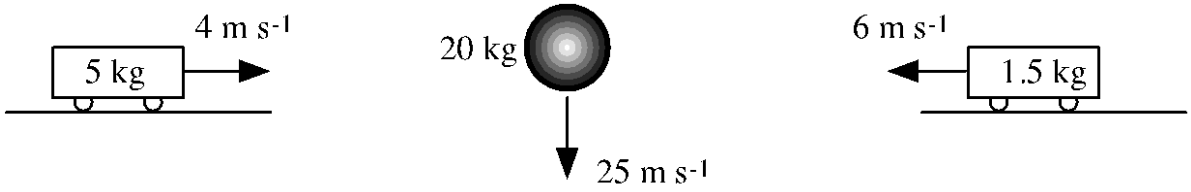
Section 3: Collisions and explosions

1. What is the momentum of the object in each of the following situations?

(a) (b) (c)

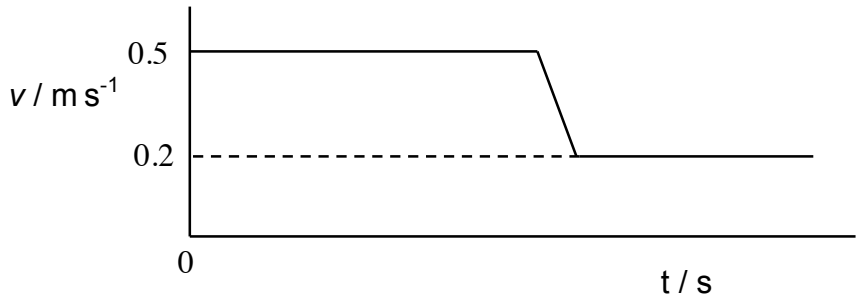


2. A trolley of mass 2·0 kg is travelling with a speed of 1·5 m s^{-1}. The trolley collides and sticks to a stationary trolley of mass 2·0 kg.

   (a) Calculate the velocity of the trolleys immediately after the collision.
   (b) Show that the collision is inelastic.

3. A target of mass 4·0 kg hangs from a tree by a long string. An arrow of mass 100 g is fired at the target and embeds itself in the target. The speed of the arrow is 100 m s^{-1} just before it strikes the target.
   Calculate the speed of the target immediately after the impact.

4. A trolley of mass 2·0 kg is moving at a constant speed when it collides and sticks to a second stationary trolley. The graph shows how the speed of the 2·0 kg trolley varies with time.



   Determine the mass of the second trolley.

5. In a game of bowls a bowl of mass 1·0 kg is travelling at a speed of 2·0 m s^{-1} when it hits a stationary jack 'straight on'. The jack has a mass of 300 g. The bowl continues to move straight on with a speed of 1·2 m s^{-1} after the collision.

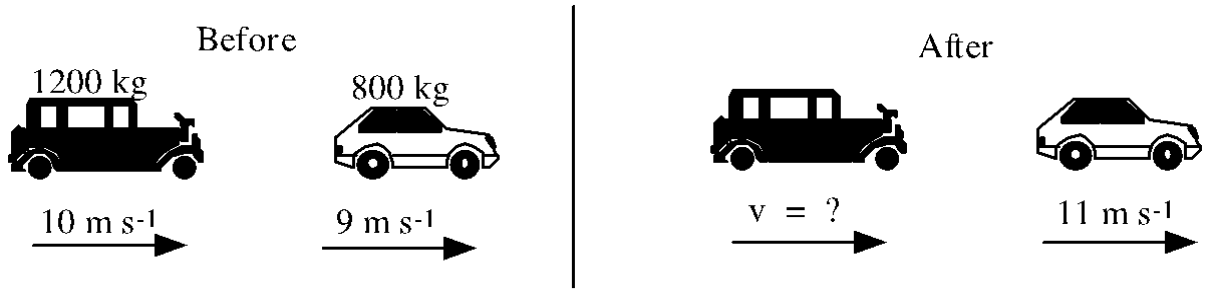
   (a) Calculate the speed of the jack immediately after the collision.
   (b) How much kinetic energy is lost during the collision?

6. Two space vehicles make a docking manoeuvre (joining together) in space. One vehicle has a mass of 2000 kg and is travelling at 9·0 m s^{-1}. The second vehicle has a mass of 1500 kg and is moving at 8·0 m s^{-1} in the same direction as the first. Determine their common velocity after docking.

7. Two cars are travelling along a race track. The car in front has a mass of 1400 kg and is moving at 20 m s^{-1}. The car behind has a mass of 1000 kg and is moving at 30 m s^{-1}. The cars collide and as a result of the collision the car in front has a speed of 25 m s^{-1}.

   (a) Determine the speed of the rear car after the collision.
   (b) Show clearly whether this collision is elastic or inelastic.

8. One vehicle approaches another from behind as shown.



   The vehicle at the rear is moving faster than the one in front and they collide. This causes the vehicle in front to be 'nudged' forward with an increased speed. Determine the speed of the rear vehicle immediately after the collision.

9. A trolley of mass 0·8 kg is travelling at a speed 1·5 m s^{-1}. It collides head-on with another vehicle of mass 1·2 kg travelling at 2·0 m s^{-1} in the opposite direction. The vehicles lock together on impact.
   Determine the speed and direction of the vehicles after the collision.

10. A firework is launched vertically and when it reaches its maximum height it explodes into two pieces. One piece has a mass of 200 g and moves off with a speed of 10 m s^{-1}. The other piece has a mass of 120 g.
    Calculate the velocity of the second piece of the firework.

11. Two trolleys initially at rest and in contact move apart when a plunger on one trolley is released. One trolley with a mass of 2·0 kg moves off with a speed of 4·0 m s^{-1}. The other trolley moves off with a speed of 2·0 m s^{-1}, in the opposite direction.
    Calculate the mass of this trolley.

12. A man of mass 80 kg and woman of mass 50 kg are skating on ice. At one point they stand next to each other and the woman pushes the man. As a result of the push the man moves off at a speed of 0·50 m s^{-1}.
    Calculate the velocity of the woman as a result of the push.

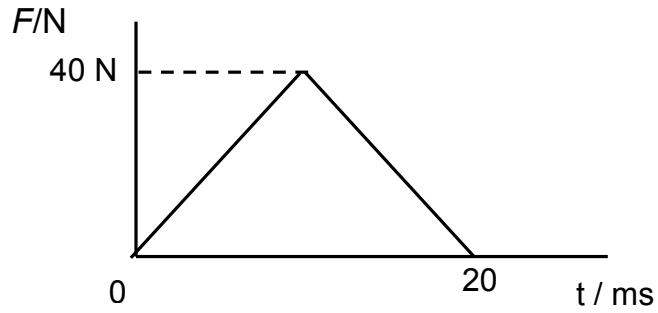
13. Two trolleys initially at rest and in contact fly apart when a plunger on one of them is released. One trolley has a mass of 2·0 kg and moves off at a speed of 2·0 m s^{-1}. The second trolley has a mass of 3·0 kg.
Calculate the velocity of this trolley.

14. A cue exerts an average force of 7·00 N on a stationary snooker ball of mass 200 g. The impact of the cue on the ball lasts for 45·0 ms.
Calculate the speed of the ball as it leaves the cue.

15 A football of mass 500 g is stationary. When a girl kicks the ball her foot is in contact with the ball for a time of 50 ms. As a result of the kick the ball moves off at a speed of 10 m s^{-1}.
Calculate the average force exerted by her foot on the ball.

16. A stationary golf ball of mass 100 g is struck by a club. The ball moves off at a speed of 30 m s^{-1}. The average force of the club on the ball is 100 N. Calculate the time of contact between the club and the ball.

17. The graph shows how the force exerted by a hockey stick on a stationary hockey ball varies with time.



The mass of the ball is 150 g.
Determine the speed of the ball as it leaves the stick.

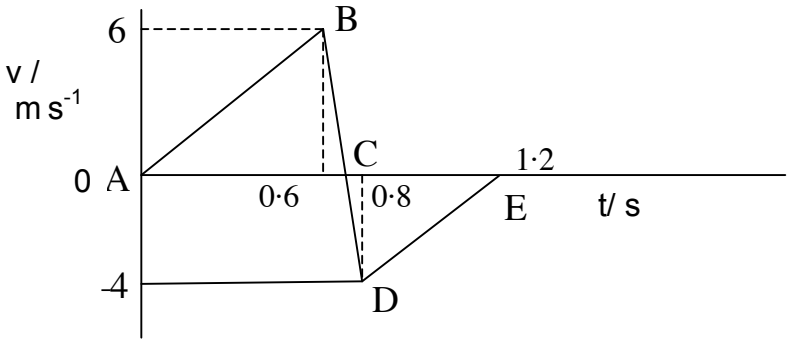
18. A ball of mass 100 g falls from a height of 0·20 m onto concrete. The ball rebounds to a height of 0·18 m. The duration of the impact is
25 ms. Calculate:

(a) the change in momentum of the ball caused by the ‘bounce’
(b) the impulse on the ball during the bounce
(c) the average unbalanced force exerted on the ball by the concrete
(d) the average unbalanced force of the concrete on the ball.
(e) What is in the total average upwards force on the ball during impact?

19. A rubber ball of mass 40·0 g is dropped from a height of 0·800 m onto the pavement. The ball rebounds to a height of 0·450 m. The average force of contact between the pavement and the ball is 2·80 N.

    (a) Calculate the velocity of the ball just before it hits the ground and the velocity just after hitting the ground.
    (b) Calculate the time of contact between the ball and pavement.

20. A ball of mass 400 g travels falls from rest and hits the ground. The velocity-time graph represents the motion of the ball for the first 1·2 s after it starts to fall.



    (a) Describe the motion of the ball during sections AB, BC, CD and DE on the graph.
    (b) What is the time of contact of the ball with the ground?
    (c) Calculate the average unbalanced force of the ground on the ball.
    (d) How much energy is lost due to contact with the ground?

21. Water with a speed of 50 m s^{-1} is ejected horizontally from a fire hose at a rate of 25 kg s^{-1}. The water hits a wall horizontally and does not rebound from the wall. Calculate the average force exerted on the wall by the water.

22. A rocket ejects gas at a rate of 50 kg s^{-1}, ejecting it with a constant speed of 1800 m s^{-1}.
    Calculate magnitude of the force exerted by the ejected gas on the rocket.

23. Describe in detail an experiment that you would do to determine the average force between a football boot and a football as the ball is being kicked.
    Draw a diagram of the apparatus and include all the measurements taken and details of the calculations carried out.

24. A 2·0 kg trolley travelling at 6·0 m s^{-1} collides with a stationary 1·0 kg trolley. The trolleys remain connected after the collision.

(a) Calculate:
(i) the velocity of the trolleys just after the collision
(ii) the momentum gained by the 1·0 kg trolley
(iii) the momentum lost by the 2·0 kg trolley.

(b) The collision lasts for 0·50 s. Calculate the magnitude of the average force acting on each trolley.

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1. (a) 20 kg m s^{-1} to the right
   (b) 500 kg m s^{-1} downwards
   (c) 9 kg m s^{-1} to the left

2. (a) 0·75 m s^{-1} in the direction in which the first trolley was moving

3. 2·4 m s^{-1}

4. 3·0 kg

5. (a) 2·7 m s^{-1}
   (b) 0·19 J

6. 8·6 m s^{-1} in the original direction of travel

7. (a) 23 m s^{-1}

8. 8·7 m s^{-1}

9. 0·6 m s^{-1} in the original direction of travel of the 1·2 kg trolley

10. 16·7 m s^{-1} in the opposite direction to the first piece

11. 4 kg

12. 0·8 m s^{-1} in the opposite direction to the velocity of the man

13. 1·3 m s^{-1} in the opposite direction to the velocity of the first trolley

14. 1·58 m s^{-1}

15. 100 N

16. $3·0 \times 10^{-2}$ s

17. 2·67 m s^{-1}

18 (a) + 0·39 kg m s^{-1} if you have chosen upwards directions to be positive;
   –0·39 kg m s^{-1} if you have chosen downwards directions to be positive
   (b) + 0·39 N s if you have chosen upwards directions to be positive
   (c) 15·6 N downwards
   (d) 15·6 N upwards
   (e) 16·6 N upwards

19. (a) v before = 3·96 m s^{-1} downwards; v after = 2·97 m s^{-1} upwards
(b) 9·9 × 10^{-2} s

20. (b) 0·2 s
(c) 20 N upwards (or –20 N for the sign convention used in the graph)
(d) 4·0 J

21. 1·25 × 10^{3} N towards the wall

22. 9·0 × 10^{4} N

24. (a) (i) 4·0 m s^{-1} in the direction the 2·0 kg trolley was travelling
(ii) 4·0 kg m s^{-1} in the direction the 2·0 kg trolley was travelling
(iii) 4·0 kg m s^{-1} in the opposite direction the 2·0 kg trolley was travelling
(b) 8·0 N