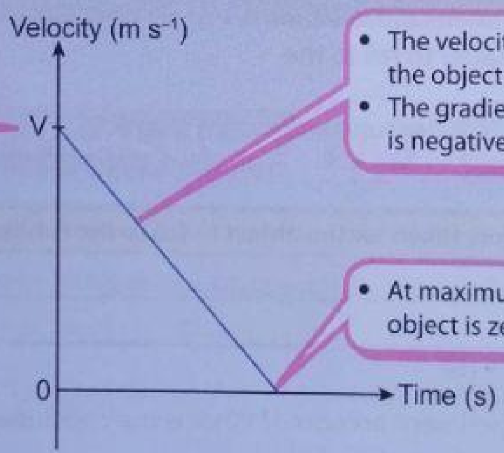


Figure 11.23 *Object thrown vertically upwards*

Velocity-time graph

- When thrown upwards, the object starts to move with a velocity of V m s^{-1}.



- The velocity of the object decreases as the object moves upwards.
- The gradient of the velocity-time graph is negative.

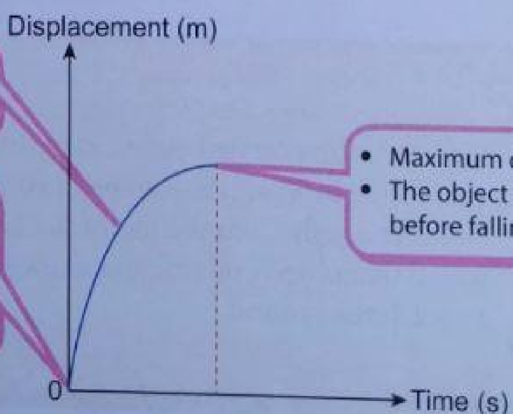
- At maximum height, the velocity of the object is zero.

Figure 11.24

Displacement-time graph

- The object moves upwards with decreasing velocity.

- Once thrown upwards, the object moves with a velocity, V m s^{-1}. At the same time, the displacement of the object changes.



- Maximum displacement, zero velocity.
- The object will momentarily stop before falling back downwards.

Figure 11.25

Experiment 11.2

Aim: To study the time taken for an object to fall during free fall and non-free fall motions.

Problem statement: Is the time taken for a free falling object to reach the ground the same as that for a non-free falling object?

Hypothesis: Time taken to reach the ground by a free falling object is shorter than a non-free falling object.

Variables:
(a) manipulated: Presence of air
(b) responding: Time taken for the object to fall to the rubber stopper
(c) constant: Height of object

Material: Pieces of paper

Apparatus: Transparent cylinder tube, rubber stopper, vacuum pump

Procedure:
1. Set up the apparatus as shown in Figure 11.26.
2. Put the pieces of paper into the transparent cylinder tube.
3. Close the open end of the cylinder tube tightly with a rubber stopper.
4. Connect the transparent cylinder tube to the vacuum pump.
5. Quickly turn the cylinder tube upside down and let the pieces of paper fall. Record the time taken for the pieces of paper to fall to the rubber stopper.
6. Pump out the air in the cylinder tube and repeat step 5.

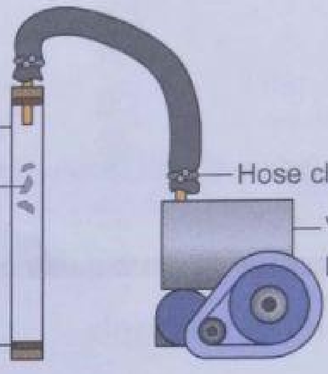


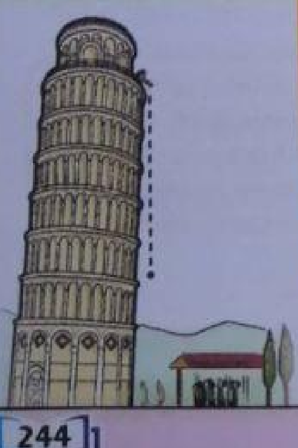
Figure 11.26 *Setup of apparatus*

Result:

Presence of air	Time taken for the object to fall to the rubber stopper (s)
Yes	
No (vacuum)	

Conclusion:
Is the hypothesis of this experiment accepted? What is the conclusion of this experiment?

Question:
Are there any forces other than gravitational force acting on the object during free fall? Explain.



Galileo Galilei carried out an experiment sometime in the years 1589 to 1592. He dropped two spheres of different mass simultaneously from the top of the Leaning Tower of Pisa. He found that objects of different masses take almost the same time to reach the ground.

Activity 11.5

STEM Project

Aim: To understand and solve issues regarding free fall motions in the context of daily life through projects based on the STEM approach.

Instructions:

1. Carry out this activity in groups to study the following statement:

   In the event of a major flood, food and medical supplies sometimes need to be dropped from the air. Often these supplies will be damaged due to high velocity impact upon reaching the surface of the earth. Parachutes are used to reduce the velocity.

2. Design and build a parachute to solve the problem above. Among the characteristics of the parachute that should be considered are:
   - size of canopy
   - material of canopy
   - length of string
   - number of strings
3. Present your work to the class.

FORMATIVE PRACTICE 11.3

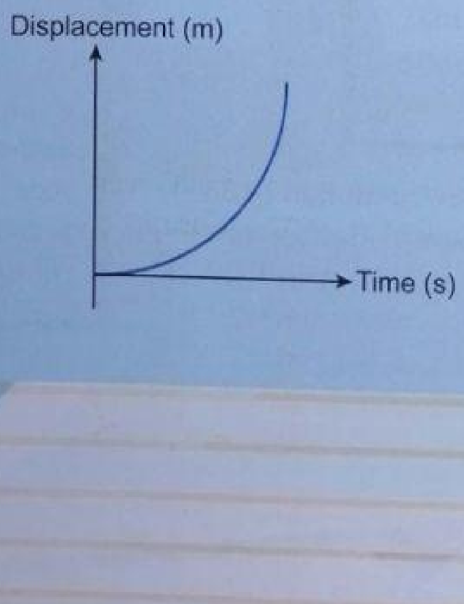
1. Fill in the blanks with the correct answer.

   (a) Free fall is the motion of an object due to ____________ force only.

   (b) The non-free fall motion of an object is affected by ____________ resistance.

   (c) ____________ is the acceleration due to gravitational force acting on an object towards the centre of Earth.

2. The graph below shows the free fall of an object.



Explain the graph.

11.4 Mass and Inertia

Photograph 11.2 *Mass of an apple is measured using a digital scale*

Mass

You were introduced to the term mass in Form 1. **Mass** is the quantity of matter in an object. The S.I. unit for mass is **kilogram** (kg). The mass of an object is constant if the quantity of matter in an object does not change.

Inertia

Inertia is the natural tendency of an object to resist any change in its original state, whether at rest or in motion. Inertia is not a physical quantity, therefore it cannot be measured, has no value and no unit. Among the situations involving inertia:

Original state of object at rest

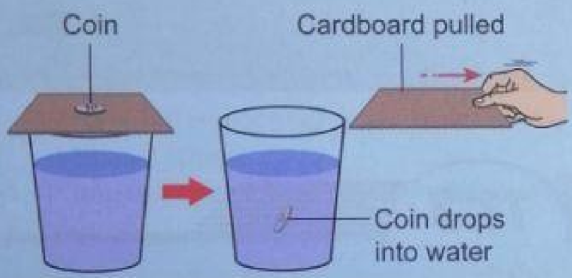


Figure 11.27

When the cardboard is pulled quickly, the coin will fall into the glass. The inertia of the coin will maintain the original state of the coin, that is, being at rest. The coin will not move together with the cardboard, instead it will fall into the glass due to gravitational force.

Inertia follows Newton's First Law of Motion by Sir Isaac Newton. **Newton's First Law of Motion** states that an object will remain in its original state, that is, being at rest or in motion with constant speed (in a straight line) if no external force acts on it.

Original state of object in motion

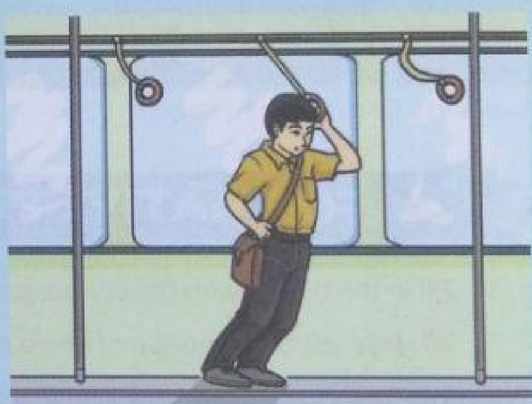


Figure 11.28

When the train moves, the passenger will move forward together with the train. When the train stops suddenly, the body of the passenger maintains its forward motion. Inertia of the passenger maintains the original state of the passenger, that is, being in motion. Thus, the passenger continues his forward motion.

Activity 11.6

Round Table

21st Century Skills

Aim: To discuss the meaning of inertia by studying situations that show the existence of inertia in daily life.

Instructions:

1. Carry out this activity in groups.
2. Discuss the following situations and relate them to inertia.
   - Our body leans to the right when the car we are in turns to the left.
   - Our body is hurled forward when the car we are in stops suddenly.
3. Present the results of your discussion.

INFORMATION
Examples of Inertia in Daily Life
http://bukuteksksm.my/Science/F4/Pg247

Relationship between Mass and Inertia

The inertia of an object is affected by its **mass**. The **larger** the mass of an object, the **larger** the inertia of the object.

The mass of an empty trolley is small, therefore the inertia of the trolley is also small. This enables the trolley to be easily moved from its original state.

The mass of a trolley filled with things is larger, therefore its inertia is also larger. This causes the trolley to be more difficult to move from its original state.

Photograph 11.3 *Situations showing the relationship between mass and inertia*

11.4.2

The relationship between mass and inertia can be studied using an **inertial balance**. The inertial balance was invented by NASA to determine the mass of objects in outer space. Let us carry out Experiment 11.3 to study the effects of mass on inertia.

Photograph 11.4 *Inertial balance*

Experiment 11.3

Aim: To study the relationship between mass and inertia.

Problem statement: Does the mass of an object affect the inertia of the object?

Hypothesis: The larger the mass of an object, the larger the inertia of the object.

Variables:

(a) manipulated: Mass of plasticine
(b) responding: Period of oscillation
(c) constant: Length of oscillating hacksaw blade, shape of plasticine

Material: Plasticine

Apparatus: G-clamp, hacksaw blade, stopwatch, electronic scale

Procedure:

1. Set up the apparatus as shown in Figure 11.29.
2. Tightly clamp the hacksaw blade horizontally onto the leg of a table using the G-clamp.
3. Stick a bit of plasticine with a mass of 30 g onto the end of the hacksaw blade.
4. Slightly pull the end of the hacksaw blade with the plasticine and release it so that it oscillates horizontally (as shown in Figure 11.29).
5. Take the time for 10 complete oscillations using a stopwatch and record it in the table.
6. Determine the period, T for one complete oscillation.
7. Repeat steps 3 to 6 using plasticine with the mass of 40 g, 50 g, 60 g and 70 g.

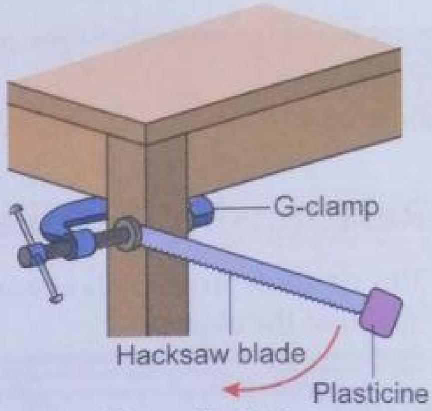


Figure 11.29 *Setup of apparatus*

Result:

Mass of plasticine (g)	Time for 10 oscillations, t (s)	Period, $T = \frac{t}{10}$ (s)
30		
40		
50		
60		
70		

Data analysis: Plot the graph of T against the mass of plasticine on a graph paper.

Conclusion:

Is the hypothesis of this experiment accepted? What is the conclusion of this experiment?

Questions:

1. State the relationship between the mass of plasticine and the period of oscillation.
2. State the relationship between the inertia of plasticine and its mass.
3. Is the period of oscillation of the hacksaw blade affected by gravitational force?

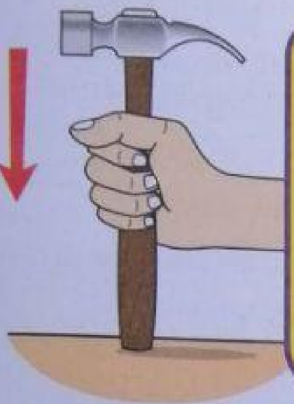
VIDEO

Experiment

http://bukuteksksssm.my/Science/F4/RelationshipbetweenMassandInertia.mp4

Effects of Inertia in Daily Life

You now know that inertia is affected by the mass of an object. Inertia can cause positive and negative effects in our daily life.
Figure 11.30 shows the positive effects of inertia.

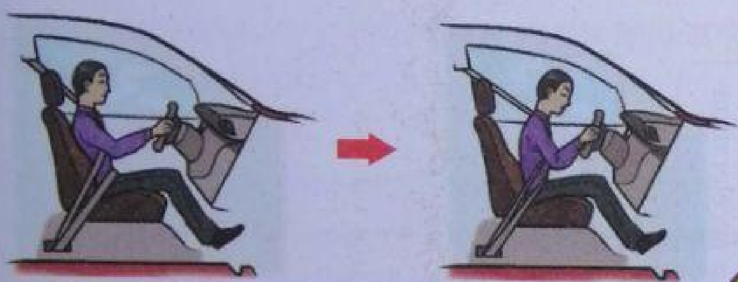


The loose head of a hammer can be tightened by banging its handle against a hard surface. A swift bang drives the hammer head downwards due to inertia.

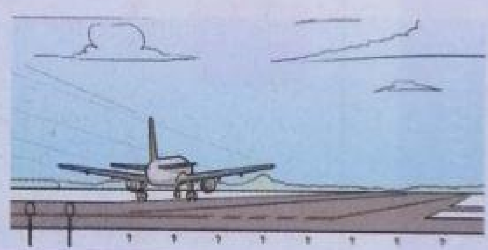
A wet umbrella can be dried by spinning the umbrella quickly and stopping it suddenly. Water droplets will continue to move even when the umbrella has stopped spinning due to inertia. So, the water droplets will fly off the umbrella.

Figure 11.30 *Positive effects of inertia*

Figure 11.31 shows the negative effects of inertia and ways to overcome it.



The effects of inertia can cause injury to car drivers. Therefore, a car is equipped with airbags, headrests and safety belts to reduce the effects of inertia.



During landing, an aeroplane of large mass cannot stop within a short distance due to inertia. Therefore, long runways are needed for the aeroplane to land safely.

Figure 11.31 *Negative effects of inertia and ways to overcome them*

Activity 11.7

Hot Seat

21st Century Skills

Aim: To discuss and share situations that show the benefits and damaging effects of inertia to humans.

Instructions:

1. Carry out this activity in groups.
2. Choose examples of the benefits and the damaging effects of inertia.
3. Present the results of the discussion in the form of 'Hot Seat' activity.

FORMATIVE PRACTICE 11.4

1. Give the meaning of inertia and provide two examples of inertia in our daily life.
2. State the relationship between mass and inertia.

11.4.4

Summary

FORCE AND MOTION

- **Linear Motion**
  - Distance and displacement
  - Speed = $\frac{\text{Distance}}{\text{Time}}$
  - Velocity = $\frac{\text{Displacement}}{\text{Time}}$
  - Acceleration $a = \frac{v - u}{t}$
- **Linear Motion Graphs**
  - Displacement-time graph
    - Gradient = velocity
  - Velocity-time graph
    - Gradient = acceleration
    - Area under the graph = displacement
- **Gravitational Acceleration and Free Fall**
  - Gravitational acceleration, g (10 m s^{-2})
  - Free fall
- **Mass and Inertia**
  - Mass
  - Inertia
  - Newton's First Law of Motion
  - Effects of inertia in daily life

Self-reflection

After studying this chapter, you are able to:

11.1 Linear Motion

- [ ] Explain the difference between distance and displacement and their units in daily life.
- [ ] Explain with examples the meaning of speed, average speed, velocity and acceleration and their units in daily life.
- [ ] Solve problems that involve speed, average speed, velocity and acceleration in daily life.
- [ ] Distinguish between the various types of linear motion.

11.2 Linear Motion Graphs

- [ ] Interpret the different types of motion from linear motion graphs to determine distance, displacement, velocity, average velocity and acceleration.

11.3 Gravitational Acceleration and Free Fall

- [ ] Carry out an experiment to determine the acceleration due to Earth's gravity, *g*.
- [ ] Interpret the motion graph for objects in free fall.
- [ ] Carry out an experiment to study free fall and non-free fall conditions.

11.4 Mass and Inertia

- [ ] Explain mass.
- [ ] Explain the meaning of inertia with examples.
- [ ] Carry out an experiment to study the relationship between mass and inertia.
- [ ] Communicate the effects of inertia in daily life.

Summative Practice 11

QUIZ

Objective Questions
http://bukuteksksssm.my/Science/F4/Q11

1. Azmeer rides his motorcycle to the north for 24 km, then to the west for 12 km and finally to the south for 12 km before he stops to rest (Figure 1). His journey takes 2 hours.
   (a) What is the distance travelled by Azmeer?
   (b) What is Azmeer's displacement?
   (c) Determine Azmeer's average speed.
   (d) Calculate the average velocity for Azmeer's displacement.

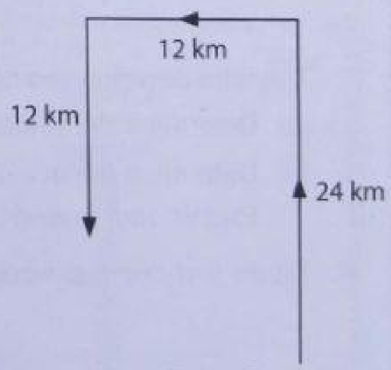


Figure 1

2. Hilmi walks to the north for 8 m, then to the east for 8 m. Hilmi takes 5 minutes to complete his journey.
   (a) What is the distance of his motion?
   (b) What is the displacement of his motion?
   (c) Determine the velocity attained by Hilmi.

3. Figure 2 is a graph that shows the motion of a car.

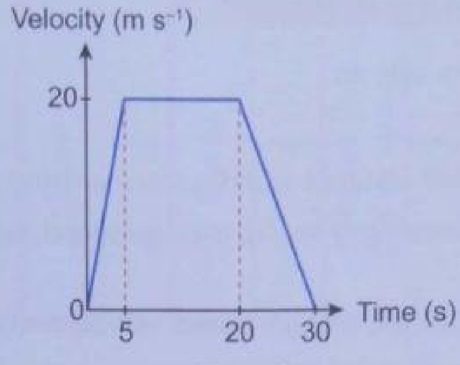


Figure 2

Based on the graph above,

(a) what represents acceleration?

(b) what is the acceleration of the car from 0 to 5 seconds?

(c) determine the total displacement of the car.

4. Figure 3 shows the motion of objects *P* and *Q* that are released simultaneously.

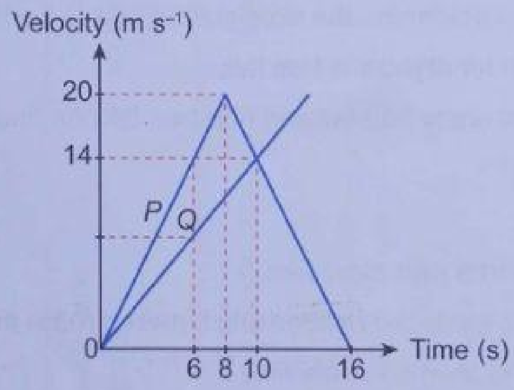


Figure 3

(a) Based on the gradient of graphs *P* and *Q*, which graph shows the higher value of acceleration at the 6th second? Explain your answer.

(b) Determine the gradient of graph *P* from 0 to 8 seconds.

5. Figure 4 shows a ticker tape strip of 16 cm in length.

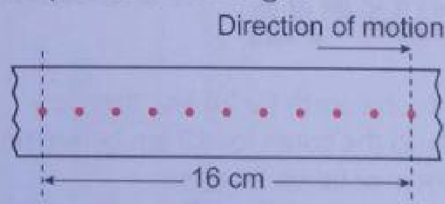


Figure 4

The time between two consecutive dots is 0.02 seconds.

(a) Determine the velocity of the ticker tape strip.

(b) Determine the acceleration of the ticker tape strip. Explain your answer.

6. Figure 5 shows two wooden blocks, *P* and *Q* which are of different sizes but have the same mass.

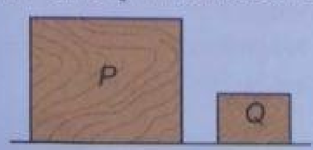


Figure 5

(a) Give the meaning of inertia.
(b) Which wooden block has a larger inertia? Explain your answer.
(c) State Newton's First Law of Motion.

7. Figure 6 shows a coin and a feather falling simultaneously inside two transparent cylinder tubes, *R* and *S*. Cylinder tube *R* contains air whereas cylinder tube *S* is a vacuum.

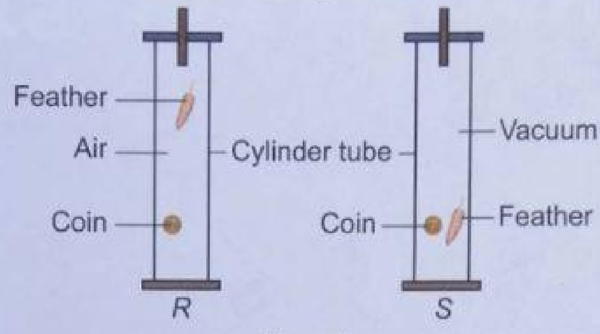


Figure 6

(a) What is meant by a free fall?
(b) Compare the time taken for the coin and the feather to fall inside cylinder tubes *R* and *S*. Explain your answer.
(c) Create a suitable conclusion for the activity above.

Mind Challenge

8. Figure 7 shows a ticker tape chart of a trolley moving down an inclined runway. The ticker timer being used vibrates at a frequency of 50 Hz.
(a) Determine the time for 10 ticks.
(b) What is the velocity for ticker tape 1 and ticker tape 5?
(c) The runway is inclined further so that the trolley moves down faster. Predict the length of the ticker tape chart that will be obtained.

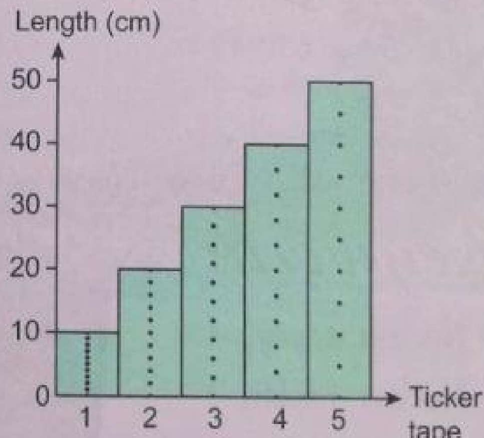


Figure 7

9. Figure 8 shows a student banging the handle of a hammer against a hard surface.
(a) What is the actual purpose of the student doing so?
(b) What is the concept used by the student?
(c) Explain two of your daily activities that use the concept stated in question **9**(b).

Figure 8