Cumbernauld Academy
Higher Physics
Our Dynamic Universe
Booklet 1- Mechanics Problems

Revision problems
Speed

1. The world downhill skiing speed trial takes place at Les Arcs every year. Describe a method that could be used to find the average speed of the skier over the 1 km run. Your description should include:

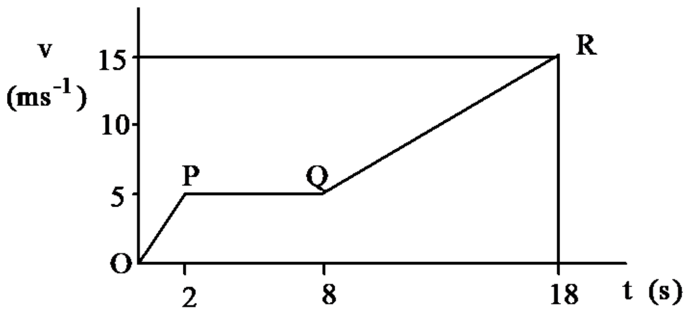
   (a) any apparatus required
   (b) details of what measurements need to be taken
   (c) an explanation of how you would use the measurements to carry out the calculations.

2. An athlete runs a 1500 m race in a time of 3 min 40 s. Calculate his average speed for the race.

3. It takes light 8·0 minutes to travel from the Sun to the Earth. How far away is the Sun from the Earth?
   (speed of light = $3{\cdot}0 \times 10^8$ m s^{-1}).

4. The distance between London and New York is 4800 km. A plane travels at an average speed of Mach 1·3 between London and New York.
   Calculate the time, to the nearest minute, for this journey. (Mach 1 is the speed of sound. Take the speed of sound to be 340 m s^{-1}).

5. The graph shows how the speed of a girl varies with time from the instant she starts to run for a bus.



   She starts from stand still at O and jumps on the bus at Q.
   Find:

   (a) the steady speed at which she runs
   (b) the distance she runs
   (c) the increase in the speed of the bus while the girl is on it
   (d) how far the bus travels during QR
   (e) how far the girl travels during OR.

6. A ground-to-air guided missile starts from rest and accelerates at 150 m s^{-2} for 5 s. What is the speed of the missile 5 s after launching?

7. An Aston Martin has an acceleration of 6 m s^{-2} from rest. What time does it take to reach a speed of 30 m s^{-1}?

8. A car is travelling at a speed of 34 m s^{-1}. The driver applies the brakes and the car slows down at a rate of 15 m s^{-2}. What is the time taken for the speed of the car to reduce to 4 m s^{-1}?

Acceleration

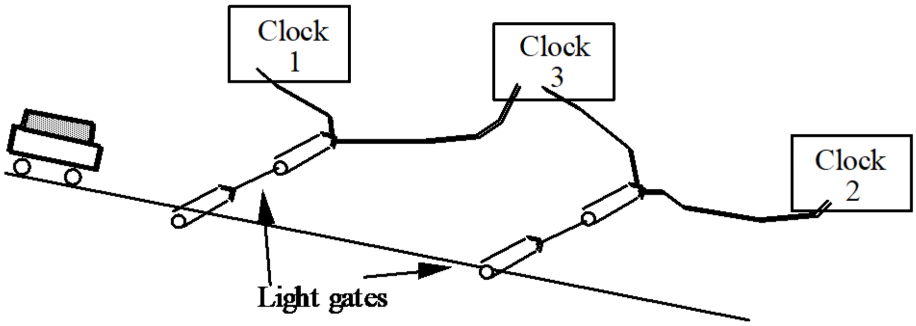
1. A skateboarder starting from rest goes down a uniform slope and reaches a speed of 8 $m s^{-1}$ in 4 s.

   (a) What is the acceleration of the skateboarder?
   (b) Calculate the time taken for the skateboarder to reach a speed of 12 $m s^{-1}$.

2. In the Tour de France a cyclist is travelling at 16 $m s^{-1}$. When he reaches a downhill stretch he accelerates to a speed of 20 $m s^{-1}$ in 2·0 s.

   (a) What is the acceleration of the cyclist down the hill?
   (b) The cyclist maintains this constant acceleration. What is his speed after a further 2·0 s?
   (c) How long after he starts to accelerate does he reach a speed of 28 $m s^{-1}$?

3. A student sets up the apparatus shown to find the acceleration of a trolley down a slope.



Length of card on trolley = 50 mm

Time on clock 1 = 0·10 s (time taken for card to interrupt top light gate)
Time on clock 2 = 0·05 s (time taken for card to interrupt bottom light gate)
Time on clock 3 = 2·50 s (time taken for trolley to travel between top and bottom light gate)
Use these results to calculate the acceleration of the trolley.

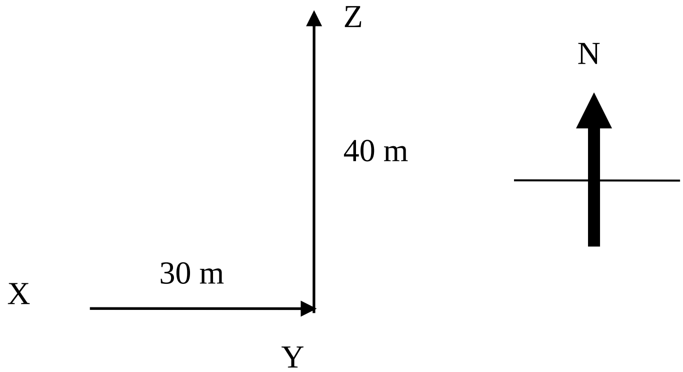
Vectors

1. A car travels 50 km due north and then returns 30 km due south. The whole journey takes 2 hours.

   Calculate:

   (a) the total distance travelled by the car
   (b) the average speed of the car
   (c) the resultant displacement of the car
   (d) the average velocity of the car.

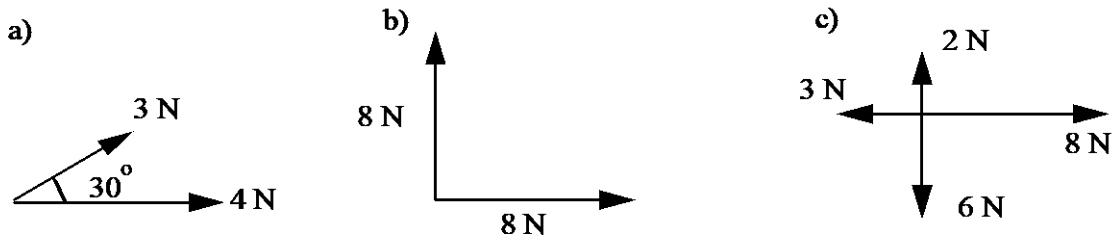
2. A girl delivers newspapers to three houses, X, Y and Z, as shown in the diagram.



   She starts at X and walks directly from X to Y and then to Z.

   (a) Calculate the total distance the girl walks.
   (b) Calculate the girl's final displacement from X.
   (c) The girl walks at a steady speed of 1 ms^{-1}.
      (i) Calculate the time she takes to get from X to Z.
      (ii) Calculate her resultant velocity.

3. Find the resultant force in the following example:



4. State what is meant by a vector quantity and scalar quantity.
   Give two examples of each.

5. An orienteer runs 5 km due south then 4 km due west and then 2 km due north. The total time taken for this is 1 hours. Calculate the average speed and average velocity of the orienteer for this run.

6. A football is kicked up at an angle of 60° at 15 ms^{-1}.

   Calculate:
   (a) the horizontal component of the velocity
   (b) the vertical component of the velocity.

Section 1: Equations of motion
Equations of motion

1. An object is travelling at a speed of 8·0 m s^{-1}. It then accelerates uniformly at 4·0 m s^{-2} for 10 s. How far does the object travel in this 10 s?

2. A car is travelling at a speed of 15·0 m s^{-1}.
It accelerates uniformly at 6·0 m s^{-2} and travels a distance of 200 m while accelerating. Calculate the velocity of the car at the end of the 200 m.

3. A ball is thrown vertically upwards to a height of 40 m above its starting point. Calculate the speed at which it was thrown.

4. A car is travelling at a speed of 30·0 m s^{-1}. It then slows down at 1·80 m s^{-2} until it comes to rest. It travels a distance of 250 m while slowing down. What time does it take to travel the 250 m?

5. A stone is thrown with an initial speed 5·0 m s^{-1} vertically down a well. The stone strikes the water 60 m below where it was thrown.
Calculate the time taken for the stone to reach the surface of the water.
The effects of friction can be ignored.

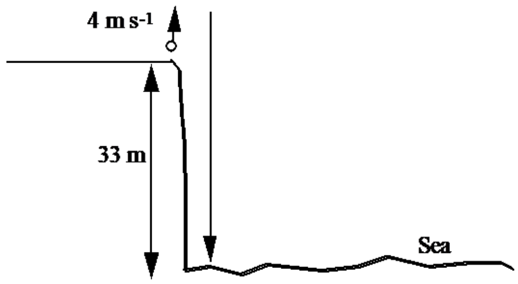
6. A tennis ball launcher is 0·60 m long. A tennis ball leaves the launcher at a speed of 30 m s^{-1}.
   (a) Calculate the average acceleration of the tennis ball in the launcher.
   (b) Calculate the time the ball accelerates in the launcher.

7. In an experiment to find *g* a steel ball falls from rest through a distance of 0·40 *m*. The time taken to fall this distance is 0·29 *s*.
What is the value of *g* calculated from the data of this experiment?

8. A trolley accelerates uniformly down a slope. Two light gates connected to a motion computer are spaced 0·50 m apart on the slope. The speeds recorded as the trolley passes the light gates are 0·20 m s^{-1} and 0·50 m s^{-1}
   (a) Calculate the acceleration of the trolley.
   (b) What time does the trolley take to travel the 0·5 m between the light gates?

9. A helicopter is rising vertically at a speed of 10·0 m s^{-1} when a wheel falls off. The wheel hits the ground 8·00 s later.
Calculate the height of the helicopter above the ground when the wheel came off. The effects of friction can be ignored.

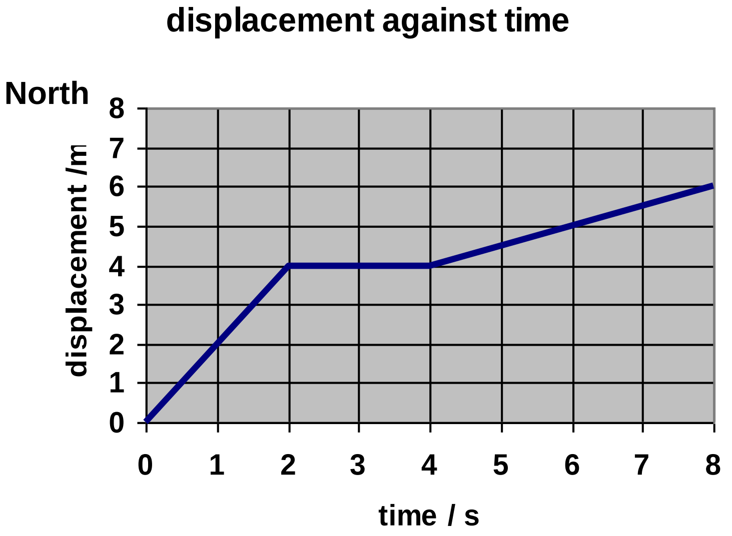
10. A ball is thrown vertically upwards from the edge of a cliff as shown in the diagram.



The effects of friction can be ignored.
   (a) (i) What is the height of the ball above sea level 2·0 s after being thrown?
   (ii) What is the velocity of the ball 2·0 s after being thrown?
   (b) What is the total distance travelled by the ball from launch to landing in the sea?

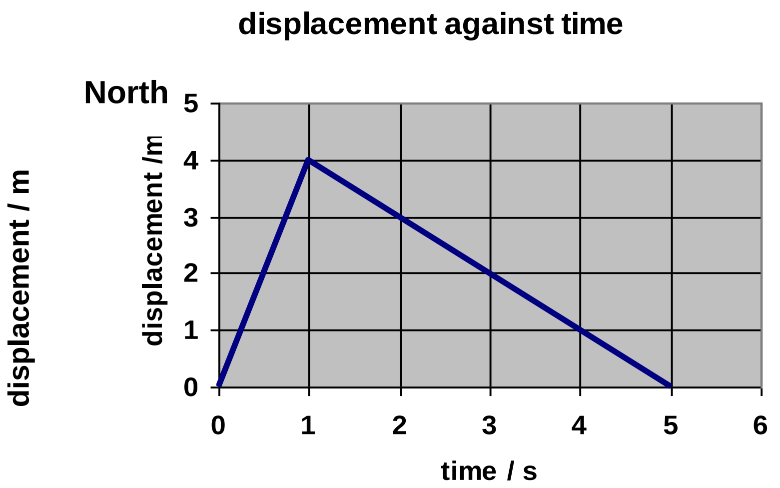
Motion – time graphs

1. The graph shows how the displacement of an object varies with time.



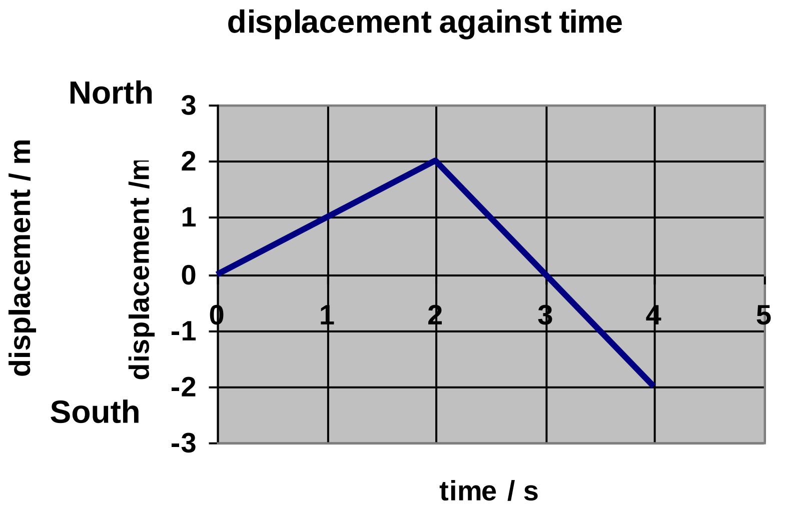
(a) Calculate the velocity of the object between 0 and 1 s.
(b) What is the velocity of the object between 2 and 4 s?
(c) Draw the corresponding distance against time graph for the movement of this object.
(d) Calculate the average speed of the object for the 8 seconds shown on the graph.
(e) Draw the corresponding velocity against time graph for the movement of this object.

2. The graph shows how the displacement of an object varies with time.



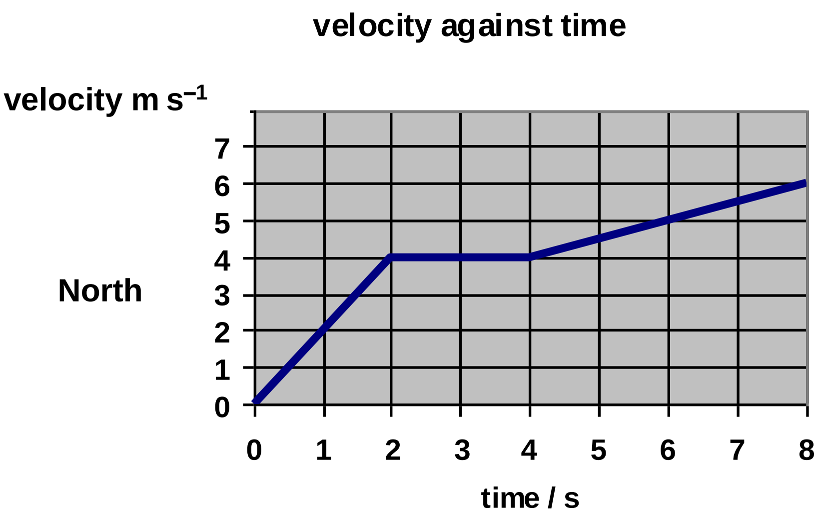
(a) Calculate the velocity of the object during the first second from the start.
(b) Calculate the velocity of the object between 1 and 5 s from the start.
(c) Draw the corresponding distance against time graph for this object.
(d) Calculate the average speed of the object for the 5 seconds.
(e) Draw the corresponding velocity against time graph for this object.
(f) What are the displacement and the velocity of the object 0·5 seconds after the start?
(g) What are the displacement and the velocity of the object 3 seconds after the start?

3. The graph shows the displacement against time graph for the movement of an object.



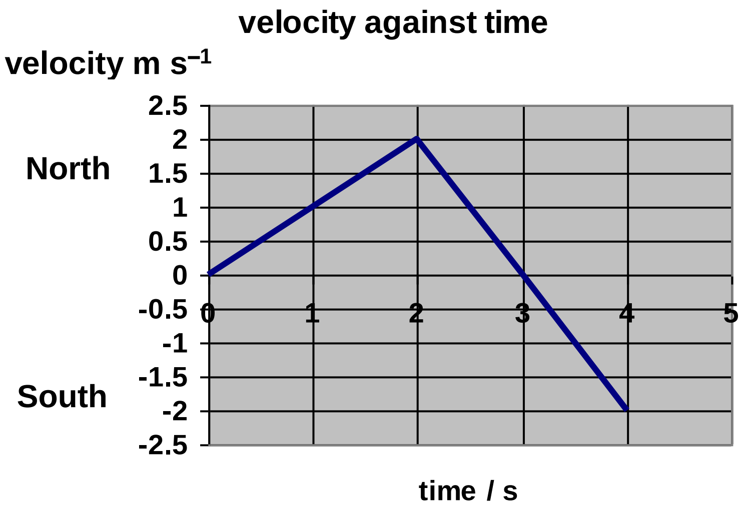
(a) Calculate the velocity of the object between 0 and 2 s.
(b) Calculate the velocity of the object between 2 and 4 s from the start.
(c) Draw the corresponding distance against time graph for this object.
(d) Calculate the average speed of the object for the 4 seconds.
(e) Draw the corresponding velocity against time graph for this object.
(f) What are the displacement and the velocity of the object 0·5 s after the start?
(g) What are the displacement and the velocity of the object 3 seconds after the start?

4. An object starts from a displacement of 0 m. The graph shows how the velocity of the object varies with time from the start.



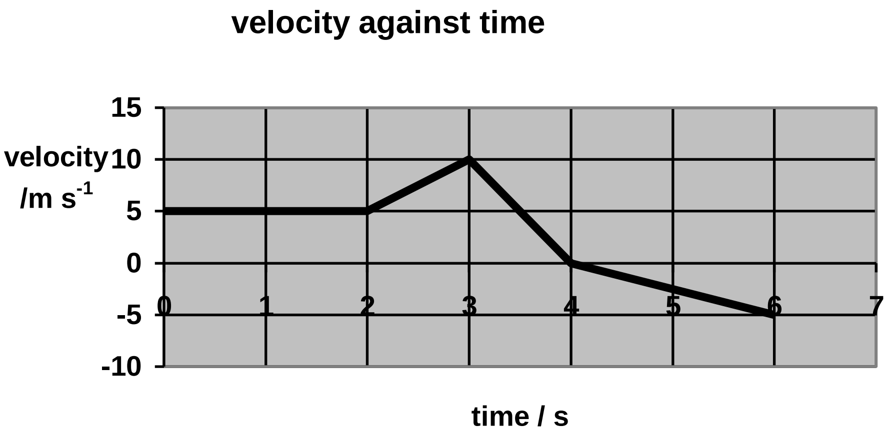
(a) Calculate the acceleration of the object between 0 and 1 s.
(b) What is the acceleration of the object between 2 and 4 s from the start?
(c) Calculate the displacement of the object 2 seconds after the start.
(d) What is the displacement of the object 8 seconds after the start?
(e) Sketch the corresponding displacement against time graph for the movement of this object.

5. An object starts from a displacement of 0 m. The graph shows how the velocity of the object varies with time from the start.



(a) Calculate the acceleration of the object between 0 and 2 s.
(b) Calculate the acceleration of the object between 2 and 4 s from the start.
(c) Draw the corresponding acceleration against time graph for this object.
(d) What are the displacement and the velocity of the object 3 seconds after the start?
(e) What are the displacement and the velocity of the object 4 seconds after the start?
(f) Sketch the corresponding displacement against time graph for the movement of this object.

6. The velocity-time graph for an object is shown below.

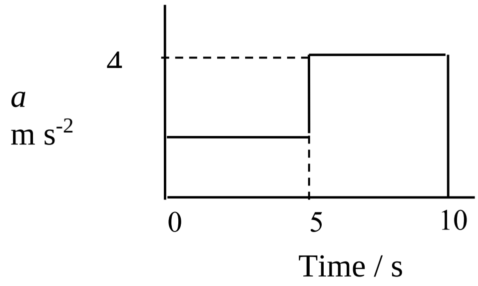


A positive value indicates a velocity due north and a negative value indicates a velocity due south. The displacement of the object is 0 at the start of timing.

(a) Calculate the displacement of the object:
  (i) 3 s after timing starts
  (ii) 4 s after timing starts
  (iii) 6 s after timing starts.

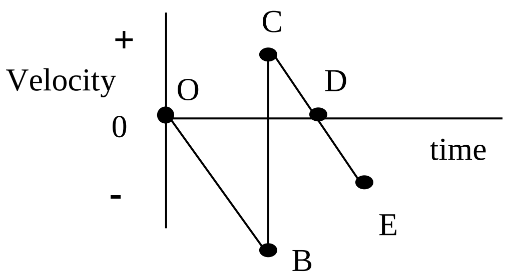
(b) Draw the corresponding acceleration-time graph.

7. The graph shows how the acceleration a of an object, starting from rest, varies with time.



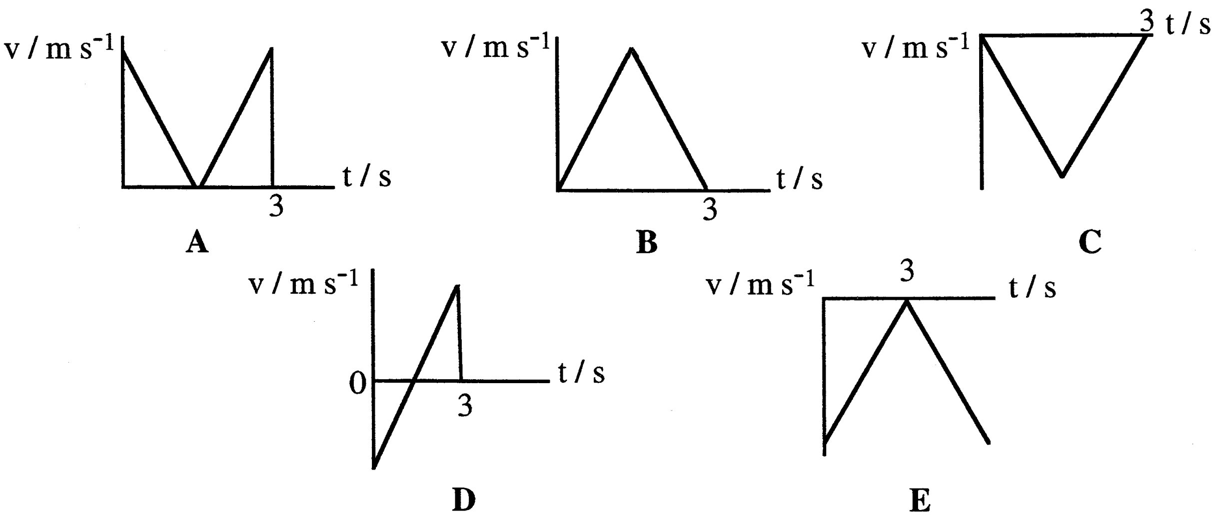
Draw a graph to show how the velocity of the object varies with time for the 10 seconds of the motion.

8. The graph shows the velocity of a ball that is dropped and bounces on a floor. An upwards direction is taken as being positive.

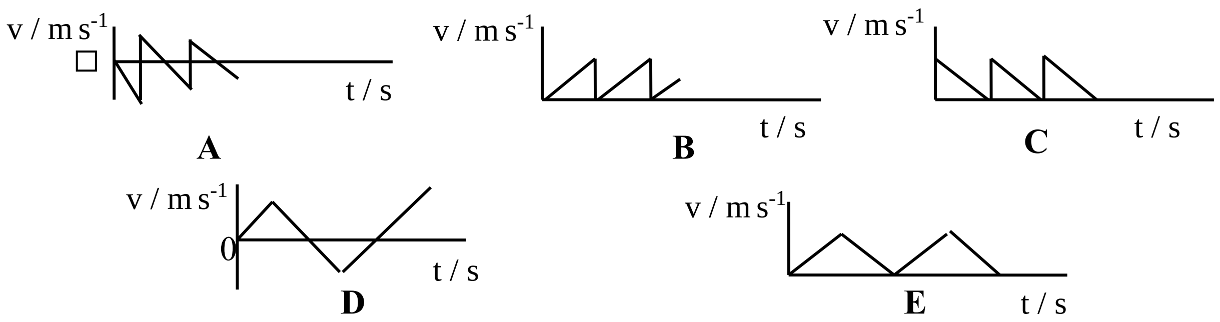


(a) In which direction is the ball travelling during section OB of the graph?
(b) Describe the *velocity* of the ball as represented by section CD of the graph.
(c) Describe the *velocity* of the ball as represented by section DE of the graph.
(d) What happened to the ball at the time represented by point B on the graph?
(e) What happened to the ball at the time represented by point C on the graph?
(f) How does the speed of the ball immediately before rebound from the floor compare with the speed immediately after rebound?
(g) Sketch a graph of acceleration against time for the movement of the ball.

9. A ball is thrown vertically upwards and returns to the thrower 3 seconds later. Which velocity-time graph represents the motion of the ball?



10. A ball is dropped from a height and bounces up and down on a horizontal surface. Which velocity-time graph represents the motion of the ball from the moment it is released?



11. Describe how you could measure the acceleration of a trolley that starts from rest and moves down a slope. You are provided with a metre stick and a stopwatch. Your description should include:

    (a) a diagram
    (b) a list of the measurements taken
    (c) how you would use these measurements to calculate the acceleration of the trolley
    (d) how you would estimate the uncertainties involved in the experiment.

12. Describe a situation where a runner has a displacement of 100 m due north, a velocity of 3 $m s^{-1}$ due north and an acceleration of 2 $m s^{-2}$ due south. Your description should include a diagram.

13. Is it possible for an object to be accelerating but have a constant speed? You must justify your answer.

14. Is it possible for an object to move with a constant *speed* for 5 seconds and have a displacement of 0 m? You must justify your answer.

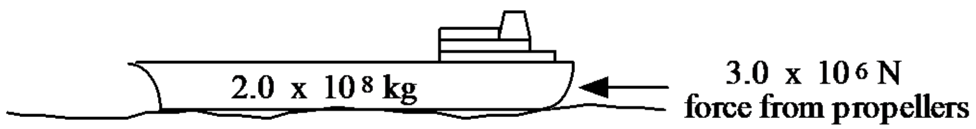
15 Is it possible for an object to move with a constant *velocity* for 5 s and have a displacement of 0 m? You must justify your answer.

Section 2: Forces, energy and power
Balanced and unbalanced forces

1. State Newton's 1st Law of Motion.

2. A lift of mass 500 kg travels upwards at a constant speed.
Calculate the tension in the cable that pulls the lift upwards.

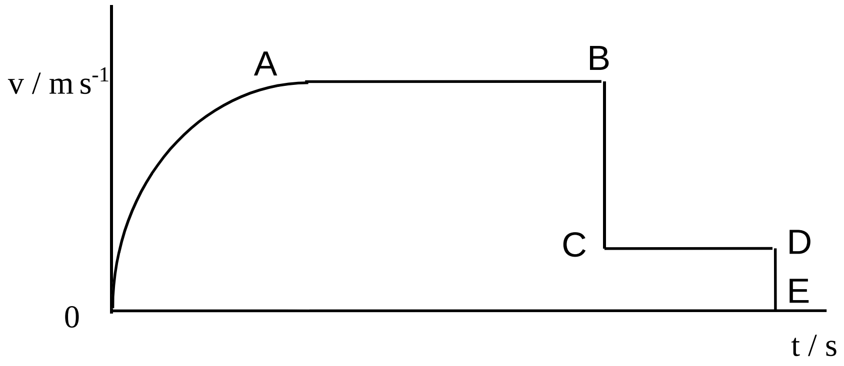
3. (a) A fully loaded oil tanker has a mass of $2{\cdot}0 \times 10^8$ kg.
As the speed of the tanker increases from 0 to a steady maximum speed of $8.0\ \text{m s}^{-1}$ the force from the propellers remains constant at 3.0×10^6 N.



(i) Calculate the acceleration of the tanker just as it starts from rest.
(ii) What is the size of the force of friction acting on the tanker when it is travelling at the steady speed of $8.0\ \text{m s}^{-1}$?

(b) When its engines are stopped, the tanker takes 50 minutes to come to rest from a speed of $8.0\ \text{m s}^{-1}$. Calculate its average deceleration.

4. The graph shows how the speed of a parachutist varies with time after having jumped from an aeroplane.



With reference to the origin of the graph and the letters A, B, C, D and E explain the variation of speed with time for each stage of the parachutist's fall.

5. Two girls push a car of mass 2000 kg. Each applies a force of 50 N and the force of friction is 60 N. Calculate the acceleration of the car.

6. A boy on a skateboard rides up a slope. The total mass of the boy and the skateboard is 90 kg. He decelerates uniformly from $12\ \text{m s}^{-1}$ to $2\ \text{m s}^{-1}$ in 6 seconds. Calculate the resultant force acting on him.

7. A box of mass 30 kg is pulled along a rough surface by a constant force of 140 N. The acceleration of the box is $4{\cdot}0\ \text{m s}^{-2}$.

(a) Calculate the magnitude of the unbalanced force causing the acceleration.
(b) Calculate the force of friction between the box and the surface.

8. A car of mass 800 kg is accelerated from rest to $18\ \text{m s}^{-1}$ in 12 seconds.

(a) What is the size of the resultant force acting on the car?
(b) How far does the car travel in these 12 seconds?
(c) At the end of the 12 seconds period the brakes are operated and the car comes to rest in a distance of 50 m.
What is the size of the average frictional force acting on the car?

9. (a) A rocket of mass $4{\cdot}0 \times 10^4$ kg is launched vertically upwards from the surface of the Earth. Its engines produce a constant thrust of $7{\cdot}0 \times 10^5$ N.
   (i) Draw a diagram showing all the forces acting on the rocket just after take-off.
   (ii) Calculate the initial acceleration of the rocket.
(b) As the rocket rises the thrust remains constant but the acceleration of the rocket increases. Give three reasons for this increase in acceleration.
(c) Explain in terms of Newton's laws of motion why a rocket can travel from the Earth to the Moon and for most of the journey not burn up any fuel.

10. A rocket takes off from the surface of the Earth and accelerates to 90 $m s^{-1}$ in a time of 4·0 s. The resultant force acting on it is 40 kN upwards.

(a) Calculate the mass of the rocket.
(b) The average force of friction is 5000 N. Calculate the thrust of the rocket engines.

11. A helicopter of mass 2000 kg rises upwards with an acceleration of 4·00 $m s^{-2}$. The force of friction caused by air resistance is 1000 N. Calculate the upwards force produced by the rotors of the helicopter.

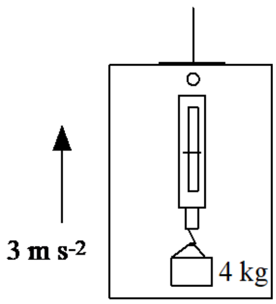
12. A crate of mass 200 kg is placed on a balance, calibrated in newtons, in a lift.

(a) What is the reading on the balance when the lift is stationary?
(b) The lift now accelerates upwards at 1·50 $m s^{-2}$. What is the new reading on the balance?
(c) The lift then travels upwards at a constant speed of 5·00 $m s^{-1}$. What is the new reading on the balance?
(d) For the last stage of the journey the lift decelerates at 1·50 $m s^{-2}$ while going up. Calculate the reading on the balance.

13. A small lift in a hotel is fully loaded and has a total mass of 250 kg. For safety reasons the tension in the pulling cable must never be greater than 3500 N.

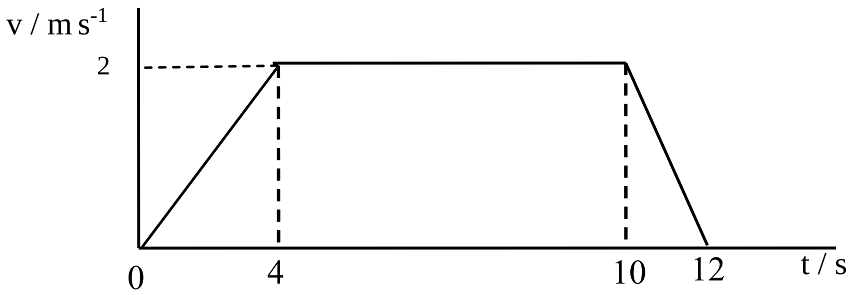
(a) What is the tension in the cable when the lift is:
   (i) at rest
   (ii) moving upwards at a constant speed of 1 $m s^{-1}$
   (iii) moving upwards with a constant acceleration of 2 $m s^{-2}$
   (iv) accelerating downwards with a constant acceleration of 2 $m s^{-2}$.
(b) Calculate the maximum permitted upward acceleration of the fully loaded lift.
(c) Describe a situation where the lift could have an upward acceleration greater than the value in (b) without breaching safety regulations.

14. A package of mass 4·00 kg is hung from a spring (Newton) balance attached to the ceiling of a lift.



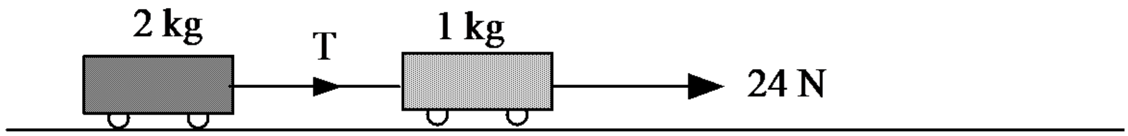
The lift is accelerating upwards at 3·00 $m s^{-2}$.
What is the reading on the spring balance?

15. The graph shows how the *downward* speed of a lift varies with time.



(a) Draw the corresponding acceleration against time graph.
(b) A 4.0 kg mass is suspended from a spring balance inside the lift. Determine the reading on the balance at each stage of the motion.

16. Two trolleys joined by a string are pulled along a frictionless flat surface as shown.



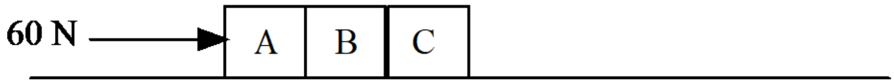
(a) Calculate the acceleration of the trolleys.
(b) Calculate the tension, *T*, in the string joining the trolleys.

17. A car of mass 1200 kg tows a caravan of mass 1000 kg. The frictional forces on the car and caravan are 200 N and 500 N, respectively.
The car accelerates at 2.0 $m s^{-2}$.

(a) Calculate the force exerted by the engine of the car.
(b) What force does the tow bar exert on the caravan?
(c) The car then travels at a constant speed of 10 $m s^{-1}$.
Assuming the frictional forces to be unchanged, calculate:
(i) the new engine force
(ii) the force exerted by the tow bar on the caravan.
(d) The car brakes and decelerates at 5·0 $m s^{-2}$.
Calculate the force exerted by the brakes (assume the other frictional forces remain constant).

18. A log of mass 400 kg is stationary. A tractor of mass 1200 kg pulls the log with a tow rope. The tension in the tow rope is 2000 N and the frictional force on the log is 800 N. How far will the log move in 4 s?

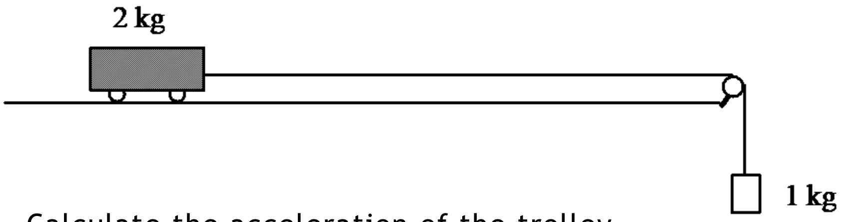
19. A force of 60 N is used to push three blocks as shown.



Each block has a mass of 8·0 kg and the force of friction on each block is 4·0 N.

(a) Calculate:
(i) the acceleration of the blocks
(ii) the force that block A exerts on block B
(iii) the force block B exerts on block C.
(b) The pushing force is then reduced until the blocks move at constant speed.
(i) Calculate the value of this pushing force.
(ii) Does the force that block A exerts on block B now equal the force that block B exerts on block C? Explain.

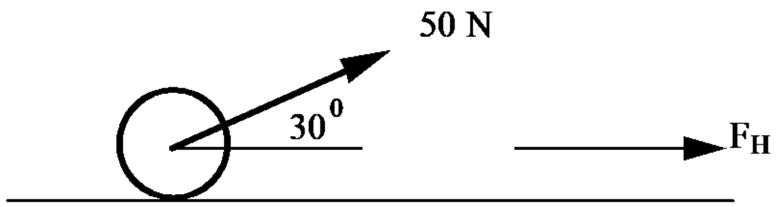
20. A 2·0 kg trolley is connected by string to a 1·0 kg mass as shown. The bench and pulley are frictionless.



(a) Calculate the acceleration of the trolley.
(b) Calculate the tension in the string.

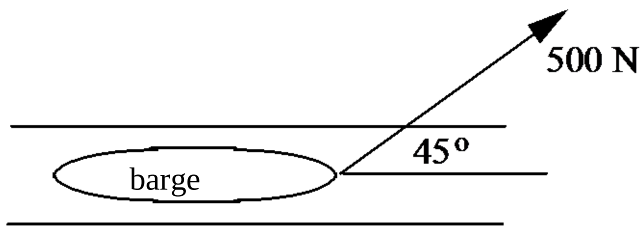
Resolution of forces

1. A man pulls a garden roller with a force of 50 N.



(a) Find the effective horizontal force applied to the roller.
(b) Describe and explain how the man can increase this effective horizontal force without changing the size of the force applied.

2. A barge is dragged along a canal as shown below.

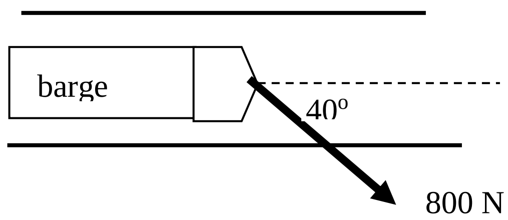


What is the size of the component of the force parallel to the canal?

3. A toy train of mass 0·20 kg is given a push of 10 N along the rails at an angle of 30° above the horizontal.
Calculate:

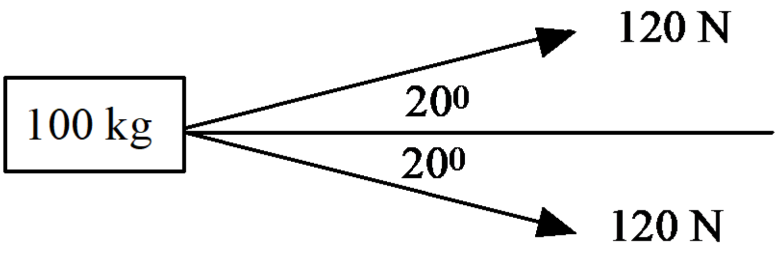
(a) the magnitude of the component of force along the rails
(b) the acceleration of the train.

4. A barge of mass 1000 kg is pulled by a rope along a canal as shown.



The rope applies a force of 800 N at an angle of 40° to the direction of the canal. The force of friction between the barge and the water is 100 N. Calculate the acceleration of the barge.

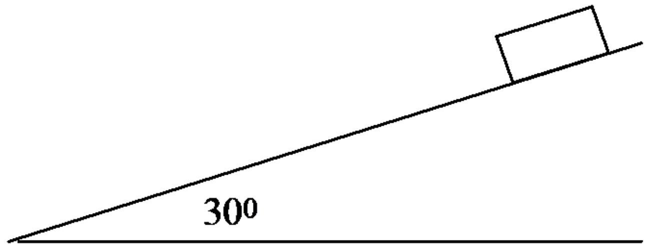
5. A crate of mass 100 kg is pulled along a rough surface by two ropes at the angles shown.



(a) The crate is moving at a constant speed of 1·0 $m s^{-1}$. What is the size of the force of friction?

(b) The forces are now each increased to 140 N at the same angle. Assuming the friction force remains constant, calculate the acceleration of the crate.

6. A 2·0 kg block of wood is placed on a slope as shown.



The block remains stationary. What are the size and direction of the frictional force on the block?

7. A runway is 2·0 m long and raised 0·30 m at one end. A trolley of mass 0·50 kg is placed on the runway. The trolley moves down the runway with constant speed. Calculate the magnitude of the force of friction acting on the trolley.

8. A car of mass 900 kg is parked on a hill. The slope of the hill is 15° to the horizontal. The brakes on the car fail. The car runs down the hill for a distance of 50 m until it crashes into a hedge. The average force of friction on the car as it runs down the hill is 300 N.

(a) Calculate the component of the weight acting down the slope.

(b) Find the acceleration of the car.

(c) Calculate the speed of the car just before it hits the hedge.

9. A trolley of mass 2·0 kg is placed on a slope which makes an angle of 60° to the horizontal.

(a) A student pushes the trolley and then releases it so that it moves up the slope. The force of friction on the trolley is 1·0 N.

(i) Why does the trolley continue to move up the slope after it is released?

(ii) Calculate the unbalanced force on the trolley as it moves up the slope.

(iii) Calculate the rate at which the trolley loses speed as it moves up the slope.

(b) The trolley eventually comes to rest then starts to move down the slope.

(i) Calculate the unbalanced force on the trolley as it moves down the slope.

(ii) Calculate the acceleration of the trolley down the slope.

Work done, kinetic and potential energy

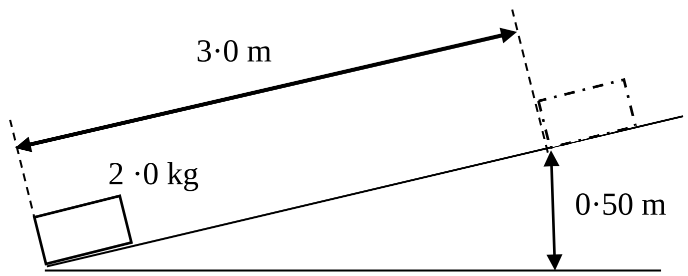
1. A small ball of mass 0·20 kg is dropped from a height of 4·0 m above the ground. The ball rebounds to a height of 2·0 m.

   (a) Calculate total loss in energy of the ball.
   (b) Calculate the speed of the ball just before it hits the ground.
   (c) Calculate the speed of the ball just after it leaves the ground.

2. A box of mass 70 kg is pulled along a horizontal surface by a horizontal force of 90 N. The box is pulled a distance of 12 m. There is a frictional force of 80 N between the box and the surface.

   (a) Calculate the total work done by the pulling force.
   (b) Calculate the amount of kinetic energy gained by the box.

3. A box of mass 2·0 kg is pulled up a frictionless slope as shown.



   (a) Calculate the gravitational potential energy gained by the box when it is pulled up the slope.
   (b) The block is now released.
      (i) Use conservation of energy to find the speed of the box at the bottom of the slope.
      (ii) Use another method to confirm your answer to (i).

4. A winch driven by a motor is used to lift a crate of mass 50 kg through a vertical height of 20 m.

   (a) Calculate the size of the minimum force required to lift the crate.
   (b) Calculate the minimum amount of work done by the winch while lifting the crate.
   (c) The power of the winch is 2·5 kW. Calculate the minimum time taken to lift the crate to the required height.

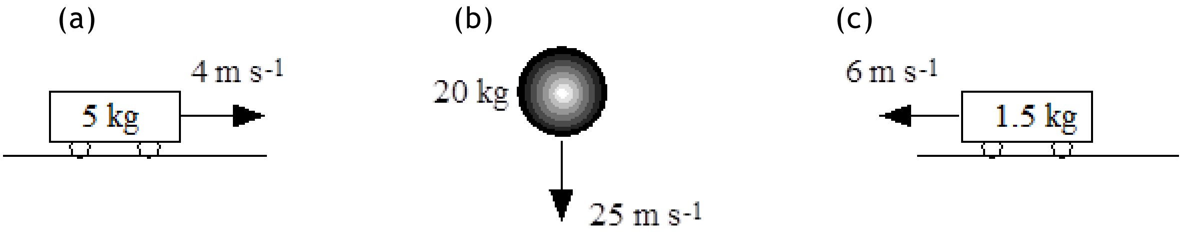
5. A train has a constant speed of 10 m s^{-1} over a distance of 2·0 km. The driving force of the train engine is $3{\cdot}0 \times 10^4$ N.
   What is the power developed by the train engine?

6. An arrow of mass 22 g has a speed of 30 m s^{-1} as it strikes a target. The tip of the arrow goes $3{\cdot}0 \times 10^{-2}$ m into the target.

   (a) Calculate the average force of the target on the arrow.
   (b) What is the time taken for the arrow to come to rest after striking the target, assuming the target exerts a constant force on the arrow?

Section 3: Collisions and explosions

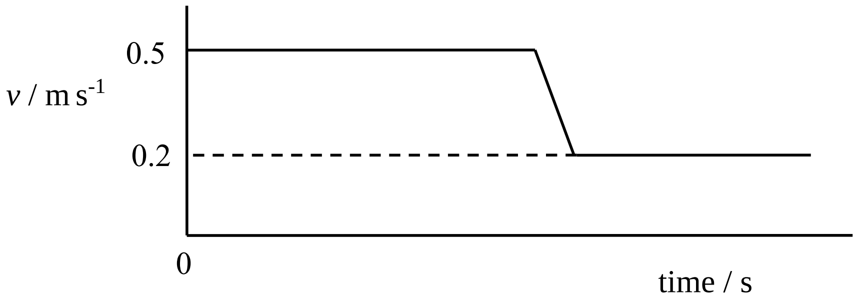
1. What is the momentum of the object in each of the following situations?



2. A trolley of mass 2·0 kg is travelling with a speed of 1·5 ms^{-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 ms^{-1} just before it strikes the target. What is 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.



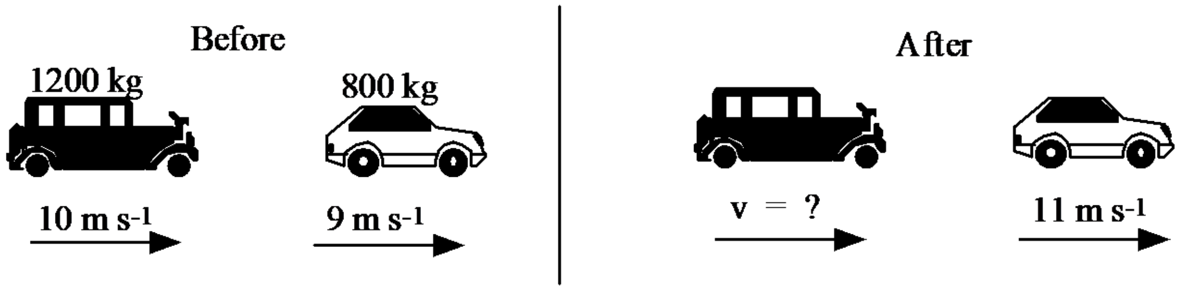
Determine the mass of the second trolley.

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 ms^{-1} after the collision.
   (a) What is 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 ms^{-1}. The second vehicle has a mass of 1500 kg and is moving at 8·0 ms^{-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 ms^{-1}. The car behind has a mass of 1000 kg and is moving at 30 ms^{-1}. The cars collide and as a result of the collision the car in front has a speed of 25 ms^{-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. What is 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 kg moves off with a speed of 4 $m s^{-1}$. The other moves off with a speed of 2 $m s^{-1}$, 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 0·5 $m s^{-1}$. What is the velocity of the woman as a result of the push?

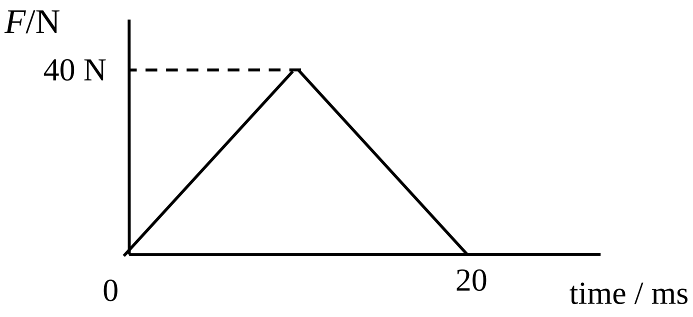
13. Two trolleys initially at rest and in contact fly apart when a plunger on one of them is released. One trolley has a mass of 2·0 kg and moves off at a speed of 2·0 $m s^{-1}$. The second trolley has a mass of 3·0 kg. Calculate the velocity of this trolley.

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. What is 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.

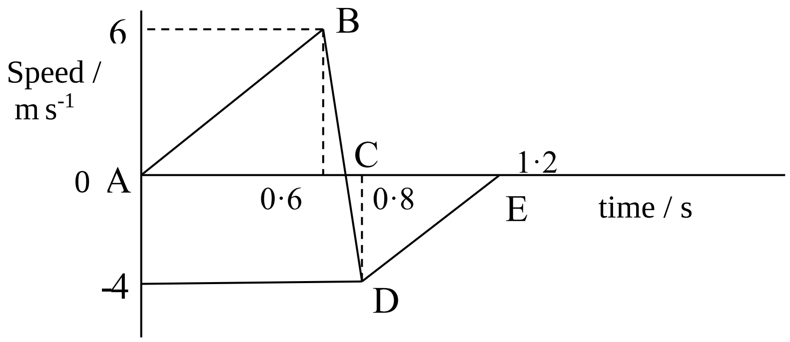
18. A ball of mass 100 g falls from a height of 0·20 m onto concrete. The ball rebounds to a height of 0·18 m. The duration of the impact is 25 ms. Calculate:

(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.

25. In a problem two objects, having known masses and velocities, collide and stick together. Why does the problem ask for the velocity *immediately* after collision to be calculated?

26. A Newton's cradle apparatus is used to demonstrate conservation of momentum. Four steel spheres, each of mass 0.1 kg, are suspended so that they are in a straight line.
Sphere 1 is pulled to the side and released, as shown in diagram I.

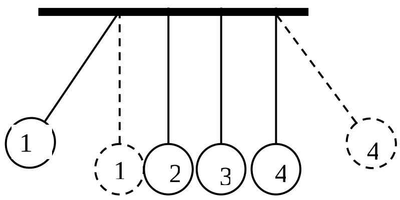


Diagram I

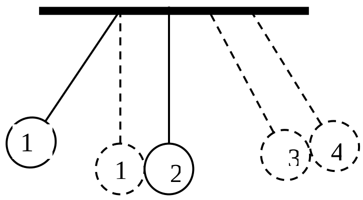


Diagram II

When sphere 1 strikes sphere 2 (as shown by the dotted lines) then sphere 4 moves off the line and reaches the position shown by the dotted lines.
The student estimates that sphere 1 has a speed of 2 $m s^{-1}$ when it strikes sphere 2. She also estimates that sphere 4 leaves the line with an initial speed of 2 $m s^{-1}$. Hence conservation of momentum has been demonstrated.
A second student suggests that when the demonstration is repeated there is a possibility that spheres 3 and 4, each with a speed of 0·5 $m s^{-1}$, could move off the line as shown in diagram II.

Use your knowledge of physics to show this is not possible.

Solutions

Speed

2. $6 \cdot 8\ ms^{-1}$
3. $1 \cdot 4 \times 10^{11}$ m
4. 181 minutes
5. (a) $5\ ms^{-1}$
   (b) 35 m
   (c) $10\ ms^{-1}$
   (d) 100 m
   (e) 135 m
6. $750\ ms^{-1}$
7 5 s
8. 2 s

Acceleration

1. (a) $2\ ms^{-2}$
   (b) 6 s
2. (a) $2 \cdot 0\ ms^{-2}$
   (b) $24\ ms^{-1}$
   (c) 6·0 s
3. $0 \cdot 20\ ms^{-2}$

Vectors

1. (a) 80 km
   (b) $40\ km\,h^{-1}$
   (c) 20 km north
   (d) $10\ km\,h^{-1}$ north
2. (a) 70 m
   (b) 50 m bearing 037
   (c) (i) 70 s
   (ii) $0 \cdot 71\ ms^{-1}$ bearing 037
3. (a) 6·8 N bearing 077
   (b) 11·3 N bearing 045
   (c) 6·4 N bearing 129
5. Average speed = $11\ km\ h^{-1}$
   Average velocity = $5\ km\ h^{-1}$ bearing 233
6. (a) $7 \cdot 5\ ms^{-1}$
   (b) $13\ ms^{-1}$

Equations of motion

1. 280 m
2. $51 \cdot 2\ m\,s^{-1}$
3. $28\ ms^{-1}$
4. 16·7 s
5. 3·0 s
6. (a) $750\ ms^{-2}$
   (b) 0·04 s
7. $9 \cdot 5\ ms^{-2}$ or $N\,kg^{-1}$
8. (a) $0 \cdot 21\ ms^{-2}$
   (b) 1·4 s
9. 234 m
10. (a) (i) 21·4 m
    (ii) $15 \cdot 6\ ms^{-1}$ downwards
    (b) 34·6 m

Motion-time graphs

1. (a) $2\ ms^{-1}$ due north
   (b) $0\ ms^{-1}$
   (d) $0 \cdot 75\ ms^{-1}$
2. (a) $4\ ms^{-1}$ due north
   (b) $1 \cdot 0\ ms^{-1}$ due south
   (d) $1 \cdot 6\ ms^{-1}$
   (f) displacement 2 m due north, velocity $4\ ms^{-1}$ due north
   (g) displacement 2 m due north, velocity $1\ ms^{-1}$ due south
3. (a) $1\ ms^{-1}$ due north
   (b) $2\ ms^{-1}$ due south
   (d) $1 \cdot 5\ ms^{-1}$
   (f) displacement 0·5 m due north, velocity $1\ ms^{-1}$ due north
   (g) displacement 0, velocity $2\ ms^{-1}$ due south
4. (a) $2\ ms^{-2}$ due north
   (b) $0\ ms^{-2}$
   (c) 4 m due north
   (d) 32 m due north
5. (a) $1\ ms^{-2}$ due north
   (b) $2\ ms^{-2}$ due south
   (d) displacement 3 m due north, velocity $0\ ms^{-1}$
   (e) displacement 2 m due north, velocity $2\ ms^{-1}$ due south
6. (a) (i) 17·5 m due north
   (ii) 22·5 m due north
   (iii) 17·5 m due north
9. D. Note that in this question, downwards is taken to be the positive direction for vectors.
10. A. Note that in this question, upwards is taken to be the positive direction for vectors.

Balanced and unbalanced forces

2. 4900 N
3. (a) (i) $0 \cdot 015\ ms^{-2}$
   (ii) $3 \cdot 0 \times 10^{6}$ N
   (b) $-2 \cdot 7 \times 10^{-3}\ ms^{-2}$
5. $0 \cdot 02\ ms^{-2}$
6. 150 N
7. (a) 120 N
   (b) 20 N
8. (a) 1200 N
   (b) 108 m
   (c) 2592 N
9. (a) (ii) $7 \cdot 7\ ms^{-2}$
10. (a) $1 \cdot 78 \times 10^{3}$ kg (1778 kg)
    (b) $6 \cdot 24 \times 10^{4}$ N (62 400 N)
11. $2 \cdot 86 \times 10^{4}$ N (28 600 N)

12. (a) $1·96 \times 10^3$ N
(b) 2.26×10^3 N
(c) 1.96×10^3 N
(d) 1.66×10^3 N
13. (a) (i) $2·45 \times 10^3$ N
(ii) $2·45 \times 10^3$ N
(iii) $2·95 \times 10^3$ N
(iv) $1·95 \times 10^3$ N
(b) 4·2 ms^{-2}
14. 51·2 N
15. (b) 0·4 s reading 37·2 N
4 s to 10 s reading 39·2 N
10 s to 12 s reading 43·2 N
16. (a) 8 ms^{-2}
(b) 16 N
17. (a) $5·1 \times 10^3$ N
(b) $2·5 \times 10^3$ N
(c) (i) 700 N
(ii) 500 N
(d) $1·03 \times 10^4$ N
18. 24 m
19. (a) (i) 2 ms^{-2}
(ii) 40 N
(iii) 20 N
(b) (i) 12 N
20. (a) 3·27 ms^{-2}
(b) 6·54 N

Resolution of forces

1. (a) 43·3 N
2. 354 N (353·6 N)
3. (a) 8·7 N
(b) 43·5 ms^{-2}
4. 0·513 ms^{-2}
5. (a) 226 N
(b) 0·371 ms^{-2}
6. 9·8 N up the slope
7. 0·735 N
8. (a) 2280 N (2283 N)
(b) 2·2 ms^{-2}
(c) 14·8 ms^{-1}
9. (a) (ii) 18 N down the slope
(iii) 9 ms^{-2} down the slope
(b) (i) 16 N down the slope
(ii) 8 ms^{-2} down the slope

Work done, kinetic and potential energy

1. (a) 3·92 J
(b) 8·9 ms^{-1} (8·85 ms^{-1})
(c) 6·3 ms^{-1} up(6·26 ms^{-1})
2. (a) 1080 J
(b) 120 J
3. (a) 9·8 J
(b) (i) 3·1 ms^{-1}
4. (a) 490 N
(b) $9·8 \times 10^3$ J
(c) 3·9 s
5. $3·0 \times 10^5$ W
6. (a) 330 N
(b) $2·0 \times 10^{-3}$ s

Collisions and explosions

1. (a) 20 kg ms^{-1} to the right
(b) 500 kg ms^{-1} downwards
(c) 9 kg ms^{-1} to the left
2. (a) 0·75 ms^{-1} in the direction in which the first trolley was moving
3. 2·4 ms^{-1}
4. 3·0 kg
5. (a) 2·7 ms^{-1}
(b) 0·19 J
6. 8·6 ms^{-1} in the original direction of travel
7. (a) 23 ms^{-1}
8. 8·7 ms^{-1} (8·67 ms^{-1})
9. 0·6 ms^{-1} in the original direction of travel of the 1·2 kg trolley
10. 16·7 ms^{-1} in the opposite direction to the first piece
11. 4 kg
12. 0·8 ms^{-1} in the opposite direction to the velocity of the man
13. 1·3 ms^{-1} in the opposite direction to the velocity of the first trolley
14. 1·58 ms^{-1}
15. 100 N
16. $3·0 \times 10^{-2}$ s
17. 2·67 ms^{-1}
18 (a) + 0·39 kg ms^{-1} (0.386 kg ms^{-1})if you have chosen upwards directions to be positive;
-0·39 kg ms^{-1} (-0.386 kg ms^{-1})if you have chosen downwards directions to be positive
(b) + 0·39 N s (0.386 N s) if you have chosen upwards
-0·39 N s (-0.386 N s) if you have chosen downwards directions to be positive
(c) 15·6 N upwards (15.4 N if you use 0.386)
(d) 15·6 N upwards (15.4 N if you use 0.386)
(e) 16·6 N upwards (16.4 N if you use 0.386)

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