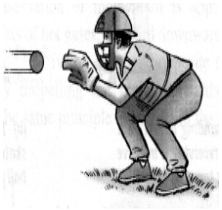
2.4 Analysing Momentum

Define the momentum of an object



- Any moving object has momentum.
- A moving object has mass and velocity.
- The effect of stopping objects in motion depends on two factors :
  - the _____ of the object
  - the _____ of the object.
- A softball ball is _____ than a ping-pong ball. When both balls are moving at the same velocity, the heavier softball ball is much more _____ to stop. A larger resistive force is required to stop the ball. Therefore the softball ball has a larger momentum than a ping-pong ball.
- A slow softball ball is _____ to stop than a fast softball ball. For objects of the same mass moving at different velocity, the higher the velocity, the _____ the momentum. Therefore, a larger resistive force is required to stop the object.
- The amount of momentum depends on its _____ and _____.

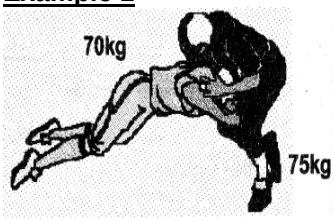
Carry out Hands-on Activity on page 22 of the practical book.

Define momentum as the products of mass and velocity

Momentum = Mass x velocity = mv
SI unit: kg ms^{-1}. It can also be written as N s (Newton second)

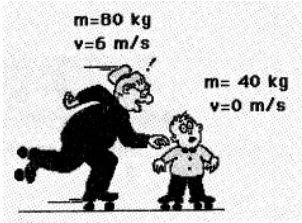
Momentum is a vector quantitiy. The direciton of momentum follows the direction of the velocity.

<u>Example 1</u>



In a football game a player of mass 70 kg is moving with velocity of 4 ms^{-1} and the other player of mass 75 kg is moving with 3 ms^{-1} towards each other as shown. Calculate the momentum of both players.

<u>Example 2</u>
Granny (m = 80 kg) whizzes around the rink with a velocity of 6 ms^{-1}, She suddenly collide with Brad Pitt (m = 40 kg) who is at rest directly in her path. Calculate the momentum of granny and Brad Pitt.



State the principle of conservation of momentum

Principle of Conservation of Momentum said that in the absence of an external force, the total momentum of a system remains <u>unchanged</u>.

If no external force acts on a system, the total momentum before collision (or explosion) is <u>equal</u> to the total momentum after collision (or explosion)

<u>Activity 1</u>

Diagram shows two brothers are skating. The elder brother moves and collides with his younger brother who is at rest. What is their movement after the collision?

The speed of the elder brother _____

The speed of the younger brother _____

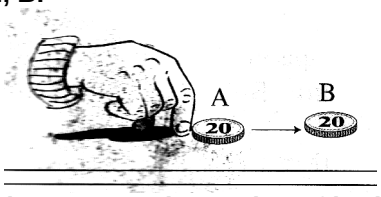
Momentum of the elder brother _____

Momentum of the younger brother _____

Is the total momentum before equal with the total momentum after collision? _____

<u>Activity 2</u>

Flick a 20-cent coin, A, directly to another 20-cent coin, B.



(a) What happens to the motion of both coins after collision?

_____

_____

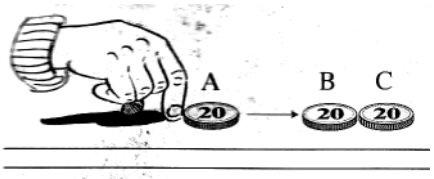
(b) What happens to the momentum of coin A after collision?

_____

_____

<u>Activity 3</u>

Flick a 20-cent coin A, directly to 20-cent coins B and C.



(a) Describe the motion of all coins after collision.

Coin A: _____

Coin B: _____

Coin C: _____

(b) What happens to the momentum of coin A after collision?

_____

_____

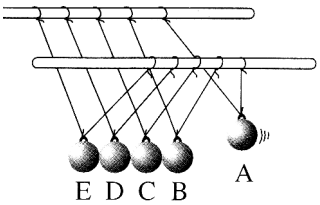
<u>Activity 4</u>

Diagram show a steel ball, A is pulled and released.

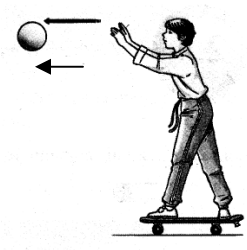
(a) The ball will _____ with the other four balls. This will cause the last ball, E to move to the _____ and rise to the _____ height as ball A. Is the momentum conserved? _____

(b) What will happen if two balls A and B are pulled and then released?

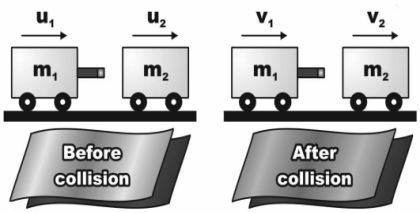
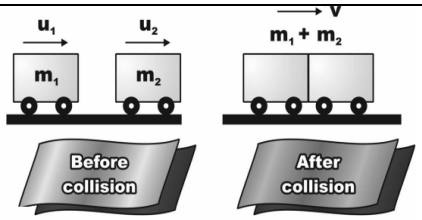
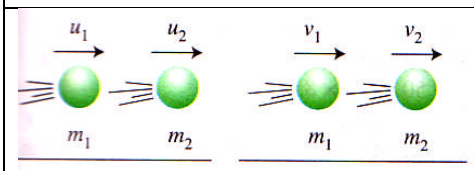
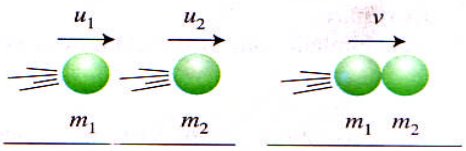
_____



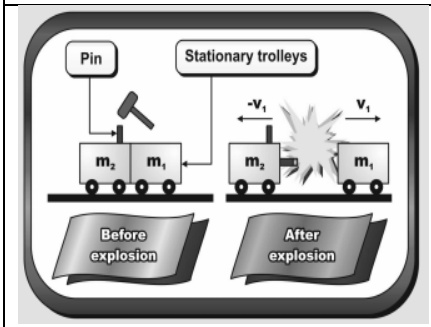
Activity 5



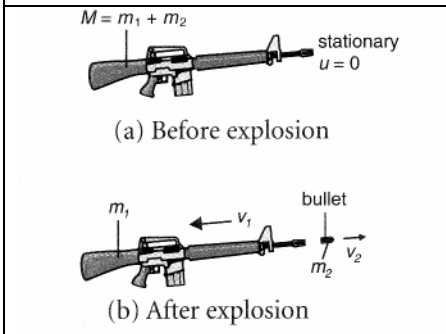
A girl is standing at rest on the skateboard. She throws the massive ball forward. The ball moves to the _____. The girl moves to the _____.
Momentum of the ball before the throw = _____
Momentum of the girl before the throw = _____
Total momentum after the throw is _____ total momentum before the throw = _____.
Total momentum after the throw = momentum of the ball + momentum of the girl = _____.
Therefore, the momentum of the girl is _____ but _____ direction to the momentum of the ball.

Elastic Collision	Inelastic collision
	
▪ Both objects move independently at their respective velocities after the collision. ▪ Momentum is conserved. ▪ Kinetic energy is conserved. ▪ Total energy is conserved.	▪ The two objects combine and move together with a common velocity after the collision. ▪ Momentum is conserved. ▪ Kinetic energy is not conserved. ▪ Total energy is conserved.
 Total Momentum Before = total momentum After $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$	 Total Momentum Before = Total Momentum After $m_1u_1 + m_2u_2 = (m_1 + m_2)\, v$

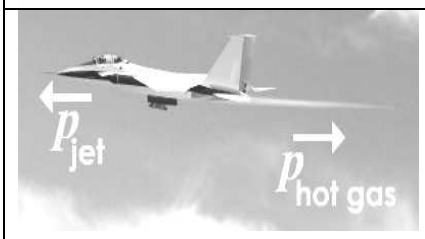
Explosion

	Before explosion both object stick together and at rest. After collision, both object move at opposite direction.	
	Total Momentum before collision Is zero	Total Momentum after collision : $m_1v_1 + m_2v_2$
	From the law of conservation of momentum: Total Momentum = Total Momentum Before collision after collision $0 = m_1v_1 + m_2v_2$ $m_1v_1 = - m_2v_2$ -ve sign means opposite direction	

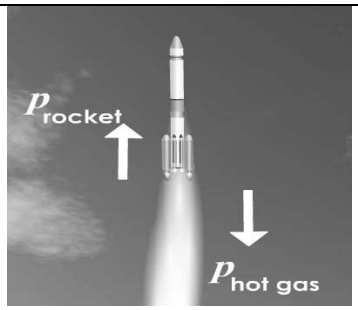
Describe applications of the principle of conservation of linear momentum



- **When a rifle is fired, the bullet of mass m, moves with a high velocity, v. This creates a momentum in the _____ direction.**
- **From the principle of conservation of momentum, an _____ but _____ <u>momentum</u> is produced to recoil the riffle _____.**

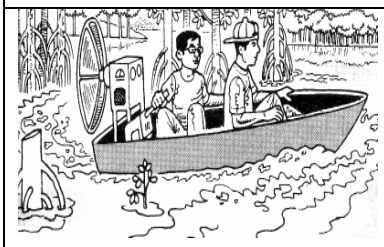


Application in the jet engine:
A high-speed hot gases are ejected from the back with high _____.
This produces an _____ and _____ momentum to propel the jet plane _____.



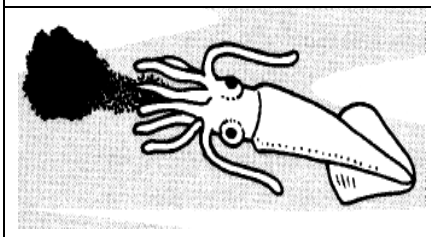
<u>The launching of rocket</u>

- **Mixture of hydrogen and oxygen fuels burn explosively in the combustion chamber. Jets of hot gases are expelled at very high _____ through the exhaust.**
- **These high speed hot gases produce a large amount of momentum _____.**
- **By conservation of momentum, an _____ but _____ momentum is produced and acted on the rocket, propelling the rocket _____.**



In a swamp area, a fan boat is used.

- **The fan produces a high speed movement of air _____. This produces a large _____ backward.**
- **By conservation of momentum, an _____ but _____ momentum is produced and acted on the boat. So the boat will move _____.**



A squid propels by expelling water at high velocity. Water enters through a large opening and exits through a small tube. The water is forced out at a high speed backward.

Total Mom. before= Total Mom. after

0 =Mom water + Mom squid

$$0 = m_w v_w + m_s v_s$$

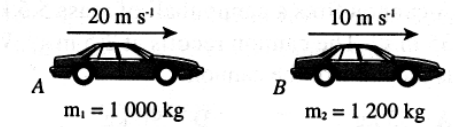
$$-m_w v_w = m_s v_s$$

The magnitude of the momentum of water and squid are _____ but _____ direction.
This causes the squid to jet _____.

Solve problems involving linear momentum

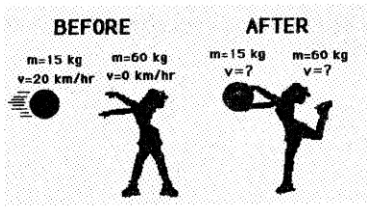
Example 1

Car A of mass 1000 kg moving at 20 ms^{-1} collides with a car B of mass 1200 kg moving at 10 m s^{-1} in same direction. If the car B is shunted forwards at 15 m s^{-1} by the impact, what is the velocity, v, of the car A immediately after the crash?



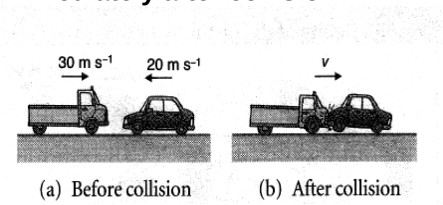
Example 2

A 15 kg medicine ball is thrown at a velocity of 20 km/hr to a 60 kg person who is at rest on ice. The person catches the ball and subsequently slides with the ball across the ice. Determine the velocity of the person and the ball after the collsion.



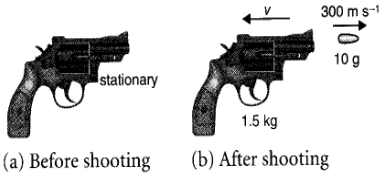
Example 3

A truck of mass 1200 kg moving at 30 m/s collides with a car of mass 1000 kg which is traveling in the opposite direction at 20 m/s. After the collision, the two vehicles move together. What is the velocity of both vehicles immediately after collision?



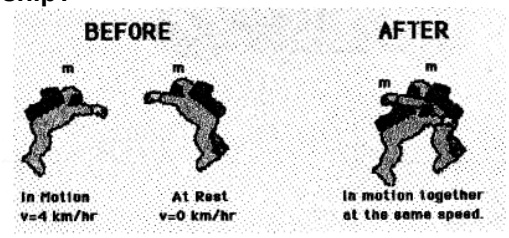
Example 4

A man fires a pistol which has a mass of 1.5 kg. If the mass of the bullet is 10 g and it reaches a velocity of 300 m/s after shooting, what is the recoil velocity of the pistol?



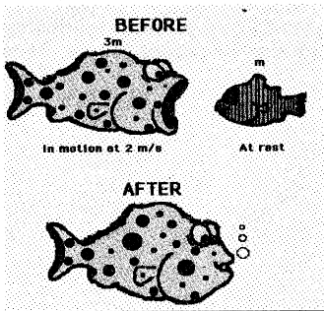
Example 5

Imagine that you are hovering next to a space shuttle in earth orbit and your buddy of equal mass who is moving at 4 km/hr (with respect to the ship) bumps into you. If she holds onto you, how fast do you move (with respect to the ship?



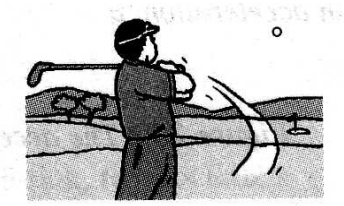
Example 6

A large fish is in motion at 2 m/s when it encounters a smaller fish which is at rest. The large fish swallows the smaller fish and continues in motion at a reduced speed. If the large fish has three times the mass of the smaller fish, then what is the speed of the large fish (and the smaller fish) after the collision?



Why does a golfer begin his swing high in the air?

- **When swung high in the air, the golf club hits the ball with a _____ momentum.**
- **A larger amount of momentum is transferred to the golf ball resulting in a higher _____ of the ball causing it to travel further.**



Describe what the goal keeper did before actually kicking the ball.

- **The goal keeper takes a few steps backward and then _____ forward while kicking the ball.**
- **The ball goes _____ when kicked while running compared to kicking without running.**
- **This is because a running footballer has a _____ momentum and his momentum is _____ to the ball.**

TUTORIAL 2.4

OBJECTIVE QUESTIONS

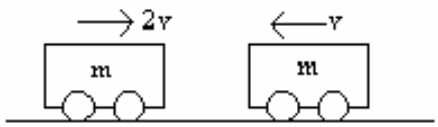
1 The SI unit of the momentum of an object is

A. kg ms^{-2}
B. kg $s^{-1}m^{-1}$
C. kg m s^{-1}
D. kg $m^{-1}s$

2 A movie trolley with velocity u collides with an identical trolley at rest on the track. The trolleys then move together. The velocity of the combined trolleys after the collision is

A. 2u
B. u
C. ½ u
D. 0

3 The diagram shows 2 trolleys of mass m approaching each other with velocity 2v and v.

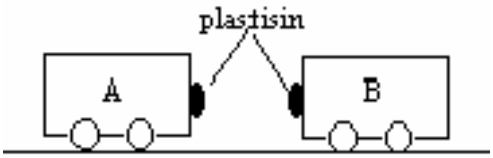


After collision, they stick together and move together with velocity

A. $\frac{v}{4}$ **B.** $\frac{v}{2}$

C. v **D. 2v**
E. 4v

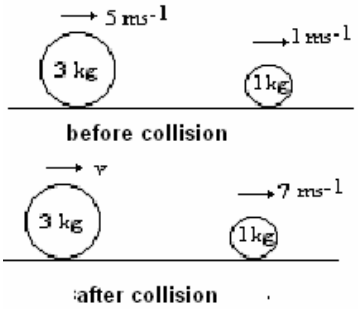
4 Trolley A and trolley B are approaching each other and collide.



Which statement is true?

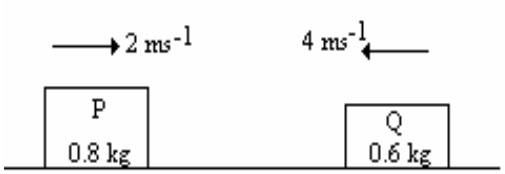
A. Elastic collision occurs
B. Total momentum is conserved
C. Total kinetic energy is conserved
D. Both objects will move with different velocity after collision.

5 Based on the diagram, calculate the velocity, v



A. 2.0 ms^{-1}
B. 2.5 ms^{-1}
C. 3.0 ms^{-1}
D. 3.5 ms^{-1}
E. 4.0 ms^{-1}

6 **Two objects P and Q of mass 0.8 kg and 0.6 kg respectively collide. After collision P bounces back with velocity of 1.6 ms^{-1}.**

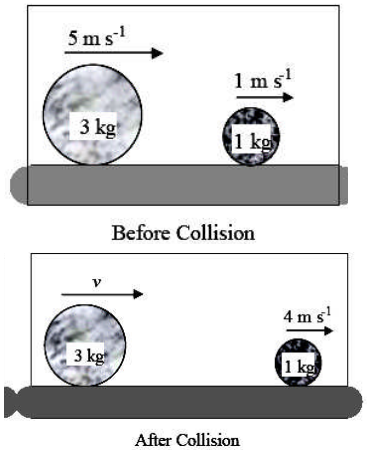


Find the velocity of object Q after the collision.
A 0.8 ms^{-1} to left
B 0.8 ms^{-1} to right
C 2.2 ms^{-1} to left
D 2.2 ms^{-1} to right

7 **A bullet of mass 10 g strikes horizontally at a target of mass 2 kg and is embedded into it. The two objects then move together with velocity 4 ms^{-1}. What is the velocity of the bullet just before collision?**
A. 404 ms^{-1}
B. 804 ms^{-1}
C. 1020 ms^{-1}
D. 1440 ms^{-1}
E. 2040 ms^{-1}

8 **A bullet of mass 10 g is fired from a gun of mass 490 g. The bullet leaves the gun with a speed of 120 ms^{-1}. Find the initial speed of recoil of the gun.**
A. 2.4 ms^{-1}
B. 4.8 ms^{-1}
C. 6.4 ms^{-1}
D. 7.4 ms^{-1}
E. 8.8 ms^{-1}

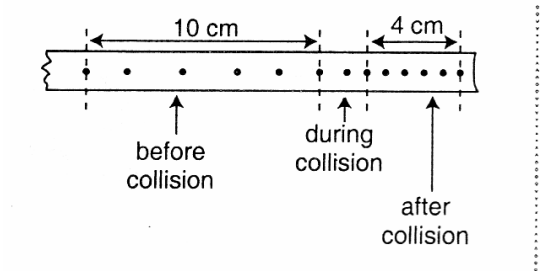
9 **The diagram describes the motion of two bodies before and after collision.**



What is the value of *v* ?.

A 1.3 m s^{-1}
B 2.6 m s^{-1}
C 4.0 m s^{-1}
D 5.0 m s^{-1}
E 6.3 m s^{-1}

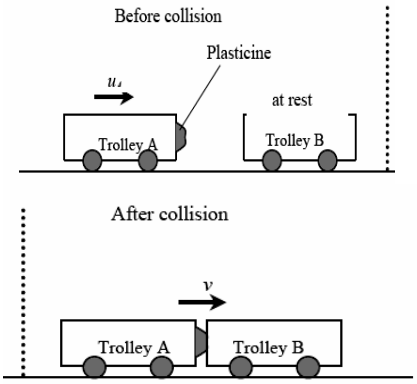
10 **The diagram below shows a ticker tape produced in a non-elastic collision between a trolley P which is moving and a trolley Q which is stationary.**



The frequency of the ticker timer used is 50 Hz and the mass of trolley P is 2.0 kg, calculate the mass of trolley Q.
A. 0.5 kg
B. 1.5 kg
C. 2.0 kg
D. 2.5 kg
E. 3.0 kg

11 **A boy of mass 50 kg is running with a velocity of 6 ms^{-1}, jumped onto a stationary trolley of mass 25 kg. They move together along the boy's original direction. What is the velocity of trolley and the boy?**
A. 1.5 ms^{-1}
B. 2.0 ms^{-1}
C. 3.0 ms^{-1}
D. 4.0 ms^{-1}
E. 4.5 ms^{-1}

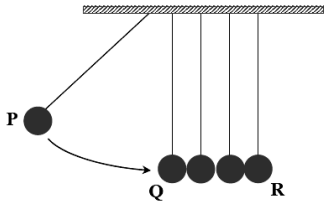
12 **The diagram shows two trolleys of the same mass before and after collision.**



Which of the following statements is correct about momentum after collision?

	Trolley A	*Trolley B*
A	Increases	Increase
B	Increases	Decreases
C	Decreases	Increases
D	No change	No change

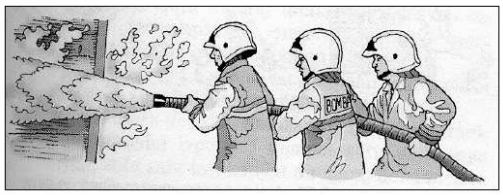
13 P, Q, and R are three similar pendulums. P has a velocity of *u* just before it collides with Q.



Predict what would happen after collision .

A. P and Q do not move while R moves with a velocity of *u*.
B. P, Q and R move together with a velocity of 1 3 *u* .
C. P stops and both Q and R move with a velocity of ½ *u*.
D. P moves backwards with a velocity of *u*, Q and R move together with a velocity of ½ *u* .

14 The picture below shows firemen holding a hose spraying out water.

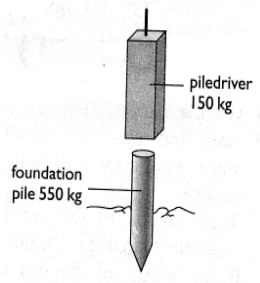


Several firemen are needed to hold the hose
A to support the weight of the hose.
B to increase the mass of water coming out
C to increase the speed of the water in the forward direction.
D to reduce the large recoil effect

15 Which of the following quantities is not conserved when two bodies are involved in an inelastic collision?

A. Mass
B. Energy
C. Momentum
D. Kinetic energy

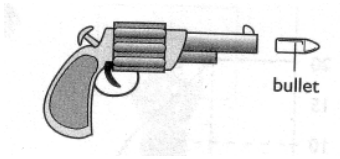
16 Figure below shows a piledriver at a velocity of 20 ms^{-1} driving a foundation pile into the ground. The piledriver and the foundation pile move together after hitting it.



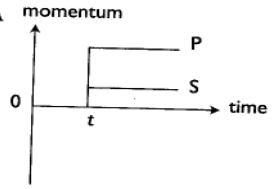
Determine the velocity of the foundation pile immediately after being hit by the piledriver.

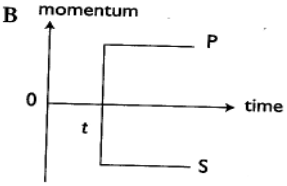
A. 0.4 ms^{-1}
B. 0.43 ms^{-1}
C. 4.28 ms^{-1}
D. 14.0 ms^{-1}
E. 30.0 ms^{-1}

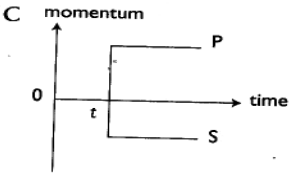
17 Figure below shows a pistol in its initial stationary position and then firing a shot at time t.

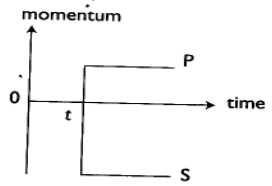


If P represents the momentum of the bullet and S the momentum of the pistol, which of the following graphs represents the changes of P and S with time?

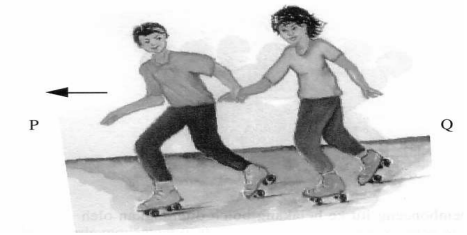
A


B


C


D


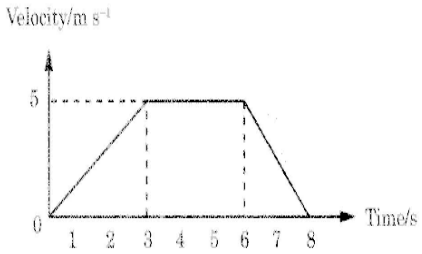
18 The diagram shows two student skating towards P.



What will happen to the girl when the boy releases her hand? (2005)

- **A. Stays stationary**
- **B. Moves towards P**
- **C. Moves towards Q**

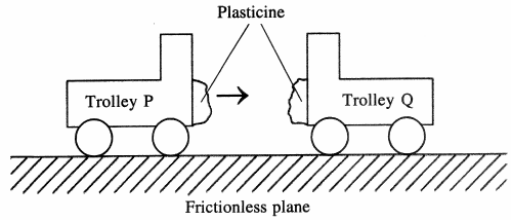
19 The diagram shows a velocity-time graph for the motion of an object.



The momentum of the object is constant from (2003)

- **A. 0 s to 3 s**
- **B. 3 s to 6 s**
- **C. 6 s to 8 s**
- **D. 0 s to 8 s**

20 Diagram below shows two trolleys, P and Q, on a frictionless plane. Trolley P moves and collides with the stationary trolley Q.



Which of the following statements is true? (2006)

- **A. The collision is an elastic collision.**
- **B. Both trolleys do not undergo changes in momentum**
- **C. The total momentum before and after collision is the same**
- **D. The total kinetic energy before and after the collision is conserved.**

STRUCTURED QUESTIONS

Question 1

Figure 1.1 shows a trolley P moving with a constant velocity, u, collide with a stationary trolley Q of mass 2 kg. After collision, the two trolleys stuck together and move with a final velocity, v. the motion of the two trolleys is recorded by a ticker tape attached to the trolley P and passing through a ticker tape timer having a frequency of 50 Hz.

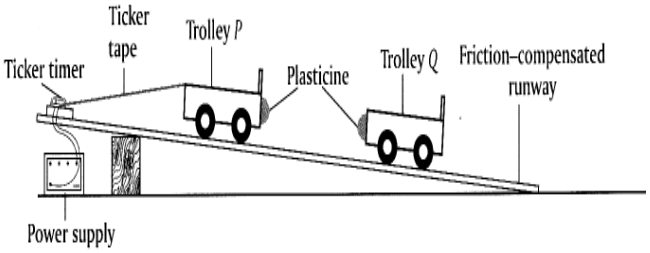


Figure 1.1

Figure 1.2 shows the dots on the ticker tape produced by the two trolleys before and after the collision.

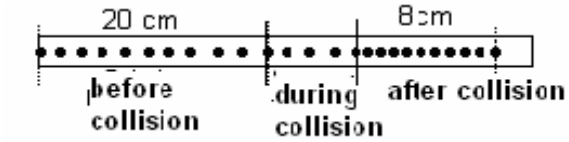


Figure 1.2

(a) Name the type of collision involved in this situation.

(b) What is the velocity of trolley P before collision?

(c) What is the total momentum before collision?

(d) What is the final velocity of the combined trolleys P and Q?

(e) Determine the mass of trolley Q.

Question 3 (SPM 2004)

Figure 3 shows a man standing on a stationary boat. He then jumps out of the boat onto the jetty. The boat moves away from the jetty as he jumps.

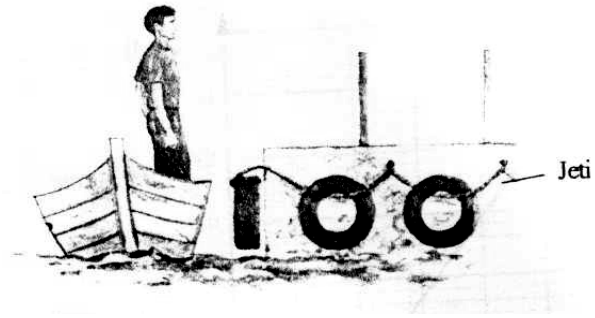


Figure 3

(a) State the physics principle that is involved in the movement of the boat as the man jumps onto the jetty.

_____

(b) Explain why the boat moves away from the jetty when the man jumps.

_____

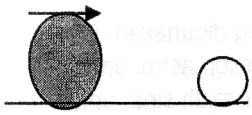
_____

(c) The mass of the man is 50 kg and he jumps at a velocity of 2 ms^{-1}. The mass of the boat is 20 kg. Calculate the velocity of the boat as the man jumps.

(d) Name one application of the physics principle stated in (a) in an exploration of outer space.

Question 4

(a) A ball is moving with constant velocity collides with another ball which has a smaller mass. Before collision, the smaller ball is at stationary.



Explain the changes which occur to each ball during the collision.

Changes:

(i) Velocity of smaller ball ……, velocity of bigger ……,

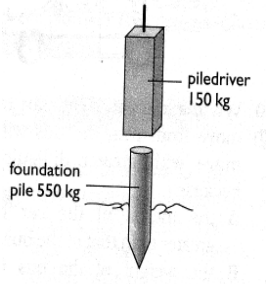
(ii) Momentum of the smaller ball ……, momentum of bigger ball ……

(iii) The bigger ball will ……, the smaller ball will ……

(b) For safety reason, explain why a bus must have passenger and speed limit.

The quantity of bus passengers will determine the …….. of the buss.
The momentum of the bus depends on the …….. and ……. of the bus.
Bigger …….. and …….. means the momentum of the bas will increase.
A ……momentum will cause the bus difficult to be stopped.

Figure below shows a piledriver at a velocity of 20 ms^{-1} driving a foundation pile into the ground. The piledriver and the foundation pile move together after hitting it.



Determine the velocity of the foundation pile immediately after being hit by the piledriver.

F. 0.4 ms^{-1}
G. 0.43 ms^{-1}
H. 4.28 ms^{-1}
I. 14.0 ms^{-1}
J. 30.0 ms^{-1}