
QUICK REVISION
SPM
PHYSICS
ILMU KEKUATAN BANGSA
The Majestic SSI
Sekolah Menengah Kebangsaan
Sultan Ismail Johor Bahru
Sekolah Kluster Kecemerlangan
MODULE 2
2.1 Linear Motion
2.2 Inertia
2.3 Momentum
2.4 Effect of Force
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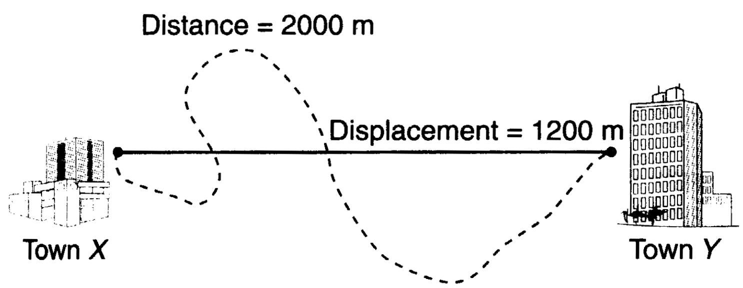
2.1 Analysing Linear Motion

1. Linear motion is motion in a straight line.

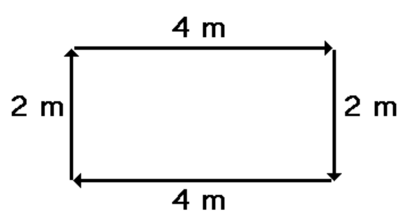
Distance And Displacement



1. Distance is the ***total length of the path traveled*** by an object.
2. Distance is a ***scalar quantity***. It has ***magnitude*** but ***no direction***.
3. Displacement is the ***distance of its final position from its initial position in specified direction***.
4. Displacement is a ***vector quantity***. It involves both ***magnitude*** and ***direction***.

Example 1

To test your understanding of this distinction, consider the motion depicted in the diagram below. A physics teacher walks 4 meters East, 2 meters South, 4 meters West, and finally 2 meters North.



Even though the physics teacher has walked a total distance of 12 meters, her displacement is 0 meters. During the course of her motion, she has "covered 12 meters of ground" (distance = 12 m). Yet, when she is finished walking, she is not "out of place" – i.e., there is no displacement for her motion (displacement = 0 m). Displacement, being a vector quantity, must give attention to direction. The 4 meters east is canceled by the 4 meters west; and the 2 meters south is canceled by the 2 meters north.

Speed and Velocity

1. Speed is the ____. Speed during the course of a motion is often computed using the following equation:

2. Velocity is the ____. Velocity is often computed using the equation:

3. Speed is a ____________________ whereas velocity is ___________________.
4. Both speed and velocity have the same SI unit. They are measured in **meter per second** or **m s^{-1}**. Other unit may be in **cm s^{-1}** or **km h^{-1}**.
5. The average speed during the course of a motion is often computed using the following equation:

6. Meanwhile, the average velocity is often computed using the equation:

Example 1

A man running in a race covers 60 m in 12 s.

(a) What is his speed in,

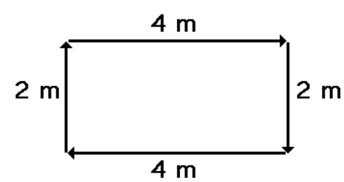
(i) m s^{-1}

(ii) km h^{-1}

(b) If he takes 40 s to complete the race, what is his distance covered?

(c) Another man runs with a speed of 7.5 m s^{-1}, how long did he take to complete the race?

Example 2



The physics teacher walks 4 meters East, 2 meters South, 4 meters West, and finally 2 meters North. The entire motion lasted for 24 seconds. Determine the average speed and the average velocity.

Acceleration And Deceleration

1. Acceleration is ____
2. It can be written as;

3. Acceleration is a ____. The SI unit for acceleration is **m s^{-2}**.
4. The acceleration is positive if the velocity increases with time. The acceleration is negative if the velocity decreases with time. It is also called **deceleration**.
5. Figure 2.1, shows that the car experiences acceleration, a constant velocity and then a deceleration.

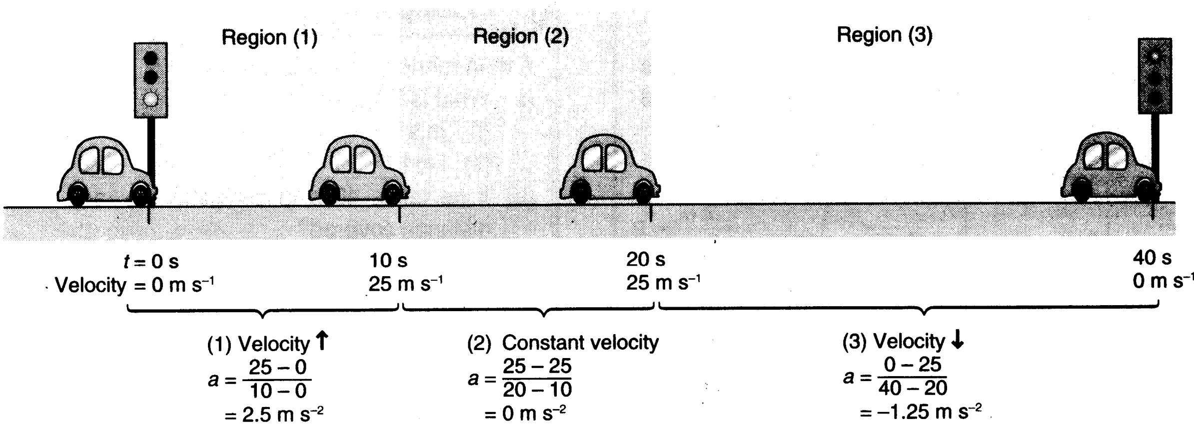


Figure 2.1

Example 1

A vehicle accelerates uniformly from rest to a speed of 25 m s^{-1} in 100 s along a straight road. It then decelerates uniformly at 0.2 m s^{-2} for 60 s. Find

(a) the initial acceleration

(b) the final speed

Study Of Linear Motion

Ticker-timer

1. In the laboratory, a ticker-timer as shown in figure 2.2, with a trolley is used to study the motion of an object for a short time interval.

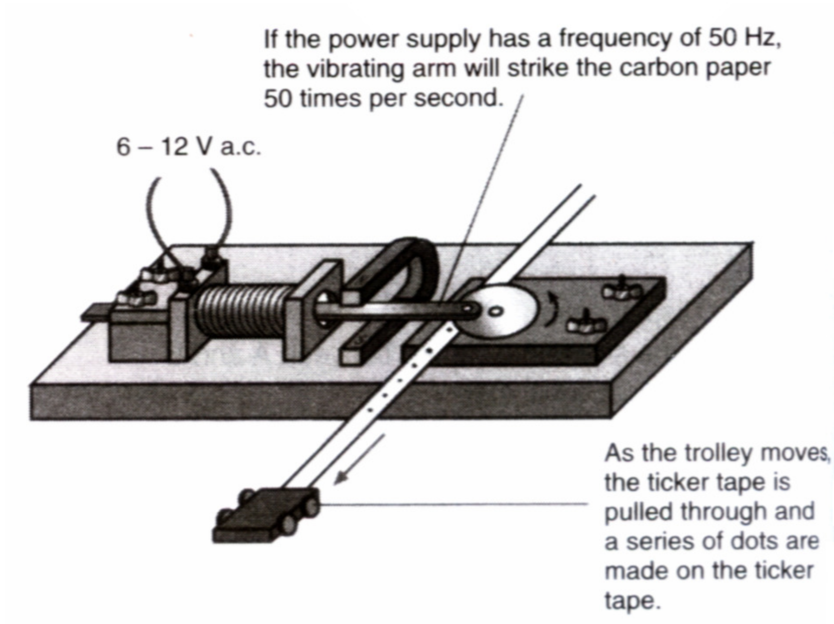


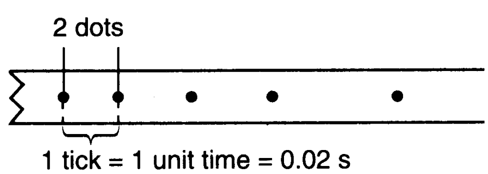
Figure 2.2

2. A ticker-timer consists of a small electrical vibrator which vibrates at the frequency of 50 Hz.
3. Hands-on Activity/page 13 in your practical book.

   Analysing motion using a ticker timer

   - to identify the types of motion
   - to determine displacement, average velocity and acceleration.

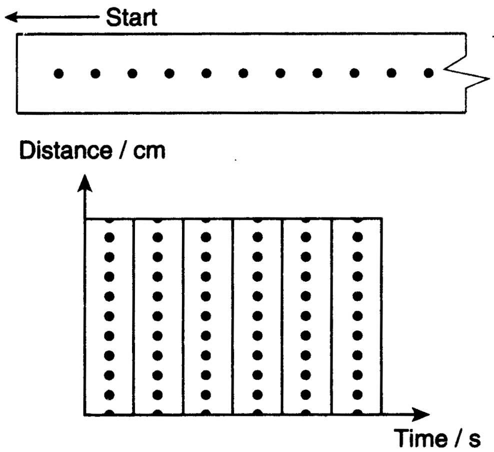
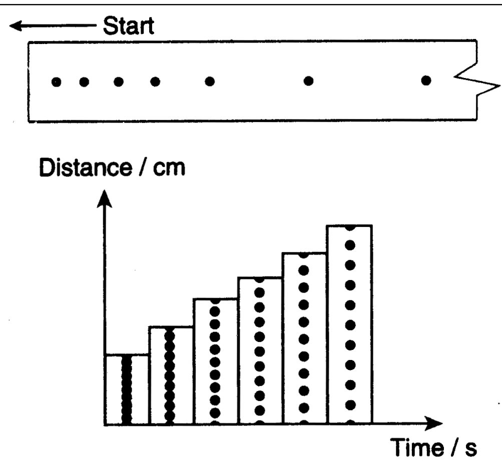
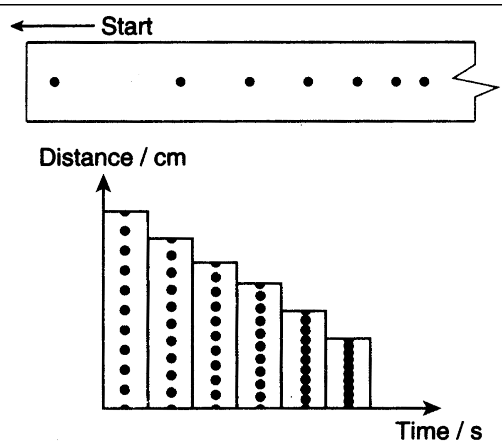
4. The time taken to make 50 dots on the ticker tape is 1 s. Hence, the time interval between 2 consecutive dots is $\frac{1}{50} = 0.02$ s



5. To determine the time interval of motion of the object:

Time interval = Number of tick x 0.02 s

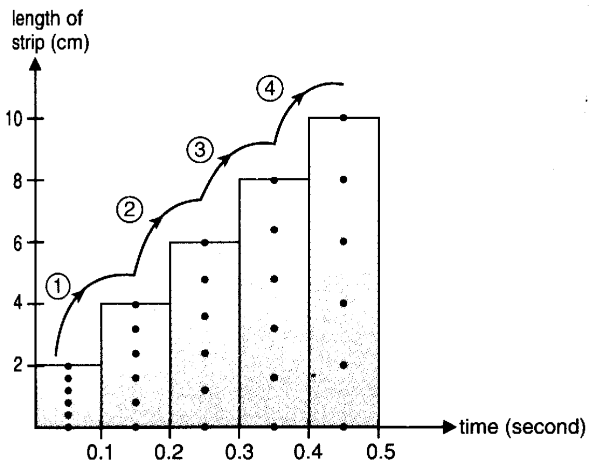
6. The following shows the different types of motion recorded on the ticker tape and tape chart.

Ticker tape and chart	Characteristics	Inference
	- The separation between dots stays the same. - The length of the strips of the tape chart is equal.	
	- The distance between the dots increases uniformly. - The length of the strips of the tape increase uniformly.	
	- The distance between the dots and the length of strips of the tape decreases uniformly.	

7. Change in distance between dots indicates a changing velocity and thus, acceleration. A constant distance between dots represents a ______________________________ and ___________________________.

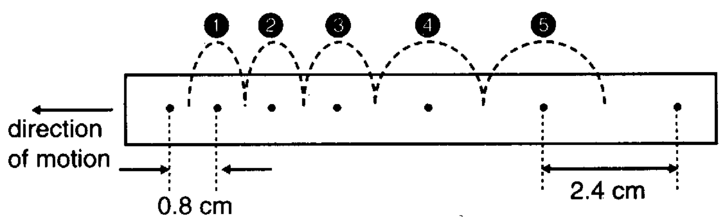
Example 1

Figure 2.3 shows a ticker tape chart obtained in an experiment to study the motion of trolley on an inclined plane. Calculate the acceleration of the trolley.

<table>
<tr>
<td rowspan="2">
</td>
<td>Time for each strip
= 5 x 0.02 s
= 0.1 s</td>
<td>Time interval, t between u and v,
= (5-1) strips x 0.1 s
= 4 x 0.1 s
= 0.4 s</td>
</tr>
<tr>
<td>Initial velocity, u
$= \frac{2.0 \text{ cm}}{0.1 \text{ s}}$
= 20 cm s^{-1}
Final velocity, v
$= \frac{10.0 \text{ cm}}{0.1 \text{ cm}}$
= 100 cm s^{-1}</td>
<td>Acceleration,
$a = \frac{v - u}{t}$
$= \frac{(100 - 20)}{0.4}$
$= \frac{80}{0.4}$
= 200 cm s^{-2} / 2 m s^{-2}</td>
</tr>
</table>

Example 2

Figure 2.4 shows a strip of ticker tape pulled through a ticker-timer by a freely falling metal sphere. The ticker-timer vibrates at a frequency of 50 Hz. Determine the acceleration of the sphere.



Initial velocity, $u = \frac{0.8}{0.02}$

= 40 cm s^{-1}

Final velocity, $v = \frac{2.4}{0.02}$

= 120 cm s^{-1}

Time interval, t between u and v,

= (6-1) x 0.02

= 5 x 0.02 s

= 0.1 s

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

$= \frac{(120 - 40)}{0.1}$

= 800 cm s^{-2} / 8 m s^{-2}

Equations of Liner Motion with Uniform Acceleration

For an object in linear motion with uniform acceleration, problems involving the displacement, velocity, acceleration and time of motion can be solve by using the equation of motion.

1.	***s = displacement***
2.	***u = initial velocity***
3.	***v = final velocity*** ***a = constant acceleration***
4.	***t = time interval***

Example 1

Ali is driving a car at velocity of 30 m s^{-1}. On seeing a student crossing the road, Ali steps on his brakes to stop the car. The speed of the car decreases uniformly and stops after traveling 150 m.

(a) What is the deceleration of the car when the brakes are applied?

(b) What is the time interval before the car stops?

REMEMBER THIS!

Linear motion equations such as $v = u + at$, $s = ut + \frac{1}{2}at^2$ and $v^2 = u^2 + 2as$ are only used with the following conditions:

- the particle is moving in a linear manner
- the acceleration of the particle is uniform.

Example 1

A car begins to move from rest and accelerates with an acceleration of $12ms^{-2}$ for 10 seconds. Calculate the distance travelled.

Solution

Given: $u = 0ms^{-1}$
$a = 12ms^{-2}$
$t = 10s$

From the equation $s = ut + \frac{1}{2}at^2$:

$s = 0 + \frac{1}{2}(12)(10)^2$

$= 600m$

Thus, the distance travelled is 600m.

Example 2

A car starts from rest and accelerates uniformly at 3 m s^{-2}. Calculate

(a) its velocity after 4 s,

(b) its displacement after 6 s.

SOLUTION

(a) $u = 0 \text{ m s}^{-1}$, $a = 3 \text{ m s}^{-2}$, $t = 4$ s

$v = u + at$
$= 0 + 3 \times 4$
$= 12 \text{ m s}^{-1}$

(b) $s = ut + \frac{1}{2}at^2$

$= 0 + \frac{1}{2} \times 3 \times 6^2$

$= 54$ m

Example 3

A car travels for 30 minutes and is brought to rest by application of its brakes. The time travelled before stopping is 9Km.
Calculate the
(a) average velocity in the first 30 minutes.
(b) initial velocity of the car.
(c) deceleration of the car.

Solution
Given: s = 9Km
= 9 000m

t = 30 minutes
= 30 × 60 seconds
= 1 800 seconds

(a) Average velocity $= \frac{s}{t}$
$= \frac{9\ 000 \text{ m}}{1\ 800 \text{ s}}$
$= 5\text{ms}^{-1}$

(b) From the equation $s = \frac{1}{2}(u + v)t$

$9\ 000 = \frac{1}{2}(u + 0)(1\ 800)$

$\frac{1}{2}u = \frac{9\ 000\text{m}}{1\ 800\text{s}}$

Thus the initial velocity, $u = 2 \times 5\text{ms}^{-1}$
$= 10\text{ms}^{-1}$

(c) From the equation $a = \frac{v - u}{t}$:

$a = \frac{0\text{ms}^{-1} - 10\text{ms}^{-1}}{1\ 800 \text{ s}}$
$= -0.0056\text{ms}^{-2}$

The deceleration of the car is 0.0056ms^{-2}

Example 4

A bullet is fired towards a nearby tree with a speed of 200 m s^{-1}. The bullet is shot at a depth of 5 cm. Find the average deceleration of the bullet inside the tree. What is the time taken for the bullet to stop after hitting the tree?

SOLUTION

u = 200 m s^{-1}, v = 0 m s^{-1},
s = 5 cm
= 0.05 m

Using $v^2 = u^2 + 2as$
$0 = 200^2 + 2 \times a \times 0.05$

$a = \frac{200 \times 200}{2 \times 0.05}$
$= -4 \times 10^5 \text{ m s}^{-2}$

The average deceleration is 4×10^5 m s^{-2}
Using $v = u + at$
$0 = 200 - 4 \times 10^5 \times t$

$t = \frac{200}{4 \times 10^5}$
$= 5 \times 10^{-4}$ s

Example 5

Figure 2.16 shows a part of a ticker tape which records the motion of a trolley down an inclined runway. The ticker time is operating at a frequency of 50 Hz.

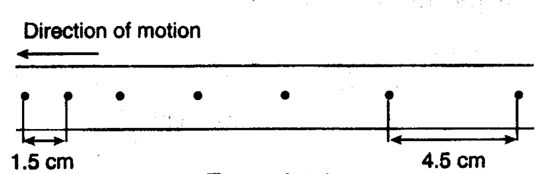


Figure 2.16

Calculate the acceleration of the trolley.

SOLUTION

$\overline{x} = \frac{4.5 - 1.5}{5}$
$= 0.6$ cm

$a = \frac{\overline{x}}{t^2}$
$= \frac{0.6}{0.02^2}$
$= 1.5 \times 10^3 \text{ cm s}^{-2}$

Very often, students forget to insert the negative sign for deceleration.

Example
Salina is driving her car at a velocity of 10 m s^{-1}. On seeing an obstacle in front, she applies the brakes to stop her car. If the deceleration of the car is 2 m s^{-2}, what is the distance her car travels before it comes to a halt?

✗ Incorrect

$u = 10$ m s^{-1}, $v = 0$ m s^{-1}, $a = 2$ **m s^{-2}**
Using $v^2 = u^2 + 2as$
$0 = 10^2 + 2(2)s$
$s = -25$ m

✔ Correct

$u = 10$ m s^{-1}, $v = 0$ m s^{-1}, $a = -2$ **m s^{-2}**
Using $v^2 = u^2 + 2as$
$0 = 10^2 + 2(-2)s$
$s = 25$ m

Example 6

By applying the brakes, a driver reduces his car's velocity from 20 m s^{-1} to 10 m s^{-1} after travelling **a** distance of 30 m. Find the deceleration of the car.

$u = 20$ m s^{-1}, $v = 10$ m s^{-1}, $s = 30$ m, $a = ?$
Using $v^2 = u^2 + 2as$
$10^2 = 20^2 + 2a(30)$
$$a = \frac{100 - 400}{2(30)} = -5 \text{ m s}^{-2}$$
Deceleration = **5 m s^{-2}**

2.2 Analysing Motion Graphs

Motion Graphs

1. There are two main types of linear motion graphs:
   (a) displacement-time
   (b) velocity-time

Displacement-Time Graph

1. We can analyze the velocity of an object by plotting a graph of displacement against time.
2. A student walks at a constant velocity from position A to reach position B in 200 s. He rests for 100 s at position B and then walks back to position A using the same straight path. He reaches position A after 200 s.

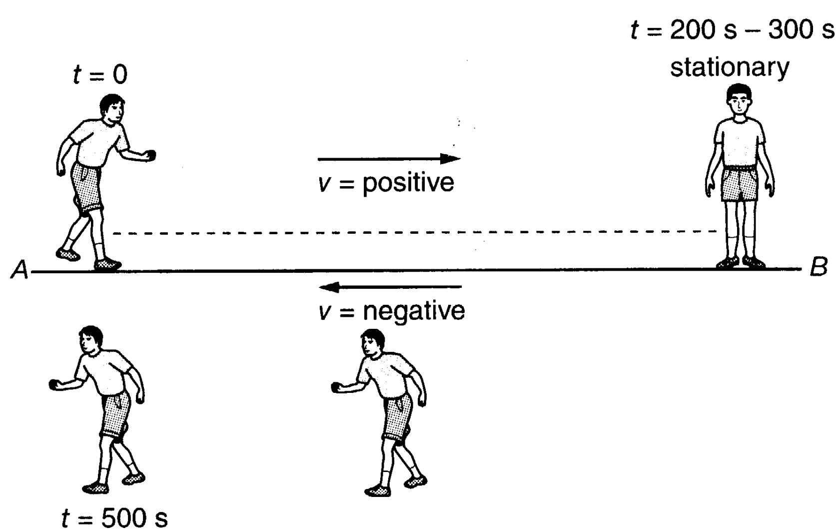


Figure 2.1

3. The graph below shows the change in the distance and direction with time of the student.

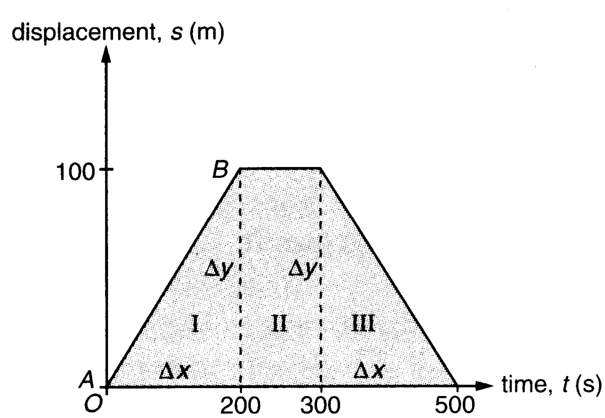


Figure 2.2

(a) On a displacement-time graph, the ________________ of the graph is equal to the ________________ of the object.

(b) Gradient of the graph in section I,

$= \frac{\Delta y}{\Delta x}$

=

=

(c) On a displacement-time graph, a **horizontal line** (gradient = 0) shows the object is ____________________

(d) In section II of the graph, the student remains at position B from 200 s to 300 s.

(e) Gradient of the graph in section III,

$= - \frac{\Delta y}{\Delta x}$

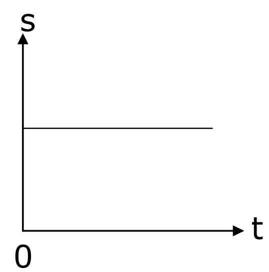
=

=

(f) The negative sign shows that the direction of ***motion is opposite*** to the original direction. (velocity is a vector quantity)

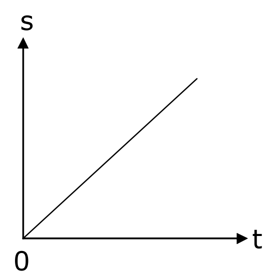
At t = 500 s, the graphs intersects the t-axis. The displacement at this moment is zero that is the student has returned to the original position.

4. The various displacement-time graphs are shown as follows;



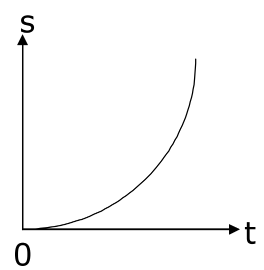
- There is no change in the displacement over time.
- The straight line graph is parallel to the time axis.
- velocity = gradient of graph = 0 m s^{-1}

(a) ___________________________



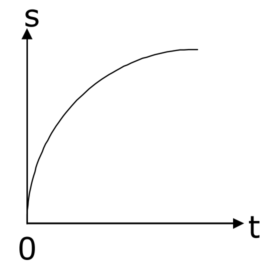
- The rate of change of displacement is constant.
- The straight line graph has a constant gradient.

(b) ___________________________



- The rate of change of displacement is increasing.
- The gradient of the curve is increasing showing that the velocity is increasing.
- The object is moving with **constant acceleration**.

(c) ___________________________



- The gradient is decreasing with time.
- The velocity is decreasing with time.
- The object is moving with **constant deceleration**.

(d) ___________________________

Velocity-Time Graph

1. A car starts from rest and accelerates for 20 s until it reaches a velocity of 60 m s^{-1}. The driver maintains this velocity for 20 seconds. The velocity of the car is then gradually reduced until it stops at t = 60 s.

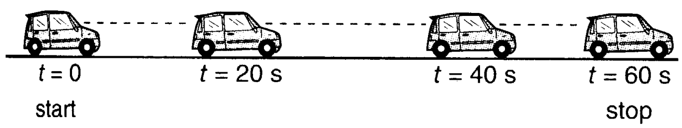


Figure 2.3

2. The graph below shows how the velocity of the car changes over a certain period of time.

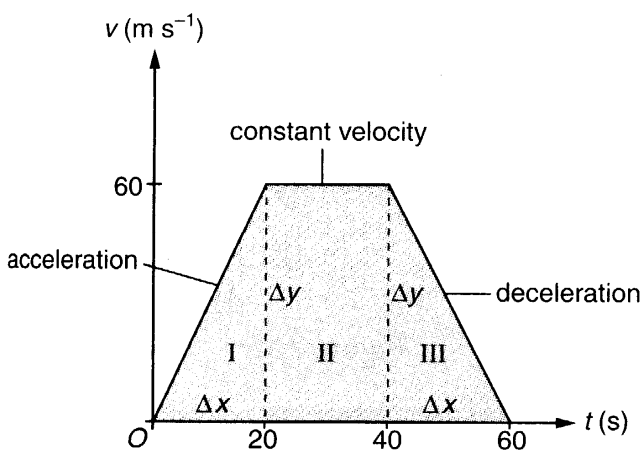


Figure 2.4

(a) On a velocity-time graph, the **gradient** of the graph is equal to the ___________________ of the object.

(b) In section I, the acceleration of the car;

$$a = \frac{\Delta y}{\Delta x}$$

=

=

(c) On a velocity-time graph, a horizontal line represents a ________________. The gradient of the graph is equal to 0.

(d) In section II, the car travels at a constant velocity of 60 m s^{-1} from t = 20 s to t = 40 s.

(e) In section III, gradient of the graph;

$= - \frac{\Delta y}{\Delta x}$

=

=

(f) The negative sign indicates a ***deceleration***.

(g) On the velocity-time graph, the **area under the graph** is equal to the _____________ traveled.

(h) In section I, the area under the graph (the shaded triangle),

=

=

=

(i) In section II, area under the graph(the shaded rectangle),

=

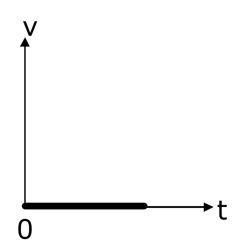
=

(j) In section III, area under the graph,

=

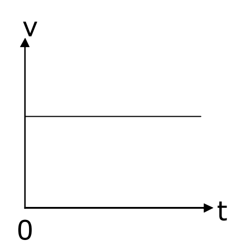
=

3. The various velocity-time graphs are shown below.



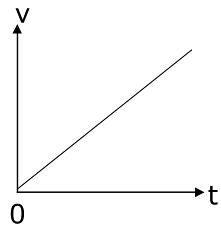
(a) __________________________

- The gradient of the graph represents acceleration.
- The gradient of the graph is zero and hence the acceleration of the object is always zero.
- The area under the graph represents displacement traveled.
- The area under the graph is zero and hence the displacement traveled is zero.



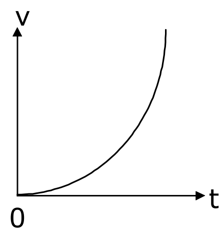
(b) __________________________

- The velocity stays the same. The object is moving with constant velocity.
- Since the gradient is equal to zero, the acceleration is zero.



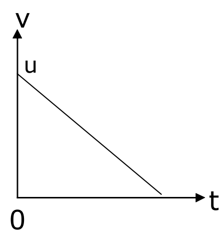
- The velocity is increasing uniformly with time.
- The gradient of the graph is constant and hence the object is moving with constant acceleration.

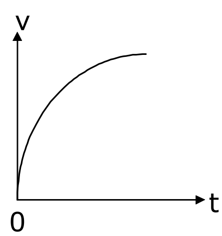
(c) ______________________________



- The gradient of the graph is increasing.
- The acceleration of the object is increasing.

(d) ______________________________





- The gradient is decreasing with time. Therefore the velocity is decreasing.
- The object is moving with constant deceleration.

(e) ______________________________

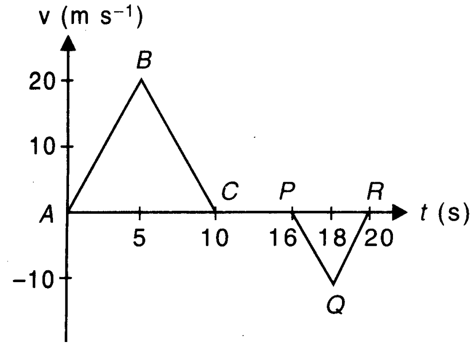
Example 1

The velocity-time graph of a object starting from rest and traveling towards the east is as shown in figure 2.5.

(a) how long does the object travel towards the east?

(b) how long does the object travel towards the west?

(c) find the average speed and the average velocity.



Solution

(a) 10 s [from t = 0 s to t = 10 s, velocity being positive]

(b) 4 s [from t = 16 s to t = 20 s, velocity being negative]

(c) Distance traveled while moving towards the west, S_1

= Area of triangle ABC

= ½ x 10 x 20

= 100 m

Distance traveled while moving towards the west, S_2

= Area of triangle PQR

= ½ x 4 x 10

= 20 m

Average speed $= \dfrac{\text{Total distance}}{\text{Time taken}}$

$= \dfrac{100 + 20}{20}$

$= 6 \text{ m s}^{-1}$

Average velocity $= \dfrac{\text{Final displacement}}{\text{Time taken}}$

$= \dfrac{100 \quad 20}{20}$

$= 4 \text{ m s}^{-1}$ to the east

Example 2

Figure 2.6 shows the motion of a motorcycle. Describe the motion of the motorcycle.

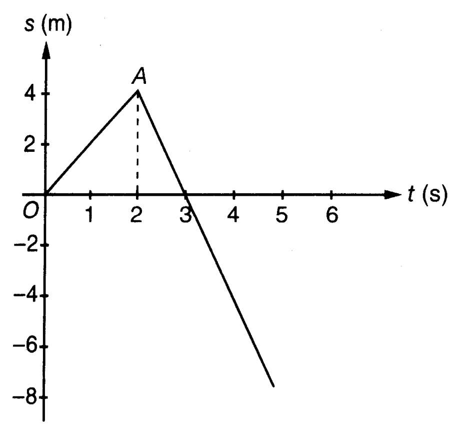


Figure 2.6

Solution

In section OA, the motorcycle is moving at a constant velocity, $v = \dfrac{4}{2} = 2 \text{ m s}^{-1}$

The motorcycle then travels in the opposite direction at a velocity of -4 m s^{-1} and reaches its original position at time, t = 3 s, and continues to travel in this direction at the same speed of -4 m s^{-1}.

Mastery Exercise

1. The figure 2.7, shows the displacement-time graph of a moving object.
   (a) What is the velocity of the object in the initial period of 3 seconds?
   (b) How long is the object stationary?
   (c) At what point in time does the particle return to its original position?
   (d) Calculate
      (i) the average speed, and
      (ii) the average velocity of the moving object.

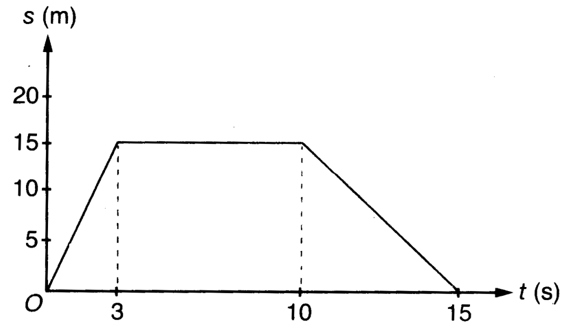


Figure 2.7

2. The figure 2.8, shows the velocity-time graph of a motorcycle starting from rest and traveling towards the north.
   (a) What is the deceleration from t = 10 s to t = 13 s?
   (b) What is the displacement of the motorcycle after 13 s?
   (c) For how long was the motorcycle traveling towards the south?
   (d) What is the displacement of the motorcycle at t = 20 s?
   (e) What is the average velocity of the motorcycle for the whole journey?

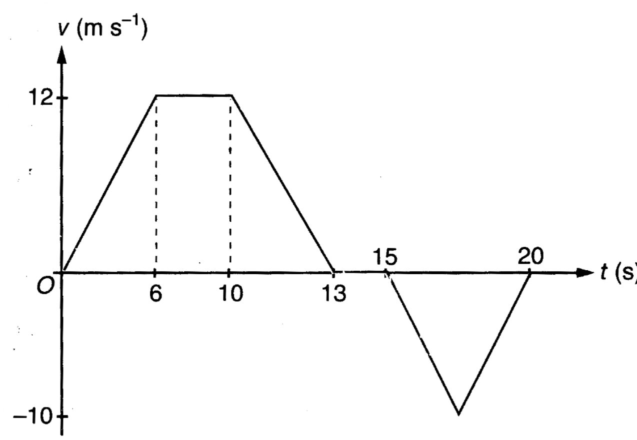


Figure 2.8

2.3 Understanding Inertia

1. The diagrams below show the situations involving inertia.

Situation 1

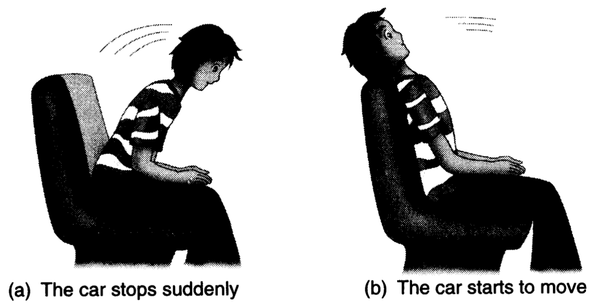


Figure 1

When a driver inside a car applies brake suddenly (figure 1 a), the driver and the passengers are move forwards. When the car suddenly accelerates (figure 1 b), the driver and passengers will move backwards.

Situation 2

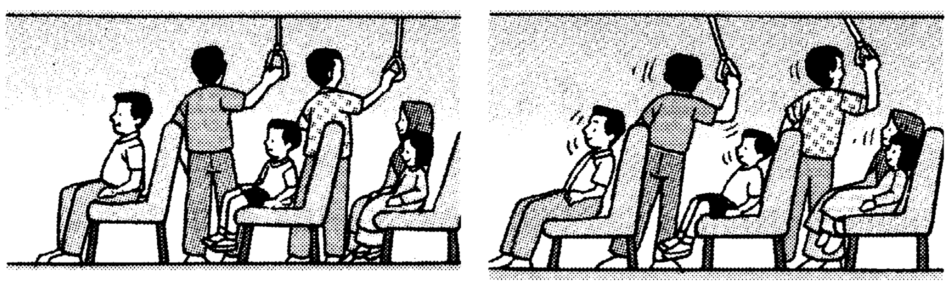


Figure 2

Passengers in a bus will fall backwards when a bus stats suddenly from rest.

Situation 3

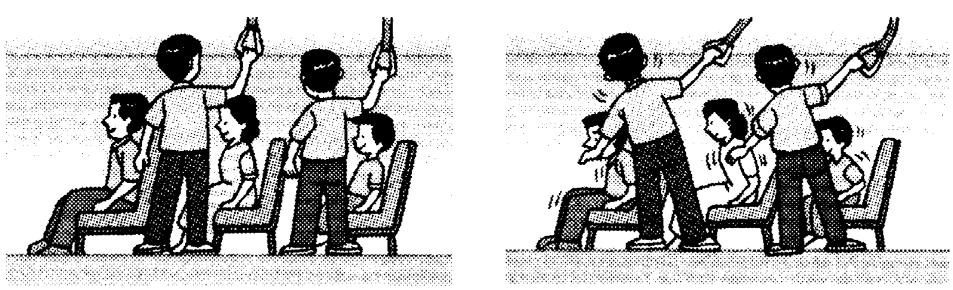


Figure 3

Passengers in a moving bus fall forward when the bus stops suddenly.

Situation 4

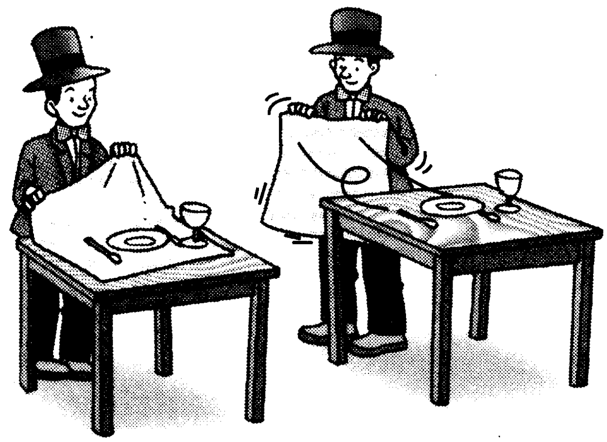
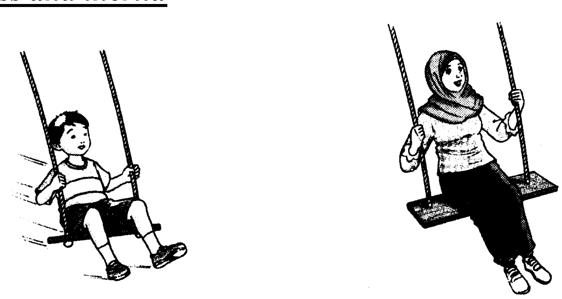


Figure 4

When the table cloth is suddenly pulled horizontally, the dishes on the table top still remain on the table.

2. The situations above show that our body has an inbuilt resistance to any change in its state of rest or motion. This reluctance to change is called inertia.
3. If an object is at rest, it tends to stay in that position unless some force puts that object into motion. If an object is moving, inertia makes the moving object continue to move at a constant speed in the same direction unless some external force changes the object's motion.
4. The inertia of an object is the tendency of the object ___________________________ or, if moving, ____
5. The concept of inertia was explained by Sir Isaac Newton in the ______________________________
6. **Newton's first law** of motion states that every object will _________________________________ or ____________________ unless it is acted by an external force.

Relationship between Mass and inertia



(a) Child *(b) Adult*

Figure 5

1. A child and an adult each sit on similar swings as shown in figure 5. If they are given a push, which one of them will be more difficult to be moved? When both swings are set in motion, which one of them will be more difficult to stop?

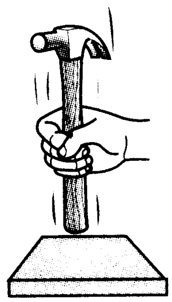
2. The adult who has more mass will show more reluctance to change her state of rest or motion. This property of the mass of a body which resists change from its state of rest or motion is known as inertia.

3. The _____________ the ___________, the ______________ its _______________

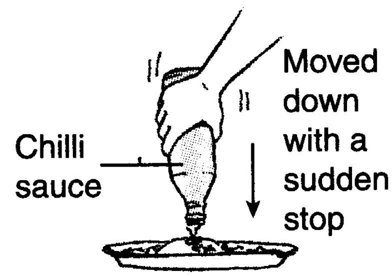
Effect of Inertia

1. The effect of inertia is often seen in our daily activities. We make use of the positive effects of inertia to solve some of our daily problems. The negative effects of inertia that can endanger our lives need to find ways to reduce them.

2. Positive effect of inertia.



The head of a hammer can be tightened onto the wooden handle by applying a knock on the handle. The head of the hammer has big mass and will remain in its state of motion, thus fitting it tighter on the handle.

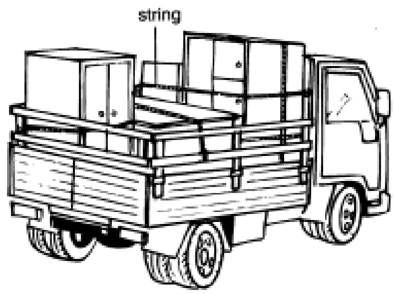


In order to pour out the chili source, the bottle is moved down fast with a sudden stop. The sauce inside the bottle moves together with the bottle. When the bottle stops suddenly, the sauces continue in its state of motion due to the effect of its inertia.

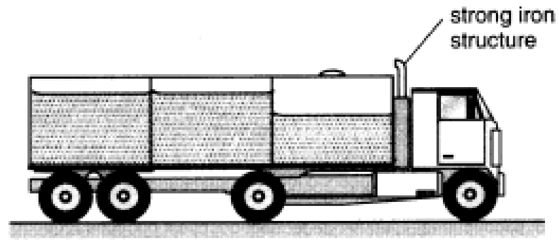
The inertia of the ice skater keeps her gliding on the surface in a straight line.

Droplets of water on a wet umbrella are spun off when the umbrella is rotated and stopped suddenly. The droplets of water initially move with the rotating umbrella. The inertia of the droplets of water causes them to continue moving even when the umbrella has stopped spinning.

3. Negative effect of inertia.



Furniture carried by a lorry normally is tied up together by string. When the lorry starts to move suddenly, the furniture is more difficult to fall off due to their inertia because their combined mass has increased.



Strong iron structure between the driver's cabin and the load to stop the inertial movement of the heavy load towards the driver when the lorry is brought to a halt suddenly.

If the car crashes while travelling, the inertia of the passengers causes them to continue in motion. This is a dangerous situation. Upon impact the passengers will crash into parts of the car immediately in front of them and suffer injuries.

4. Ways to reduce the negative effects of inertia.

(a) Wearing safety belts when driving.

(b) An air begs is fitted inside the steering wheel. It provides a cushion to prevent the driver from hitting the steering wheel or dashboard during a collision.

(c) The oil tank of an oil tanker lorry is usually divided into a few smaller compartments so that the effects of inertia can be reduced.

2.4 Analysing Momentum

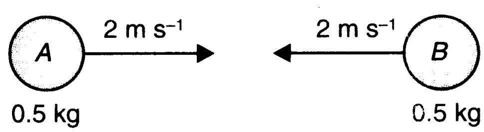
You can catch a fast moving ping-pong ball easily with your bare hand.
A softball keeper must wear a glove to catch a hard and fast moving softball.
Why is a slow moving softball much easier to catch?

1. When an object is moving with a speed in a straight line, we say that it has linear momentum.
2. The amount of linear momentum of the object depends on its mass and velocity.
3. We define linear momentum as the ____

   Momentum = **Mass x velocity**

   p = **m x v**
4. SI unit for momentum is given as ________________. It can also be written as N s (newton second)
5. Momentum is a _______________ quantity. The direction of the momentum is the same as the direction of the velocity.

   Example:



A billiard ball A of mass 0.5 kg is moving from left to right with a velocity of 2 m s^{-1} while another billiard ball B of equal mass is moving from right to left with the same speed.

Solution:

Momentum of ball A	Momentum of ball B
= $m_A v_A$	= $m_B v_B$
= 0.5 x 2	= 0.5 x (-2)
= 1 kg m s^{-1}	= -1 kg m s^{-1}

* Negative sign shows the object is moving in the opposite direction.

Principle of Conservation of Momentum

1. The of conservation of momentum states that the total momentum in a closed system is constant, if no external force acts on the system, that is, the momentum of all objects before a collision ____________ the momentum of all objects after a collision.

2. The principle of conservation of momentum is true for the following:
   (a) Collision of two objects
      - elastic collision
      - inelastic collision
   (b) Explosion

Elastic collision

- When objects collide and bounce perfectly, the collision is said to be an elastic collision (figure 2.1)

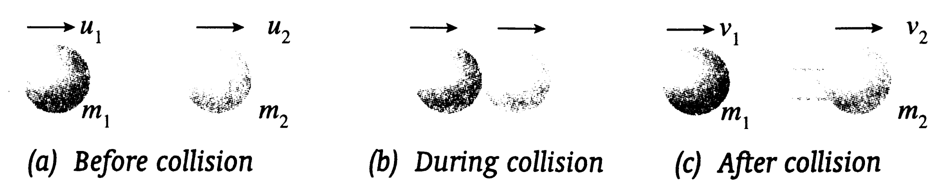


Figure 2.1

- Figure 2.2 shows the diagram of experiments to investigate the principle of conservation of momentum in elastic collisions.

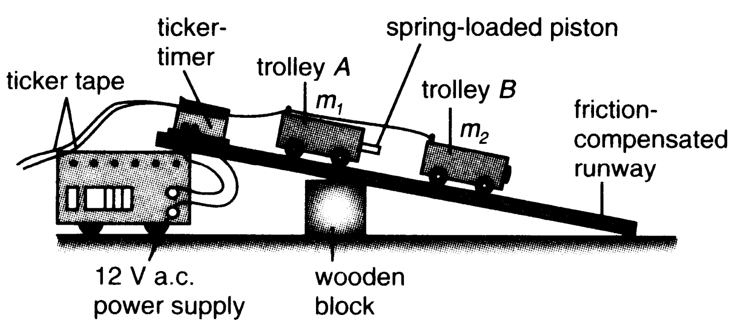


Figure 2.2

(i) The runway is adjusted to compensate the friction.

(ii) Trolley A with a spring-loaded piston is placed at the higher end of the runway and trolley B is placed halfway down the runway and stayed at rest.

(iii) Two ticker tapes are passed through the ticker timer, one attached to trolley A and another attached to trolley B.

(iv) The ticker-timer is switched on and trolley A is given a slight push so that it moves down the runway at a uniform velocity and collides with trolley B which is stationery.

(v) After collision, the two trolleys move separately.

Figure 2.3 shows the ticker tapes obtained from the experiment.

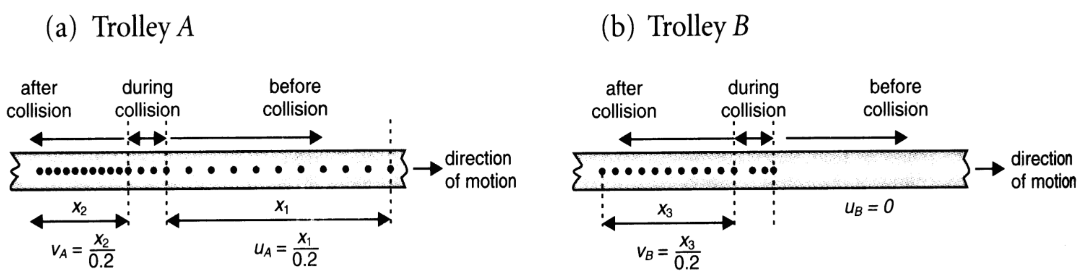


Figure 2.3

Inelastic collision

- When objects collide and attached to one another or couple together after collision, the collision is called an inelastic collision (figure 2.4).

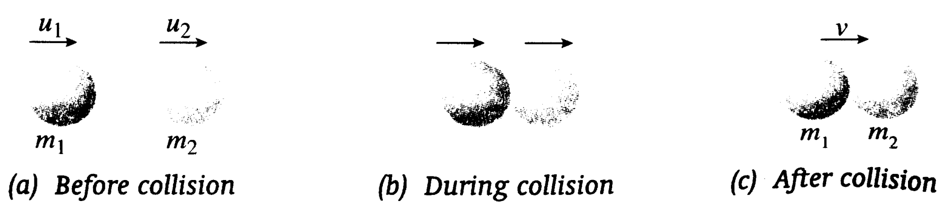


Figure 2.4

- Figure 2.5 shows the diagram of experiments to investigate the principle of conservation of momentum in elastic collisions.

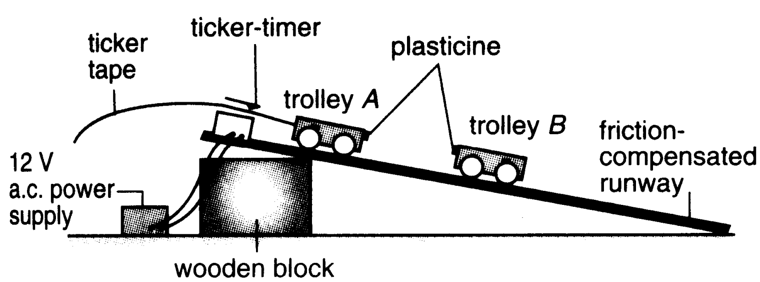


Figure 2.5

(i) The runway is adjusted to compensate the friction.

(ii) The spring loaded piston of trolley A is removed and some plasticine is pasted onto trolley A and B.

(iii) A ticker tape is attached to trolley A only.

(iv) The ticker-timer is switched on and trolley A is given a slight push so that it moves down the runway at a uniform velocity and collides with trolley B which is stationery.

(v) After collision, the two trolleys are move together.

- Figure 2.6 shows the ticker tapes obtained from the experiment.

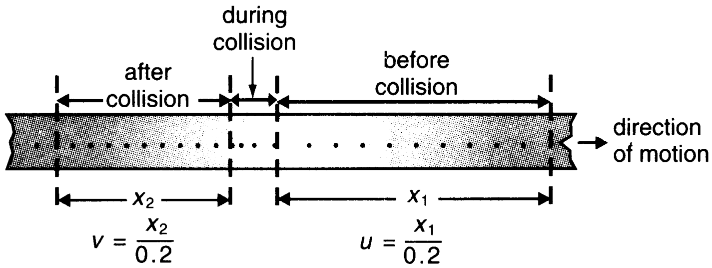


Figure 2.6

Explosion

- Means the separation of objects which are initially at rest.

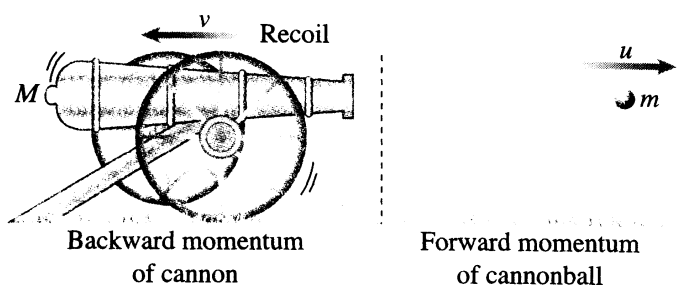
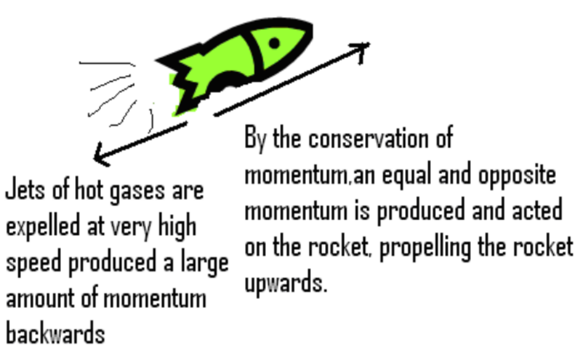


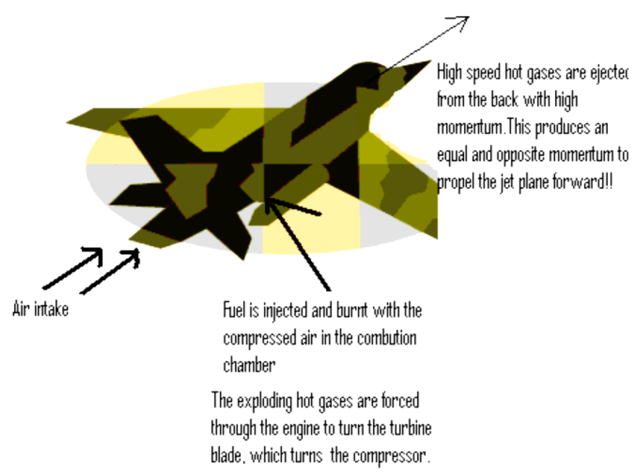
Figure 2.7

Application of Conservation of Momentum

Launching of rockets.



Jet engine



Example 1

Block A of mass 5 kg is moving with velocity 2 m s^{-1} and collides with another stationery block B of unknown mass. After the collision, block A moves with velocity 0.5 m s^{-1}. Given that the collision is elastic. Find the momentum of block B after the collision.

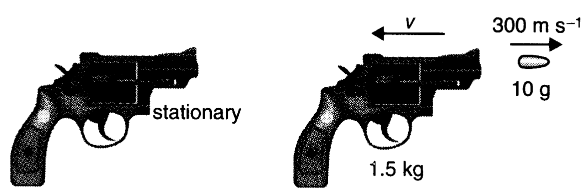
Solution

Example 2

A truck travels at a velocity of 15 m s^{-1} collides head-on with a car that travels at 30 m s^{-1}. The mass of the truck and the car are 6000 kg and 1500 kg respectively. What is the final velocity of the two vehicles after the collision if they stick together?

Solution

Example 3



(a) Before shooting (b) After shooting

An instructor fires a pistol which has a mass of 1.5 kg. If the bullet weighs 10 g and it reaches a velocity of 300 m s^{-1} after shooting, what is the recoil velocity of the pistol?

Solution

Mastery Exercises

1. A bullet of mass 10 g is fired from a rifle of mass 2.0 kg. The velocity of the bullet is found to be 100 m s^{-1}. Find the recoil velocity of the rifle.

2. Two cars have equal mass, m = 800 kg. One car moves at velocity of u = 4 m s^{-1} towards the other car which is at rest. The two cars couple together after impact. What is their common velocity?

3. A boy standing on a skateboard is moving at a constant speed of 10 m s^{-1} along a straight line, carrying a bowling ball in his hand. The mass of the boy and the ball are 50 kg and 5 kg respectively. While moving, the boy throws the ball horizontally and it is observed that his speed slows down to 9.5 m s^{-1}. What is the speed of the ball when the ball is thrown?

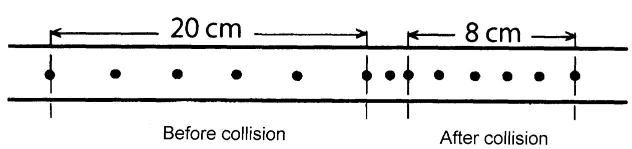


Figure 2.8

4. The figure 2.8 shows a ticker-tape produced from a collision between trolleys A and B. The ticker tapes that stick to trolley P is passed through a ticker timer which runs at a frequency of 50 Hz and collide with trolley B which is stationery. After collision, trolley A sticks to trolley B and they move together. If the mass of trolley A is 2.0 kg, what is the mass of trolley B?

2.5 *Understanding the Effect of a Force*

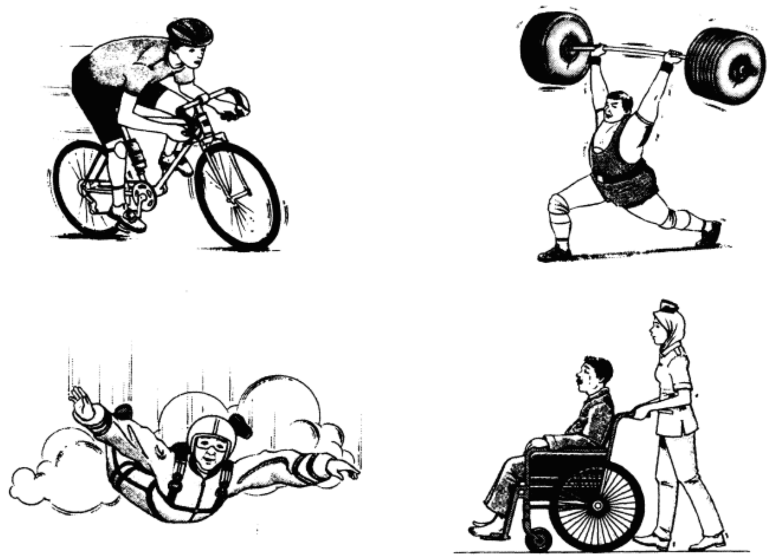
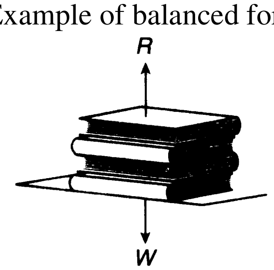


Figure 2.1 Effect of forces

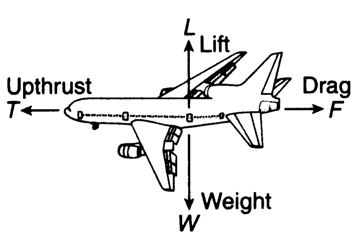
1. We use force in our daily activities
2. Forces have magnitude and direction, that is, force is a vector quantity.
3. The SI unit of force is Newton, N.
4. Force can make things;
   (a) move a stationery object.
   (b) speed up (accelerate) or slow down (decelerate) a moving object.
   (c) change the direction of a moving object.
   (d) stop a moving object.
   (e) change the shape of an object.

<u>Balanced Force</u>

1. An object may have several forces acting on it. But if the forces are in balance, they cancel each other out. Then, the object behaves as if no force is applied to it.
2. When the forces are balanced, an object is either at rest, or moving at a constant velocity.
3. Example of balanced forces;



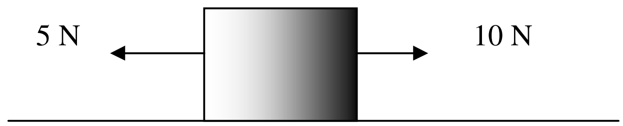
Books on the table remain at rest because normal reaction force, R is cancel with weight of the books. The net force acting on the books is zero.



An airplane can flaying horizontally with constant speed because forward thrust, T provides by the engine is cancel by a drag, F provides by the wind and air resistance.
An airplane can flying at a constant height because a lift force is balanced with its downward weight, W.
When these four forces are balanced, the net force acting on the plane is zero.

Unbalanced Forces on an Object

1. When two or more forces acting on an object are not balanced, the object will accelerate. This net force is known as the unbalanced force or the resultant force.
2. Example;



(a) When two opposite forces acting on a box, the box will move.

Relationship between Force, Mass and Acceleration (F = ma)

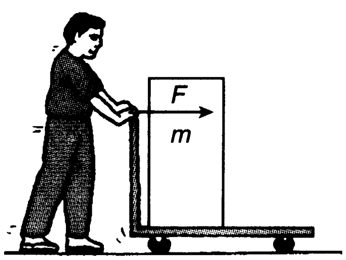


Figure 2.2

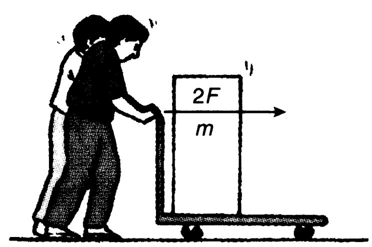


Figure 2.3

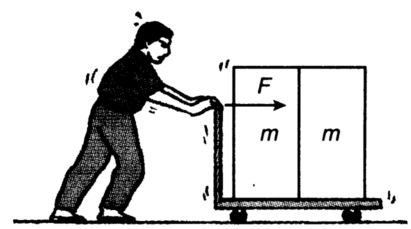


Figure 2.4

Figure 2.2 (a) shows a force, F acting on a mass, m.
The mass moves with a constant acceleration, a.

If the force acting on the same mass is doubled, its acceleration is also doubled.

If the same force, F is acting on a mass of 2m, the acceleration, a, is reduced by half.

1. The diagrams above show that the acceleration of an object is directly proportional to the unbalanced force.

$$\text{Acceleration, } a \propto \text{Net force, } F$$

2. The acceleration of an object is inversely proportional to the mass.

$$\text{Acceleration, } a \propto \frac{1}{\text{Mass, m}}$$

3. Combining the relationship above, we get;

$$F = ma$$

4. The relationship between F, m and a, is known as **Newton's second law of motion.**
5. Newton's second law of motion states that the acceleration produced by a net force on an object is directly proportional to the magnitude of the net force applied and is inversely proportional to the mass of the object.

6. In the formula, F = ma,
   - F is the net force and a, is the acceleration in the same direction as the force.

- Net force, F is the force applied minus all other opposing forces, such as friction.

7. Examples;

(i) Azhari applies a force of 50 N to move a 12 kg carton at a constant velocity. What is the frictional force acting on the carton?

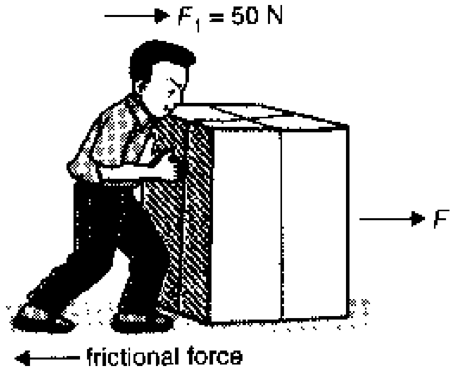


Figure 2.5

Solution

Frictional force is always acting in an opposite direction or opposing to the motion.
Constant velocity → acceleration, a = 0 m s^{-2}
Net force in the direction of velocity, F
= F_1 – Frictional force
= 50 – f

From F = ma
50 – f = 12 x 0
F = 50 N

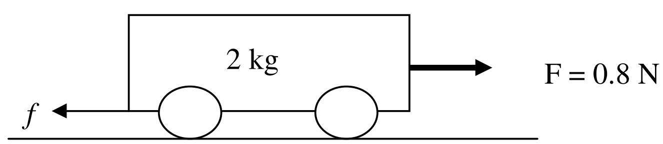


Figure 2.6

(ii) Figure 2.5 shows a trolley of mass 2 kg placed on a rough horizontal table and being pulled by a force of 2.0 N. The trolley moves at constant velocity.

(a) What is the frictional force between the trolley and the table?

(b) The force, F is then increased to 12 N. what is the acceleration of the trolley.

Solution

(a) Constant velocity → acceleration, a = 0 m s^{-2}
Net force, F = ma
0.8 – f = 2 x 0
f = 0.8 N

(b) Net force, F = ma
1.2 – 0.8 = 2 x a
$a = \frac{0.4}{2}$
a = 0.2 m s^{-2}

Analysing Impulse And Impulsive Force

1. An impulsive force is a force that acts over a short period of time during collisions or explosions.
2. Consider an impulsive force, F and the following equations;

   F = ma …………………………. (1)

   and

   $a = \frac{v-u}{t}$ ………………… (2)

   Substitute (2) into (1)

   $F = m\left(\frac{v-u}{t}\right)$

   $F = \frac{mv-mu}{t}$ ………………. (3)

   Hence,

   Impulsive force also defined as the rate of change of momentum.

   The SI unit for impulsive force is the $Kgms^{-2}$ ot N.

3. Impulse is the product between the impulsive force, F with the time of impact, t, that is,

   Rearrange (3)……. $F = \frac{mv-mu}{t}$

   Ft = mv – mu

   Hence,

   Impulse, Ft also defined as the change of momentum.

   The SI unit for impulse is $Kgms^{-1}$ or Ns.

   Example 1

   Figure 1 shows a baseball approaching a bat with an initial velocity of -30 m s^{-1}. A force is applied by the bat to hit the ball and sends it in the opposite direction with a velocity of 50 m s^{-1}.

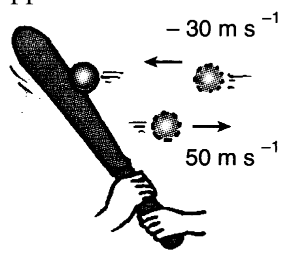


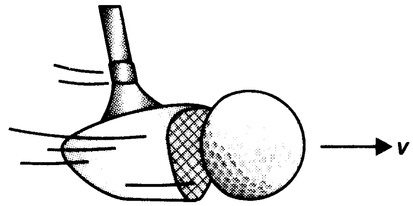
Figure 1

   If the mass of the baseball is 150 g and the time of contact between it and the bat is 1.6 x 10^{-3} s, calculate,

   (i) the impulse applied to the ball.

   (ii) the impulsive force exerted on the ball by the bat

Example 2



A 45 g golf ball is hit with a force of 5300 N. The time interval of interaction between the golf ball an d the club is 0.6 s. Calculate the velocity of the golf ball immediately after it was hit.

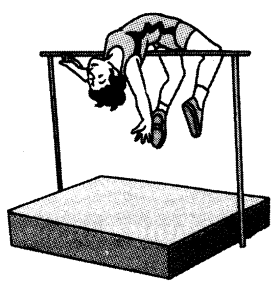
Effect of Impulsive Forces in Daily Life

1. From the formula $F = \frac{mv - mu}{t}$, it can be seen the impulsive force , F is large if the time interval, t is small,

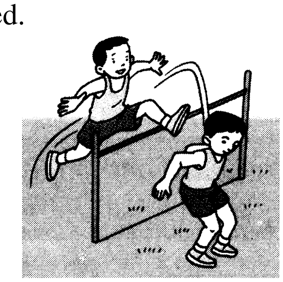
   $F \propto \frac{1}{t}$
2. This explains why in a car accident, the car experience a large impulsive force, which causes serious damage to the car and also injuries to the passengers in the car.

Reducing Impulsive Forces

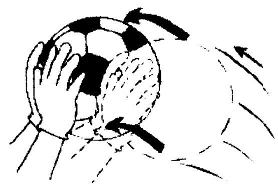
1. From the formula of impulsive force, we know that impulsive force is inversely proportional to the time interval.
2. An effective way to reduce the impulsive force in a collision is to extend the time interval of the interaction.
3. A large impulsive force resulting from a car accident can cause serious injuries to its passengers. To prevent this, cars are constructed with safety features to reduce the impact.
4. Motorcyclists should wear safety helmets and elbow and knee cushions/caps to prevent themselves from falling down and knocking onto the hard surface.
5. In sports the effects of impulsive force are reduced to prevent injuries to the participants in the games.



(a) Thick mattresses with a soft surface used in events such as the high jump, so that the time interval of impact on landing is increased.

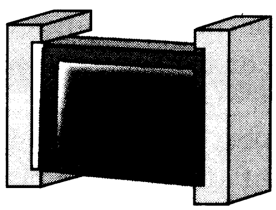


(b) Athletes who jump down from a height must bend their knees upon landing.

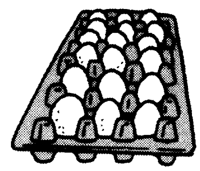


(c) When a goalkeeper catches a fast moving ball, he ends his hands to increase the time of contact when stooping the ball. With longer time of impact, a smaller impulsive force is acting on his hand.

6. Polystyrene, cardboard and rubber foam are usually used in packing fragile goods. The soft surface of these materials reduces the impulsive force during accidental dropping by lengthening the time of impact.

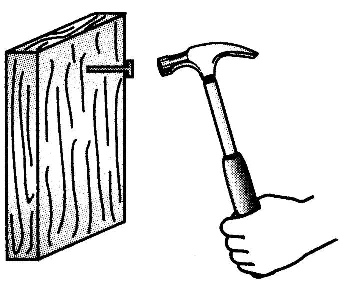


(a) Packing of electrical appliance with polystyrene

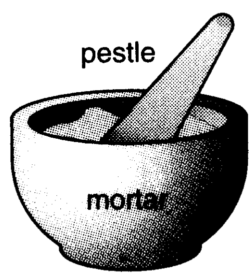


(b) Egg container

Benefits Effects of Impulsive Forces



When a hammer is used to hit a nail into wood, a large change in momentum occurs in a short time interval. It produces a large impulsive force which drives the nail into the wood.



When foodstuff such as chillies are pounded using a mortar and pestle (which are both made from stone), the action produce large impulsive force which crush the food. This occurs when the pestle is brought down at a high velocity onto the mortar with short contact times.

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