FLOREAT IUVENTUS

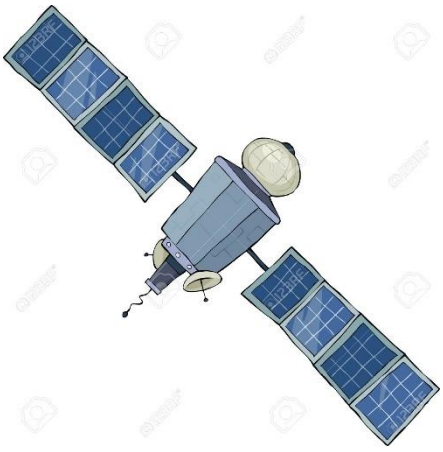
NATIONAL 5 PHYSICS

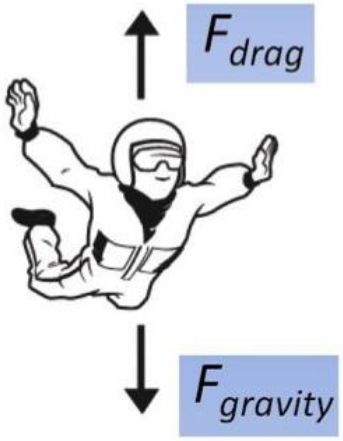
UNIT 3 —

DYNAMICS & SPACE

WRITTEN QUESTIONS

2007—2019





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Kinematics

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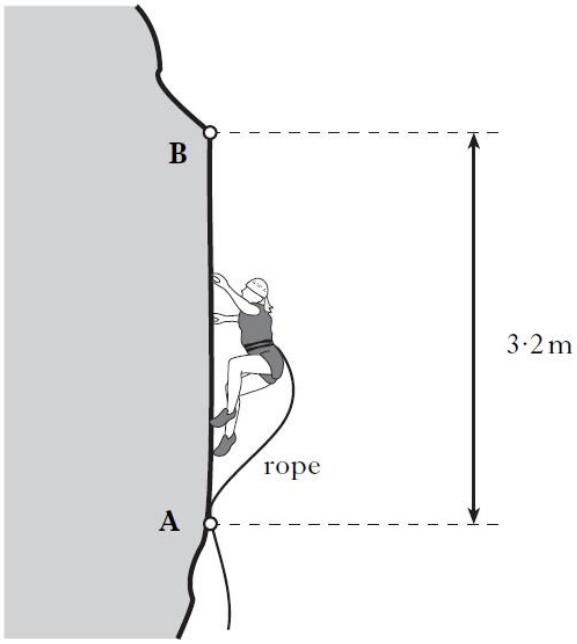
Kinematics

2007 Q 21 a(i)

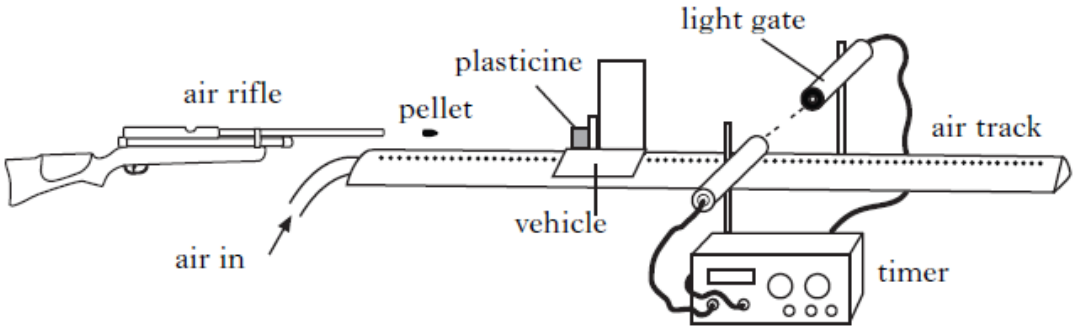
21. A climber of mass 60 kg is attached by a rope to point A on a rock face. She climbs up to point B in 20 seconds. Point B is 3·2 m vertically above point A.



(*a*) (i) Calculate the average speed of the climber between A and B. **2**

2009 Q23 a

23. The following apparatus is used to determine the speed of a pellet as it leaves an air rifle. The air rifle fires a pellet into the plasticine, causing the vehicle to move.



(*a*) Describe how the apparatus is used to determine the speed of the vehicle.

Your description must include:

- the measurements made
- any necessary calculations. **2**

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2007 Q 22

22. A cyclist rides along a road.

(*a*) Describe a method by which the average speed of the cyclist could be measured.

Your description must include the following

- Measurements made
- Equipment used
- Any necessary calculations. **3**

(*b*) The cyclist approaches traffic lights at a speed of 8 m/s. He sees the traffic lights turn red and 3 s later he applies the brakes. He comes to rest in a further 2·5 s.

(i) Calculate the acceleration of the cyclist whilst braking. **2**

(ii) Sketch a speed time graph showing the motion of the cyclist from the moment the lights turn red until he stops at the traffic lights. Numerical values **must** be included. **2**

(iii) Calculate the total distance the cyclist travels from the moment the lights turn red until he stops at the traffic lights. **2**

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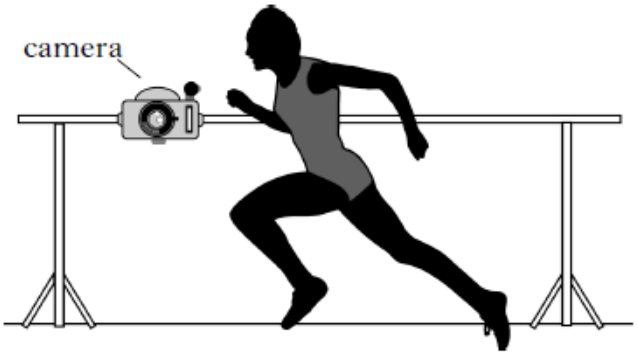
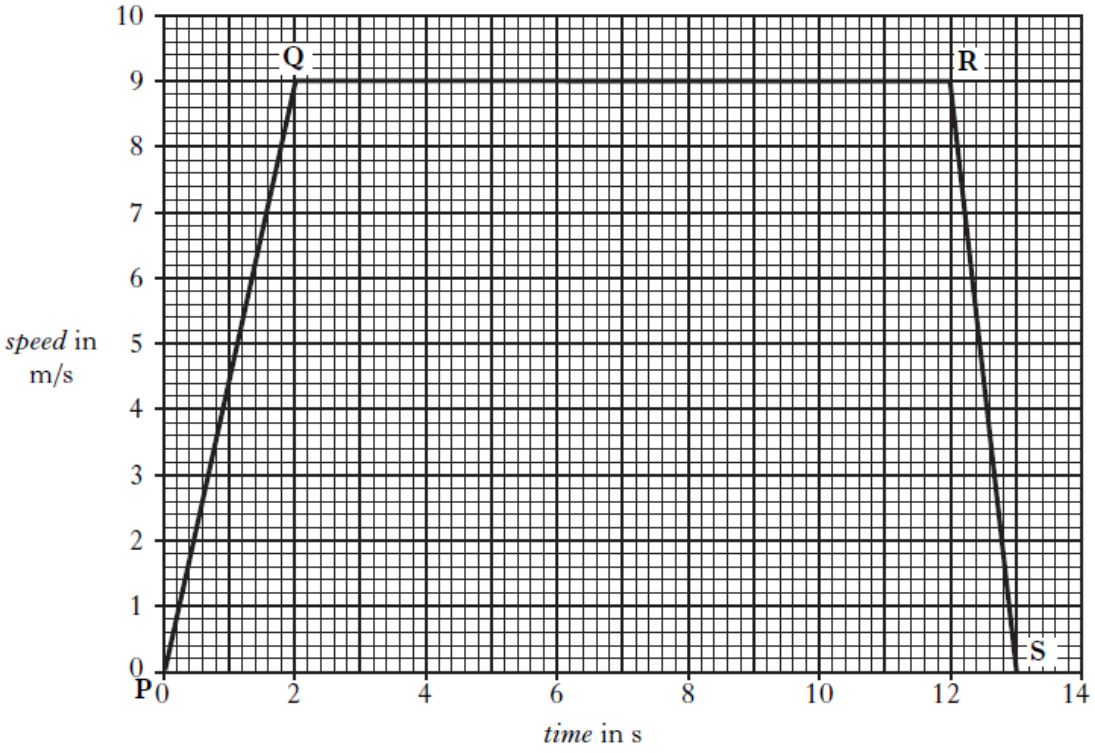
21. Athletes in a race are recorded by a TV camera which runs on rails beside the track.





The graph shows the speed of the camera during the race.

(*a*) Calculate the acceleration of the camera between **P** and **Q**. **2**

(*b*) The mass of the camera is 15 kg.

Calculate the unbalanced force needed to produce the acceleration between **P** and **Q**. **2**

(*c*) How far does the camera travel in the 13 s? **2**

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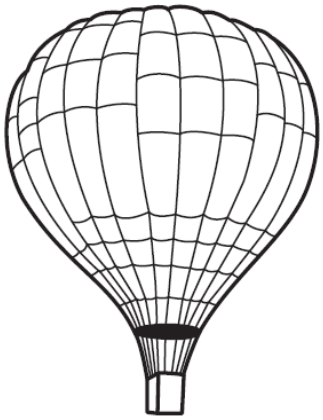
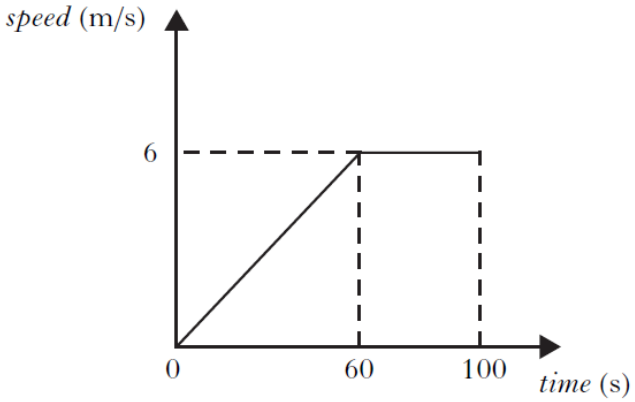
2010 Q 21 a,b,c

21. A balloon of mass 400 kg rises vertically from the ground.



The graph shows how the vertical speed of the balloon changes during the first 100 s of its upward flight.



(*a*) Calculate the acceleration of the balloon during the first 60 s. **2**

(*b*) Calculate the distance travelled by the balloon in 100 s. **2**

(*c*) Calculate the average speed of the balloon during the first 100 s. **2**

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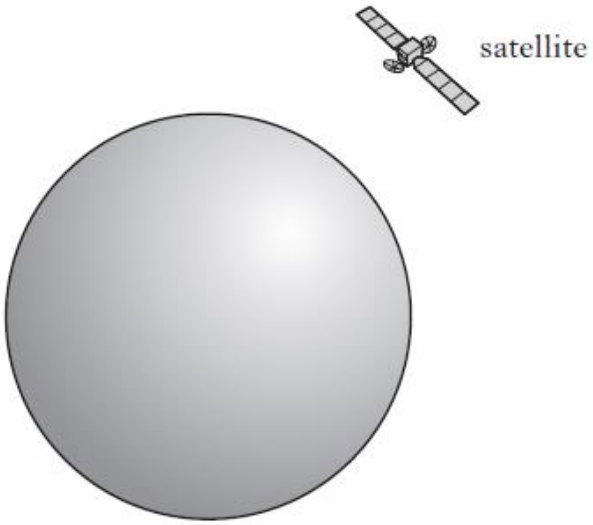
2011 Q 22 a

22. A satellite moves in a circular orbit around a planet. The satellite travels at a constant speed whilst accelerating.



(*a*) (i) Define the term *acceleration*. **1**

(ii) Explain how the satellite can be accelerating when it is travelling at a constant speed. **1**

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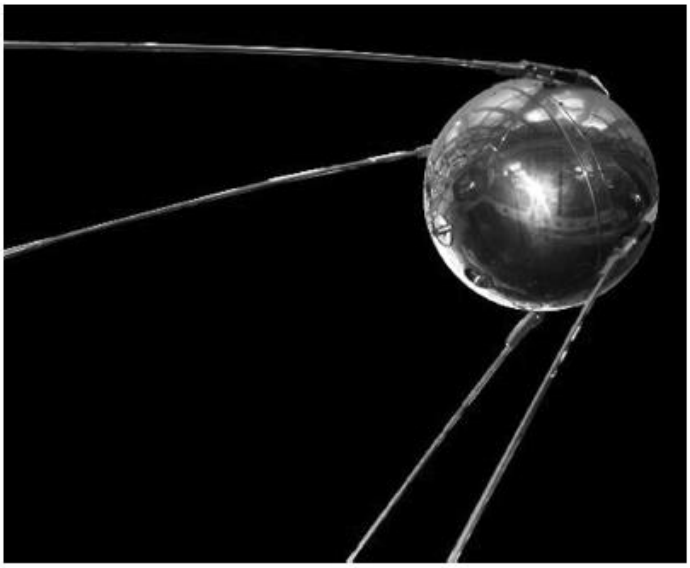
2012 Q 21 a

21. Sputnik 1, the first man-made satellite, was launched in 1957. It orbited the Earth at a speed of 8300 m/s and had a mass of 84 kg.



(*a*) (i) Sputnik 1 orbited Earth in 100 minutes.

Calculate the distance it travelled in this time. **2**

(ii) Although Sputnik 1 travelled at a constant speed in a circular orbit, it accelerated continuously.

Explain this statement. **2**

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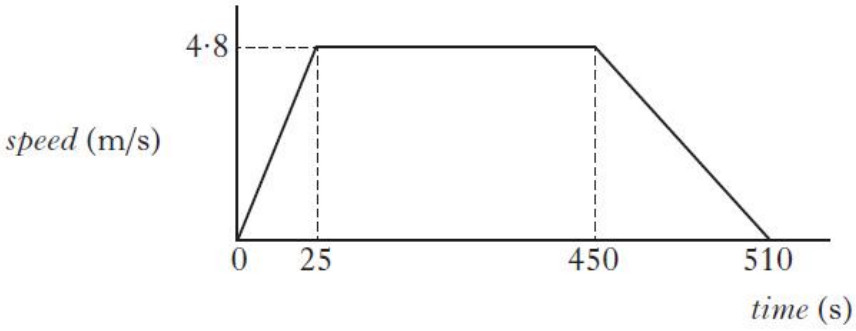
2014 Q 21

21. In a rowing event a boat moves off in a straight line.

A graph for the boat's motion is shown.



(*a*) (i) Calculate the acceleration of the boat during the first 25 s. **2**

(ii) Describe the motion of the boat between 25 s and 450 s. **1**

(iii) Draw a diagram showing the horizontal forces acting on the boat between 25 s and 450 s.

You **must** name these forces and show their directions. **2**

(*b*) The boat comes to rest after 510 s.

(i) Calculate the total distance travelled by the boat. **2**

(ii) Calculate the average speed of the boat. **2**

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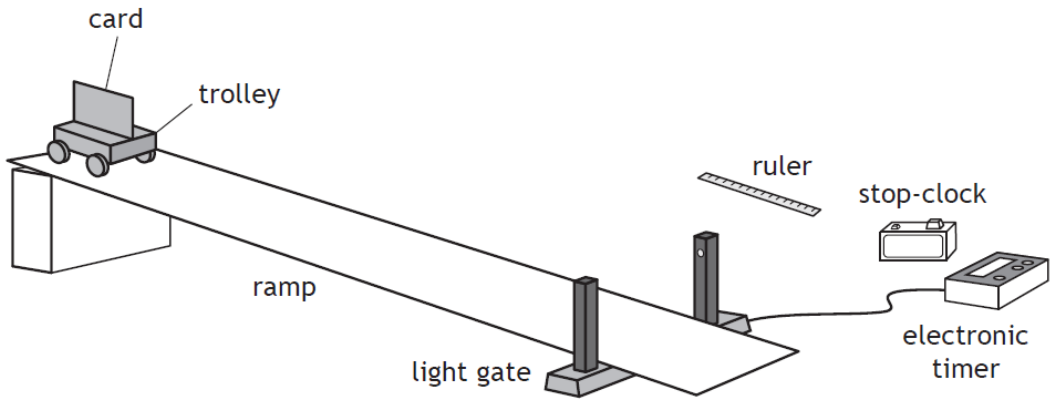
8. A student is investigating the motion of a trolley down a ramp.

MARKS

(a) The student uses the apparatus shown to carry out an experiment to determine the acceleration of a trolley as it rolls down a ramp.

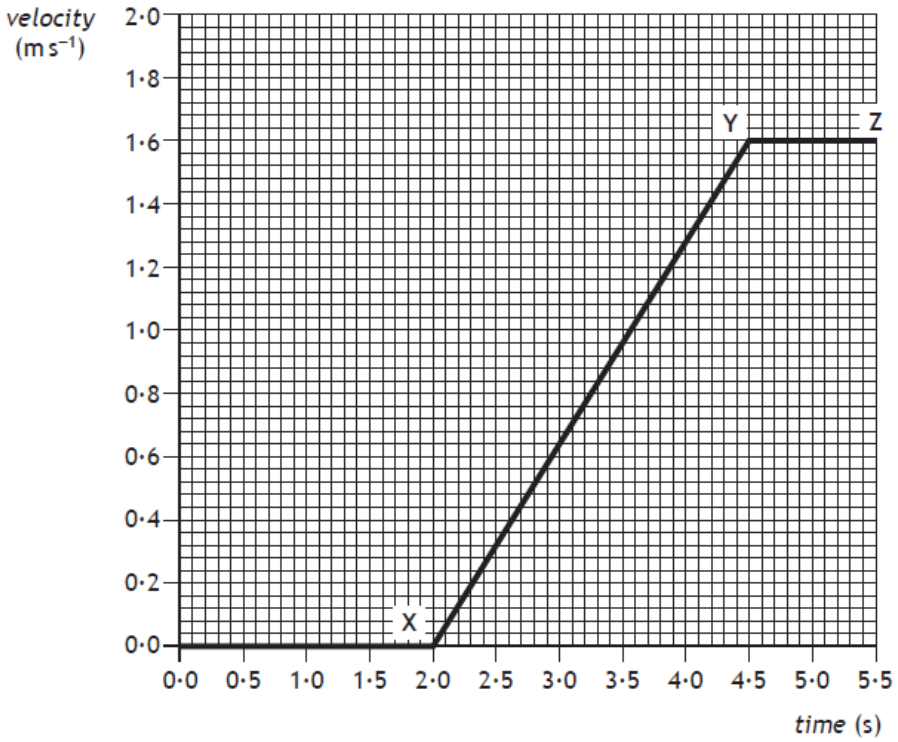
The trolley is released from rest at the top of the ramp.



(i) State the measurements the student must make to calculate the acceleration of the trolley. **3**

(ii) Suggest one reason why the acceleration calculated from these measurements might not be accurate. **1**

(b) In a second experiment, the student uses a motion sensor and computer to produce the following velocity-time graph for the trolley



Calculate the acceleration of this trolley between X and Y. **3**

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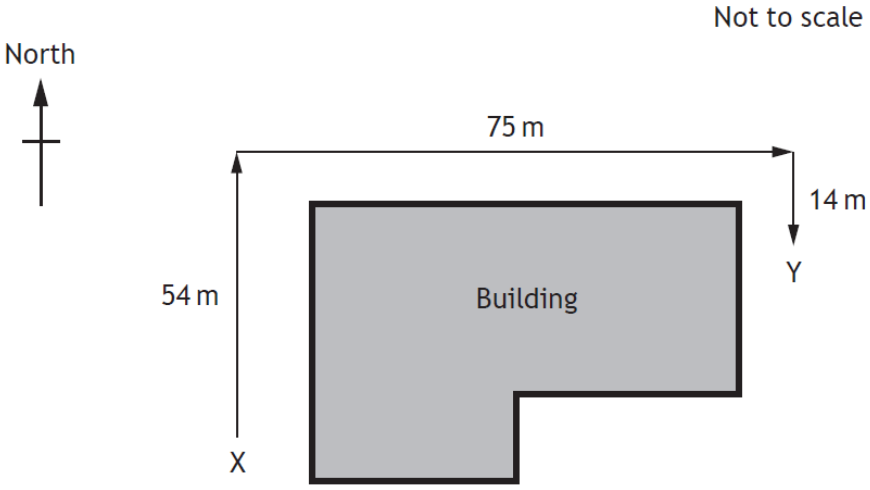
9. A student walks around a building from point X to point Y.



(a) By scale diagram, or otherwise, determine:

(i) the magnitude of the displacement of the student from point X to point Y; **2**

(ii) the direction of displacement of the student from point X to point Y. **2**

(b) The student takes 68 s to travel from point X to point Y.

(i) Determine the average velocity of the student from point X to point Y. **3**

(ii) The student states that their average speed between point X and point Y is greater than the magnitude of their average velocity between point X and point Y.

Explain why the student is correct. **2**

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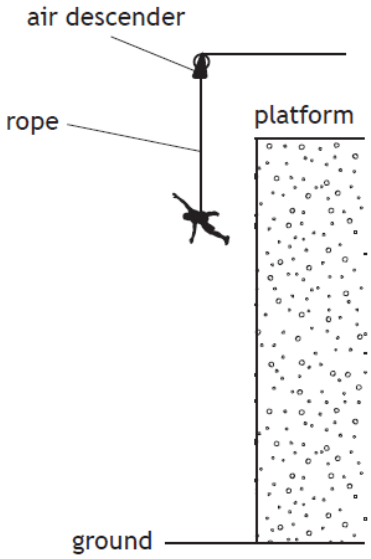
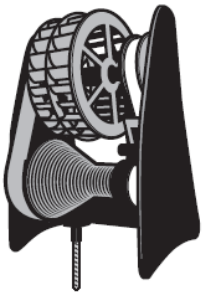
2016 Q 10 a,b

10. An air descender is a machine that controls the rate at which a climber drops from a platform at the top of a climbing wall.

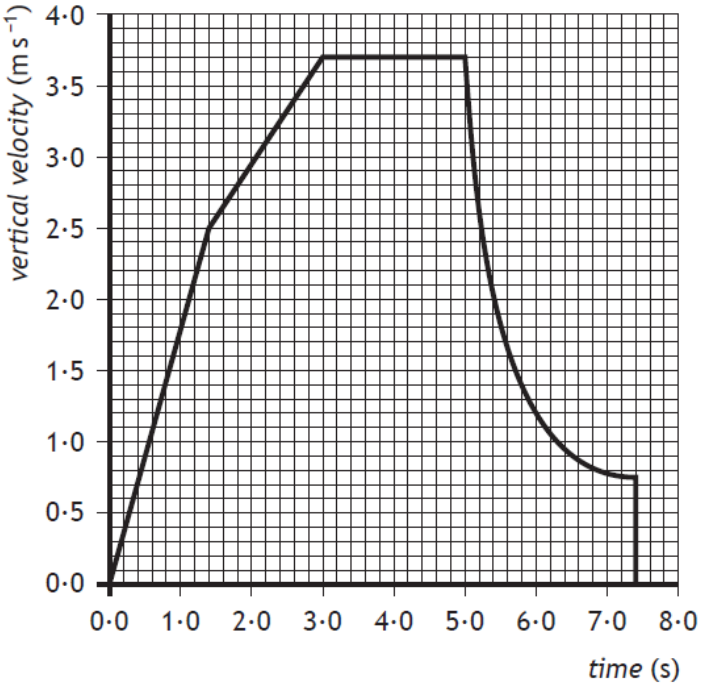
A climber, attached to the air descender by a rope, steps off the platform and drops towards the ground and lands safely.



air descender



The graph shows how the vertical velocity of the climber varies with time from the instant the climber leaves the platform until landing.



(a) Calculate the acceleration of the climber during the first 1·4 s of the drop. 3

(b) Calculate the distance the climber drops during the first 3·0 s. 3

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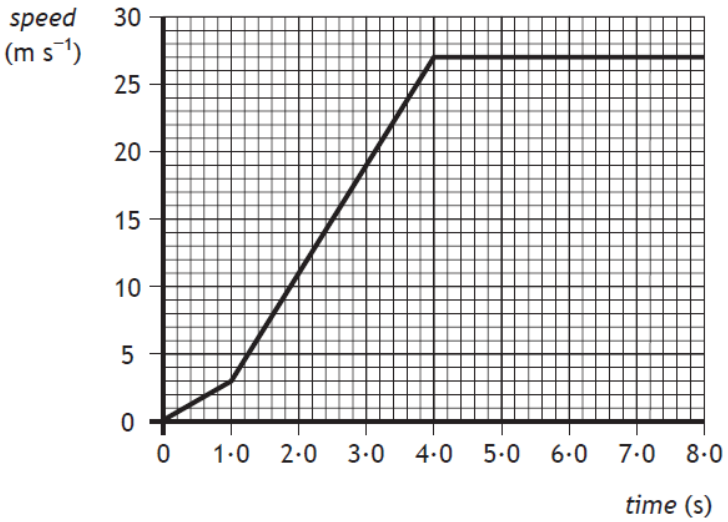
2017 Q 8

8. In speedway, motorbikes are raced anticlockwise round an oval track.

A race consists of four laps of a 380 m track.

(a) State the displacement of a motorbike from the start line to the finish line for a complete race. 1

(b) The speed-time graph of a motorbike for the first 8·0 s of a race is shown.



(i) Calculate the distance travelled by the motorbike in the first 4·0 s of the race. 3

(ii) Determine the **greatest** acceleration of the motorbike during the first 8·0 s of the race. 3

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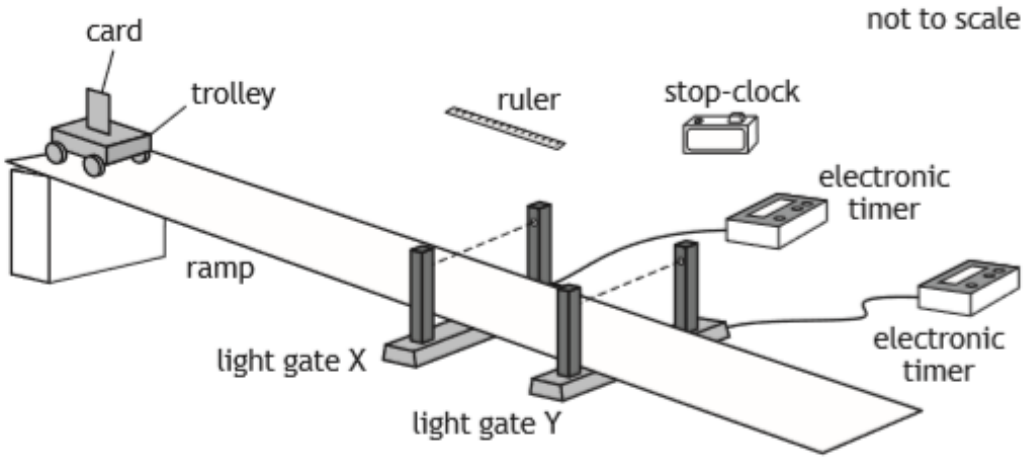
(c) The winner of the race completes all four laps in a time of 79 s.

Calculate the average speed of the winner. 3

2018 Q 2 a

2. Two students are investigating the acceleration of a trolley down a ramp.

(a) The first student uses the apparatus shown to determine the acceleration of the trolley.



Some of the measurements made by the student are shown.

Time for the card to pass through light gate Y	0·098 s
Distance between light gate X and light gate Y	0·22 m
Length of the card	0·045 m
Time for trolley to pass between light gate X and light gate Y	0·56 s

The student determines the instantaneous speed of the trolley at light gate X to be 0·32 m s^{-1}.

(i) State the **additional** measurement made by the student to determine the instantaneous speed of the trolley at light gate X. **1**

(ii) Show that the instantaneous speed of the trolley at light gate Y is 0·46 m s^{-1}. **2**

(iii) Determine the acceleration of the trolley down the ramp. **3**

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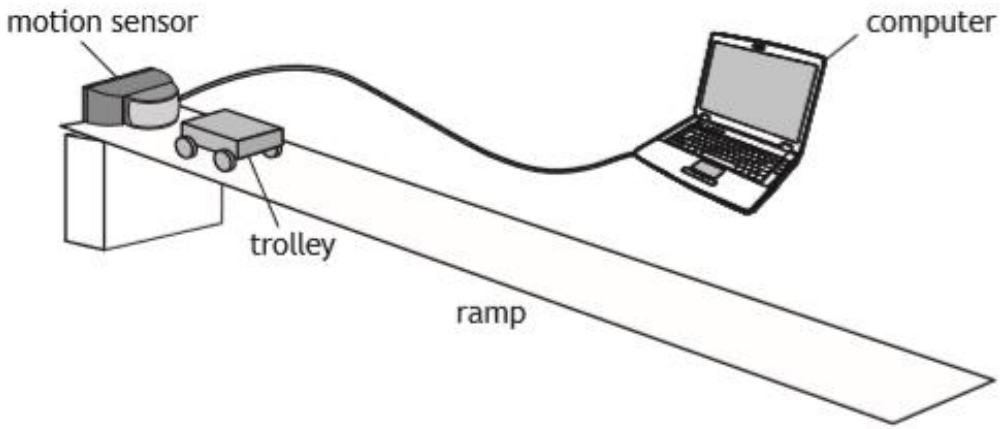
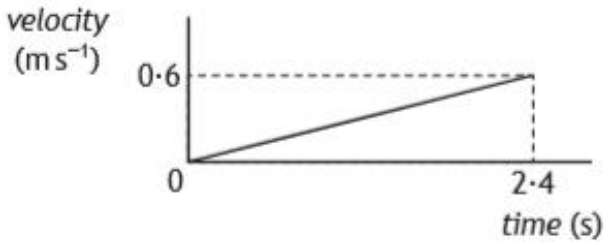
2018 Q 2 b

(b) The second student uses a motion sensor and a computer to determine the acceleration of the trolley.



The student releases the trolley. The computer displays the velocity-time graph for the motion of the trolley as it rolls down the ramp, as shown.



Determine the distance travelled by the trolley in the first 2·4 s after its release. **3**

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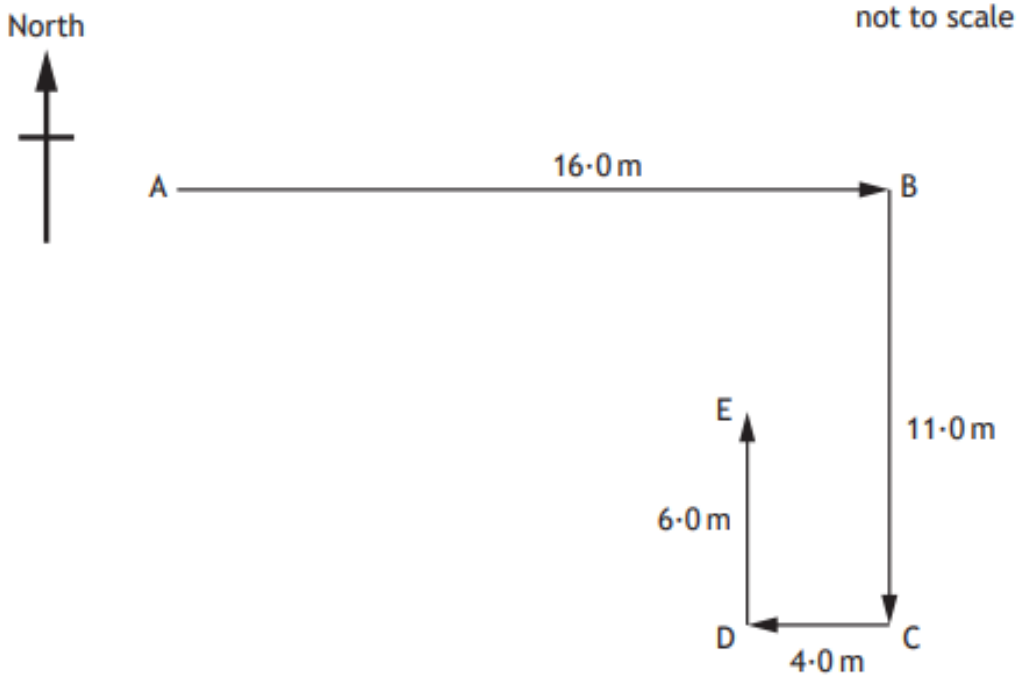
2019 Q 1 a,b,c

1. A quadcopter is a drone with four rotating blades.

(a) In a race, the quadcopter is flown along a route from point A to point E.



(i) By scale drawing or otherwise, determine the magnitude of the resultant displacement of the quadcopter from point A to point E. **2**

(ii) By scale drawing or otherwise, determine the direction of the resultant displacement of the quadcopter from point A to point E. **2**

(b) The quadcopter takes 32·5 s to complete the race.

Determine the average velocity of the quadcopter over the whole race. **3**

(c) A second quadcopter completes the race at an average speed of $1{\cdot}25\ \text{m s}^{-1}$.

The distance travelled by this quadcopter during the race is 37·0 m.

Determine the **difference** in the times taken by the quadcopters to complete the race. **3**

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Forces

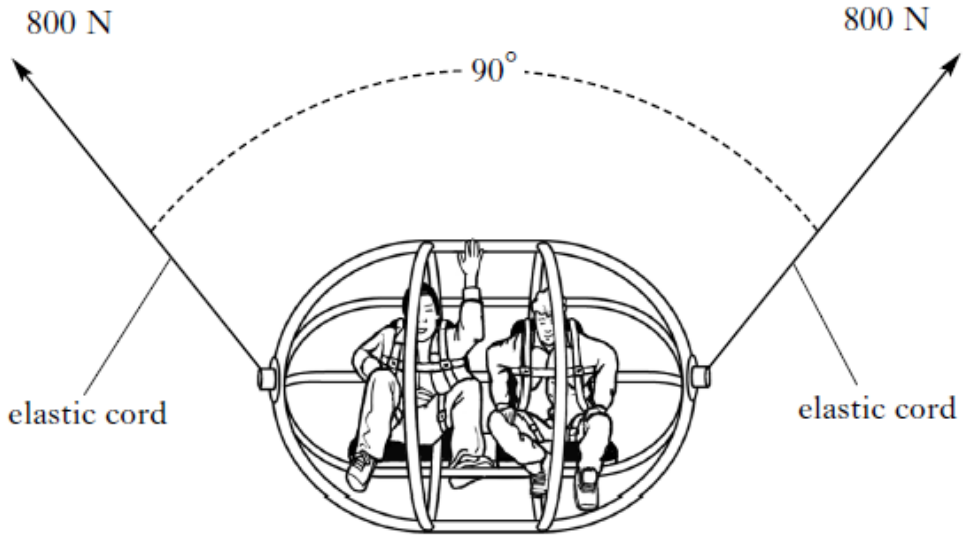
2007 Q 27 b

(*b*) As a raindrop falls it reaches a steady speed.

Using Newton's laws of motion, explain why it falls at a steady speed. **2**

2008 Q 22

22. A fairground ride uses a giant catapult to launch people upwards using elastic cords.



(*a*) Each cord applies a force of 800 N and the cords are at 90° as shown. Using a scale diagram, or otherwise, find the size of the resultant of these two forces. **2**

(*b*) The cage is now pulled further down before release. The cords provide an upward resultant force of 2700 N. The cage and its occupants have a total mass of 180 kg.

(i) Calculate the weight of the cage and occupants. **2**

(ii) Calculate the acceleration of the cage and occupants when released. **3**

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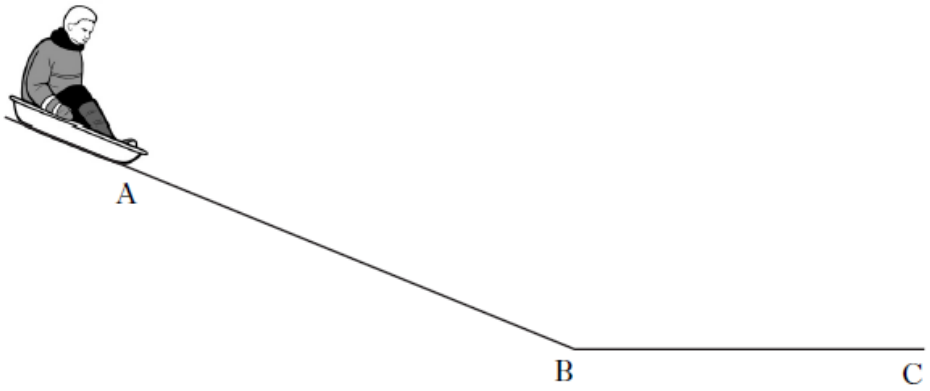
2009 Q 22

22. A child sledges down a hill.



The sledge and child are released from rest at point A. They reach a speed of 3 m/s at point B.

(*a*) The sledge and child take 5 s to reach point B.

Calculate the acceleration. **2**

(*b*) The sledge and child have a combined mass of 40 kg.

Calculate the unbalanced force acting on them. **2**

(*c*) After the sledge and child pass point B, they slow down, coming to a halt at point C.

Explain this motion in terms of forces. **2**

2010 Q 22 b

(*b*) Another water droplet within the cloud is falling with a constant speed. Draw a diagram showing the forces acting on this droplet.

Name these forces and show their directions. **2**

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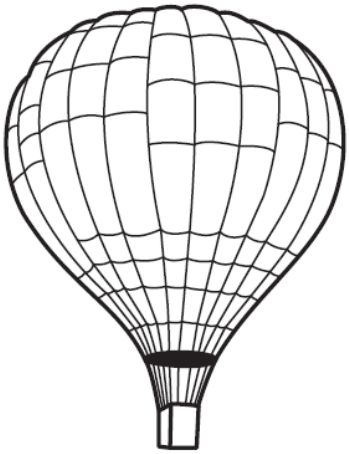
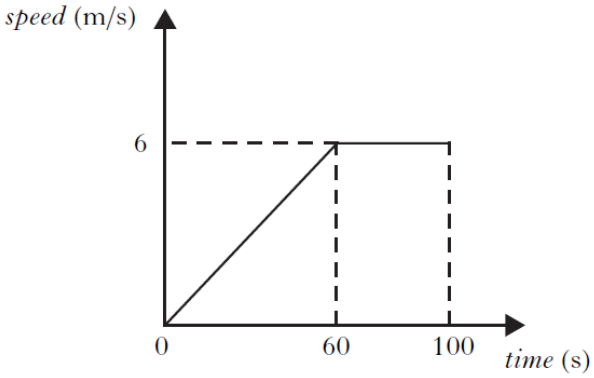
2010 Q 21 d,e

21. A balloon of mass 400 kg rises vertically from the ground.



The graph shows how the vertical speed of the balloon changes during the first 100 s of its upward flight.

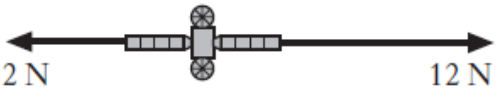


(*d*) Calculate the weight of the balloon. **2**

(*e*) Calculate the total upward force acting on the balloon during the first 60 s of its flight. **3**

2011 Q 22 b

(*b*) At one particular point in its orbit the satellite fires two rockets. The forces exerted on the satellite by these rockets are shown on the diagram.



The satellite has a mass of 50 kg. Calculate the resultant acceleration due to these forces. **3**

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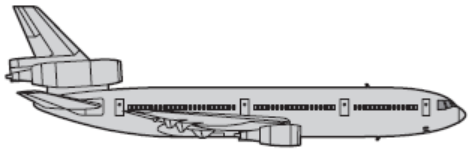
2011 Q 23 a,b,c

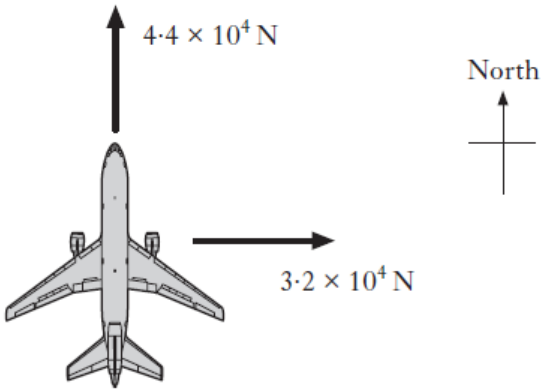
23. An aircraft is flying horizontally at a constant speed.



(*a*) The aircraft and passengers have a total mass of 50 000 kg. Calculate the total weight. **2**

(*b*) State the magnitude of the upward force acting on the aircraft. **1**

(*c*) During the flight, the aircraft's engines produce a force of $4{\cdot}4 \times 10^4$ N due North. The aircraft encounters a crosswind, blowing from west to east, which exerts a force of $3{\cdot}2 \times 10^4$ N.



Calculate the resultant force on the aircraft. **3**

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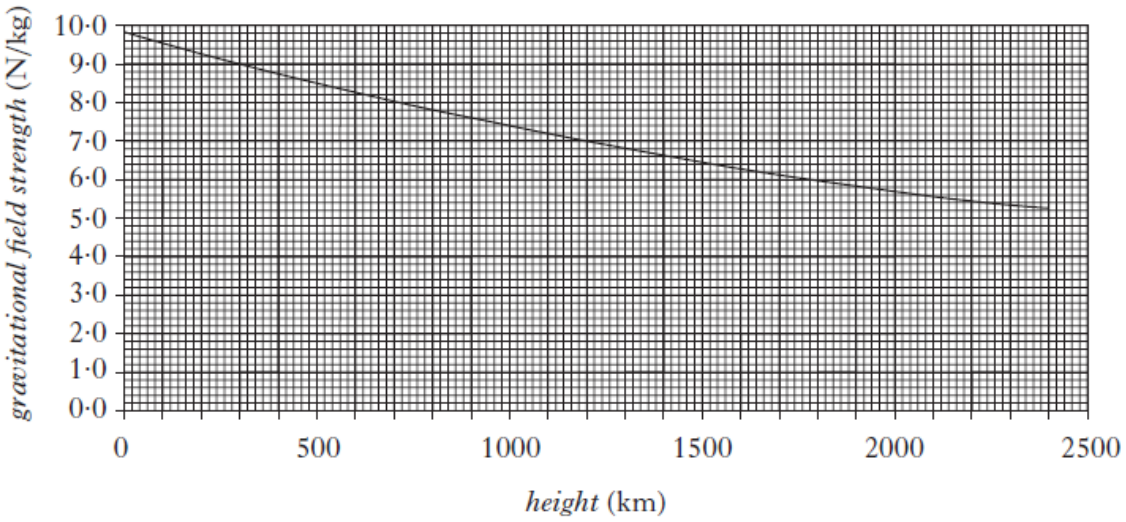
2012 Q 21 c

(*c*) The graph shows how gravitational field strength varies with height above the surface of the Earth.



(i) Define the term **gravitational field strength**. **1**

(ii) What is the value of the gravitational field strength at a height of 800 km? **1**

(iii) Calculate the weight of Sputnik 1 at this height. **2**

2013 Q 21

21. A plane of mass 750 kg is at rest on a runway. The engine applies a force of 4·50 kN.

(*a*) Calculate the magnitude of the acceleration of the plane assuming there are no other forces acting on the plane at this point. **2**

(*b*) The required speed for take-off is 54 m/s.

Calculate the time it takes to reach this speed assuming the acceleration is constant. **2**

(*c*) In practice the acceleration is not constant. Give a reason for this. **1**

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22. An arrow is fired at a target.

not to scale

The average forward force on the arrow is 500 N. The average frictional force acting on the arrow is 15 N. The arrow has a mass of 0·20 kg.

(*a*) Calculate the average acceleration of the arrow. **3**

(*b*) The arrow hits the target and accelerates at $-3600\ m/s^2$. It comes to rest in 12 ms.

Calculate the velocity of the arrow just before it hits the target. **2**

(*c*) A second arrow of mass of 0·10 kg is now fired at the target with the same average forward force and the same average frictional force.

Is the time taken for the second arrow longer, shorter or the same as the time taken for the first arrow to reach the target?

You **must** explain your answer. **2**

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2014 Q 11 a,b

11. A helicopter is used to take tourists on sightseeing flights.

Information about the helicopter is shown in the table.

weight of empty helicopter	13 500 N
maximum take-off weight	24 000 N
cruising speed	67 m s^{-1}
maximum speed	80 m s^{-1}
maximum range	610 km

(a) The pilot and passengers are weighed before they board the helicopter.

Explain the reason for this. 1

(b) Six passengers and the pilot with a combined weight of 6125 N board the helicopter.

Determine the minimum upward force required by the helicopter at take-off. 1

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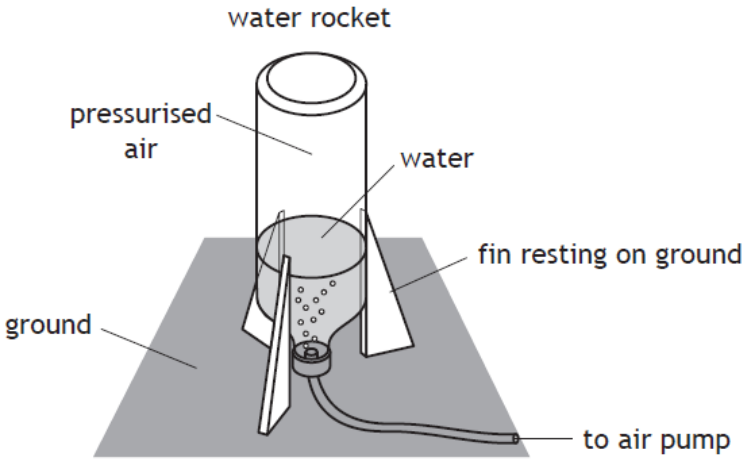
2014 Q 12 a,c,d

12. A student is investigating the motion of water rockets. The water rocket is made from an upturned plastic bottle containing some water. Air is pumped into the bottle. When the pressure of the air is great enough the plastic bottle is launched upwards.



The mass of the rocket before launch is 0·94 kg.

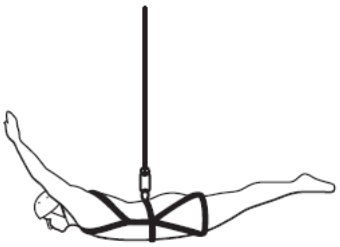
(a) Calculate the weight of the water rocket. 3

(c) Use Newton's Third Law to explain how the rocket launches. 1

(d) At launch, the initial upward thrust on the rocket is 370 N.
Calculate the initial acceleration of the rocket. 4

2016 Q 10 c

(c) During part of the drop the forces on the climber are balanced.
On the diagram below show all the forces acting vertically on the climber during this part of the drop.
You must name these forces **and** show their directions. 3



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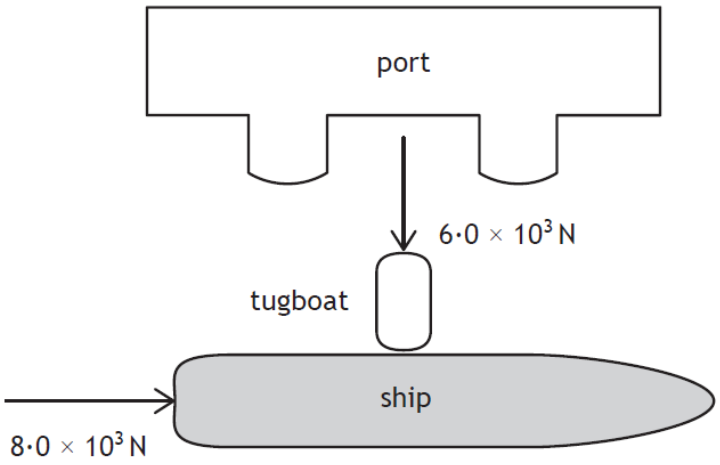
7. A ship of mass $5{\cdot}0 \times 10^6$ kg leaves a port. Its engine produces a forward force of $8{\cdot}0 \times 10^3$ N. A tugboat pushes against one side of the ship as shown. The tugboat applies a pushing force of $6{\cdot}0 \times 10^3$ N.

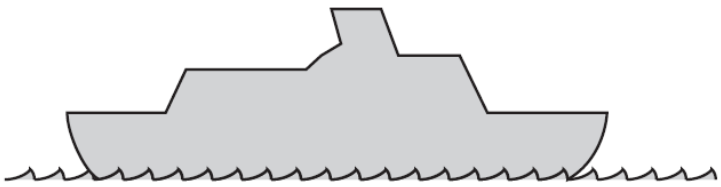


(a) (i) By scale drawing, or otherwise, determine the size of the resultant force acting on the ship. **2**

(ii) Determine the direction of the resultant force relative to the $8{\cdot}0 \times 10^3$ N force. **2**

(iii) Calculate the size of the acceleration of the ship. **3**

(b) Out in the open sea the ship comes to rest.



Explain, with the aid of a labelled diagram, why the ship floats. **3**

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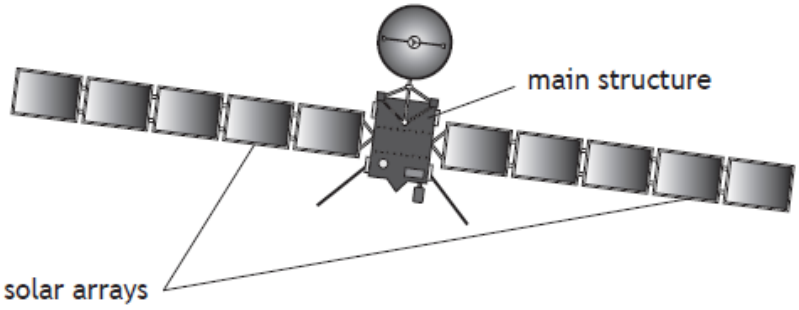
2016 Q 12 a,c

12. On 12th November 2014, on a mission known as Rosetta, the European Space Agency successfully landed a probe on the surface of a comet.



The main structure of the Rosetta spacecraft consists of an orbiter, a lander and propellant.

Rosetta spacecraft data		
Launch mass	Orbiter Lander Propellant	$1{\cdot}23 \times 10^3$ kg $0{\cdot}10 \times 10^3$ kg $1{\cdot}67 \times 10^3$ kg
	Total	$3{\cdot}00 \times 10^3$ kg
Energy source	Solar array output	850 W at 3·4 AU 395 W at 5·25 AU
Trajectory control	24 Thrusters	10 N of force each

(a) Calculate the total weight of the spacecraft on Earth. **3**

(c) At a point on its journey between Earth and the comet, the spacecraft was travelling at a constant velocity.

(i) The spacecraft switched on four of its thrusters to accelerate it in the direction of travel.

The four thrusters exerted a force on the spacecraft in the same direction.

Determine the total force produced by these thrusters. **1**

(ii) At this point, the spacecraft had used $1{\cdot}00 \times 10^3$ kg of propellant.

Calculate the acceleration of the spacecraft. **4**

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2017 Q 9

9. A weightlifter applies an upwards force of 1176 N to a barbell to hold it in a stationary position as shown.

(a) Describe how the upward force exerted by the weightlifter on the barbell compares to the weight of the barbell. 1

(b) Calculate the mass of the barbell. 3

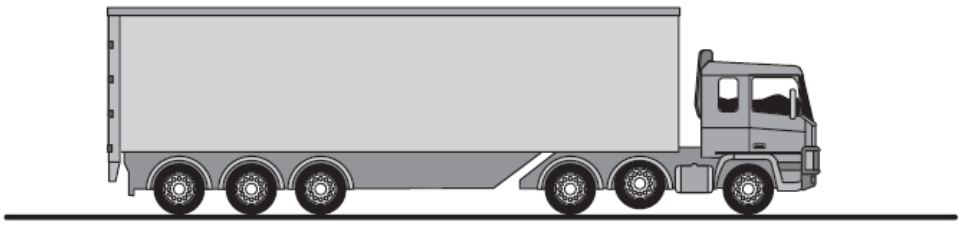
(c) The weightlifter increases the upward force on the barbell to 1344 N in order to lift the barbell above their head.

Calculate the initial acceleration of the barbell. 4

2017 Q 10

10. An articulated lorry has six pairs of wheels.

One pair of wheels can be raised off the ground.



Using your knowledge of physics, comment on situations in which the wheels may be raised or lowered. 3

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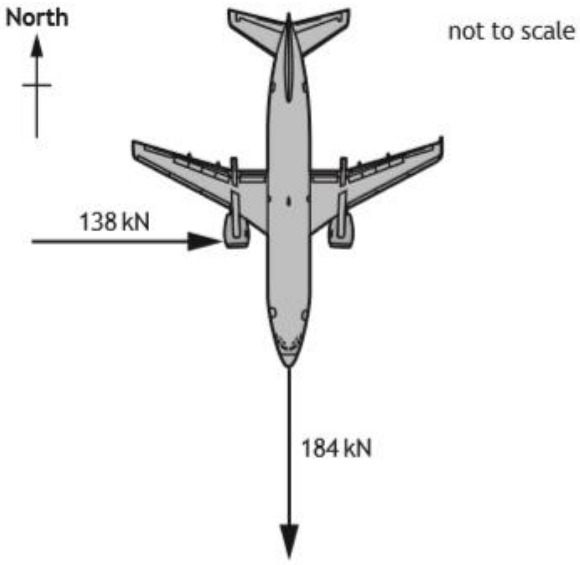
2018 Q 1 a

1. A passenger aircraft is flying horizontally.

(a) At one point during the flight the aircraft engines produce an unbalanced force of 184 kN due south (180).

At this point the aircraft also experiences a crosswind. The force of the crosswind on the aircraft is 138 kN due east (090).



(i) By scale diagram, or otherwise, determine:

(A) the magnitude of the resultant force acting on the aircraft; **2**

(B) the direction of the resultant force acting on the aircraft. **2**

(ii) The mass of the aircraft is $6{\cdot}8 \times 10^4$ kg.

Calculate the magnitude of the acceleration of the aircraft at this point. **3**

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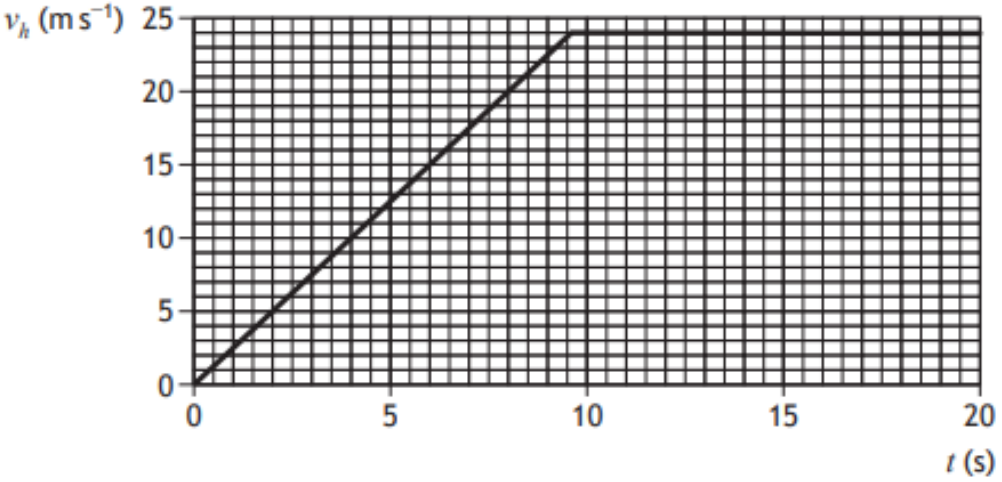
2019 Q 2 a

2. A glider is accelerated from rest by a cable attached to a winch.

The graph shows the horizontal velocity v_h of the glider for the first 20 s of its motion.



(a) The glider is accelerated by a constant unbalanced force of 925 N.

(i) Show that the initial acceleration of the glider is 2·5 m s^{-2}. **2**

(ii) Calculate the mass of the glider. **3**

(iii) At 2·0 s the cable pulls the glider with a force of 1200 N.

(A) Determine the size of the frictional forces acting on the glider at this time. **1**

(B) Suggest one design feature of the glider that reduces the frictional forces acting on it. **1**

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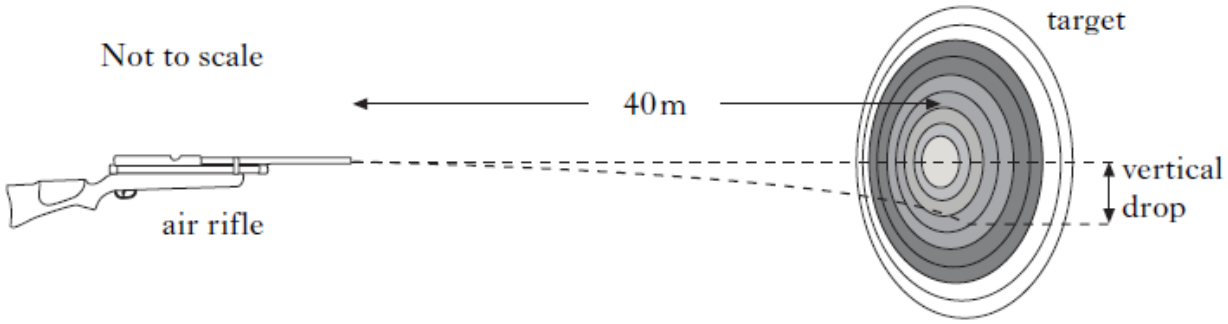
Projectiles

2009 Q 23 c

(*c*) At a firing range a pellet is fired horizontally at a target 40 m away. It takes 0·20 s to reach the target.

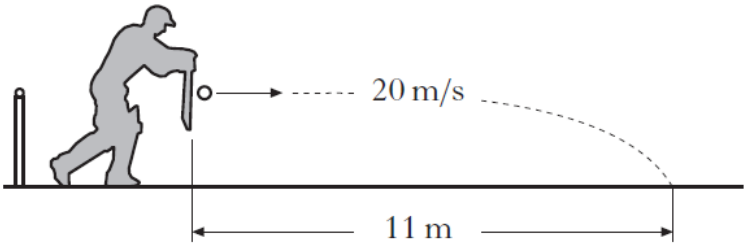


(i) Calculate the **vertical** velocity of the pellet on reaching the target. **2**

(ii) Calculate the vertical drop. **2**

2011 Q 21

21. A cricketer strikes a ball. The ball leaves the bat horizontally at 20 m/s. It hits the ground at a distance of 11 m from the point where it was struck.



Assume that air resistance is negligible.

(*a*) Calculate the time of flight of the ball. **2**

(*b*) Calculate the vertical speed of the ball as it reaches the ground. **2**

(*c*) Sketch a graph of vertical speed against time for the ball. Numerical values are required on both axes. **2**

(*d*) Calculate the vertical distance travelled by the ball during its flight. **2**

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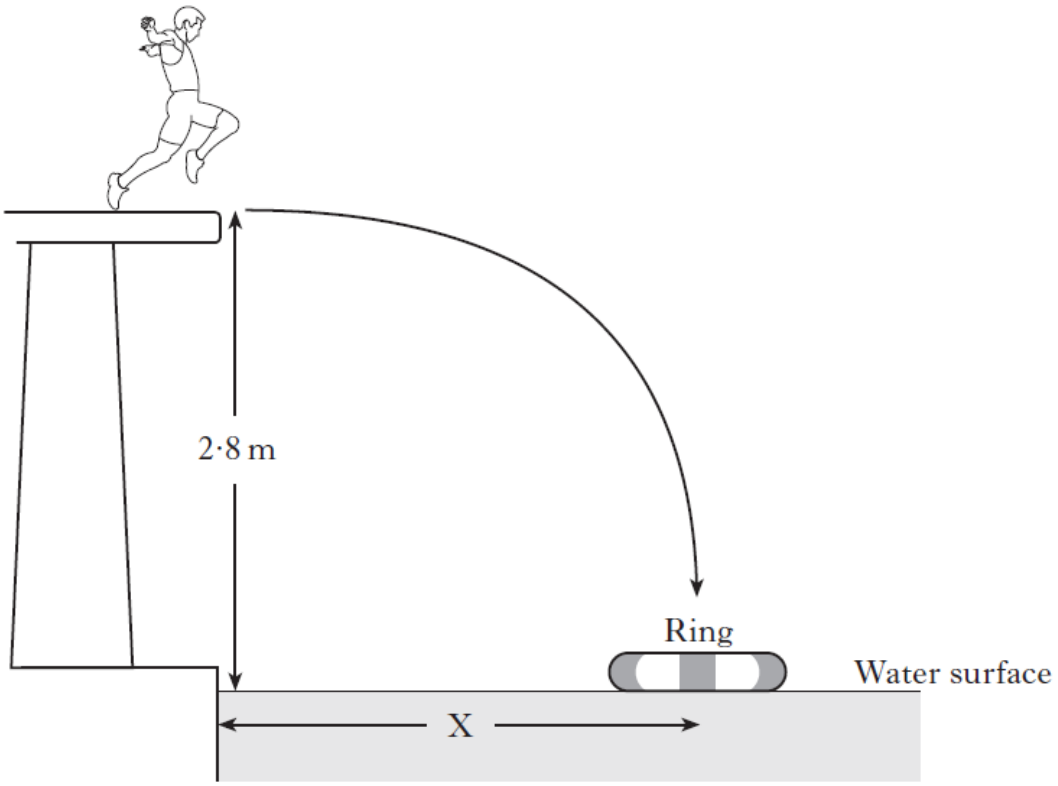
2013 Q 23

23. In a TV game show contestants are challenged to run off a horizontal platform and land in a rubber ring floating in a swimming pool.

The platform is 2·8 m above the water surface.



(*a*) A contestant has a mass of 60 kg.

He runs off the platform with a horizontal velocity of 2 m/s. He takes 0·75 s to reach the water surface in the centre of the ring.

(i) Calculate the horizontal distance X from the poolside to the centre of the ring. **2**

(ii) Calculate the vertical velocity of the contestant as he reaches the water surface. **2**

(*b*) Another contestant has a mass of 80 kg.

Will she need to run faster, slower or at the same horizontal speed as the first contestant to land in the ring?

You **must** explain your answer. **2**

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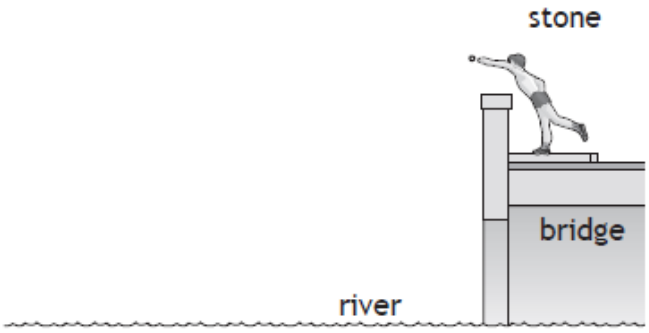
2015 Q 9

9. A child throws a stone horizontally from a bridge into a river. MARKS



(a) On the above diagram sketch the path taken by the stone between leaving the child's hand and hitting the water. 1

(b) The stone reaches the water 0·80 s after it was released.

(i) Calculate the vertical velocity of the stone as it reaches the water.

The effects of air resistance can be ignored. 3

(ii) Determine the height above the water at which the stone was released. 4

(c) The child now drops a similar stone vertically from the same height into the river.

State how the time taken for this stone to reach the water compares with the time taken for the stone in (b). 1

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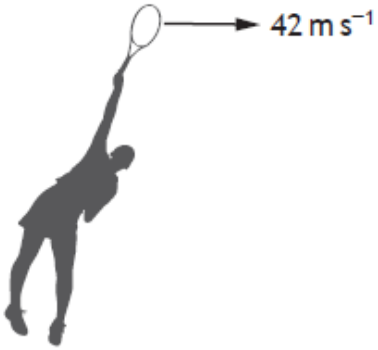
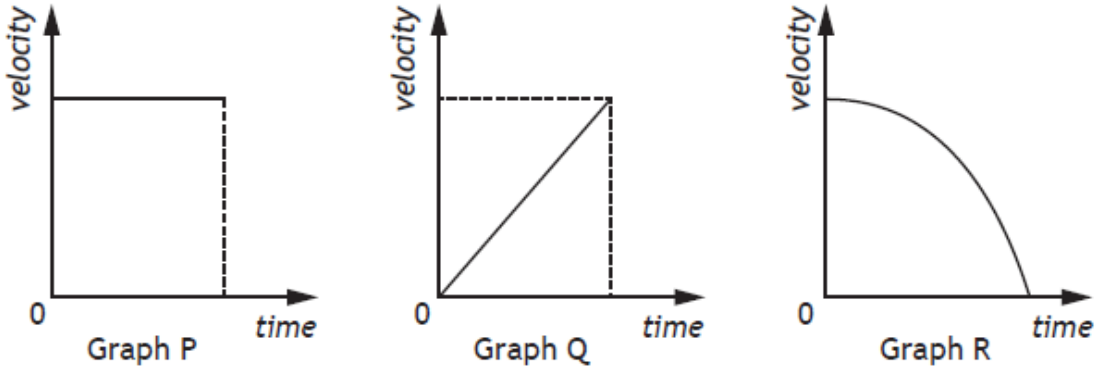
2017 Q 11 a,b

11. A tennis player serves a tennis ball horizontally at a velocity of 42 ms^{-1}.



The effects of air resistance are negligible.

(a) State which of the following graphs P, Q or R shows the vertical velocity of the ball after it leaves the player's racquet. 1



Graph: _____

(b) In a second serve the player hits the ball horizontally with a smaller velocity from the same height.

State whether the time taken for the ball to reach the ground is less than, equal to, or greater than the time taken in the first serve.

Justify your answer. 2

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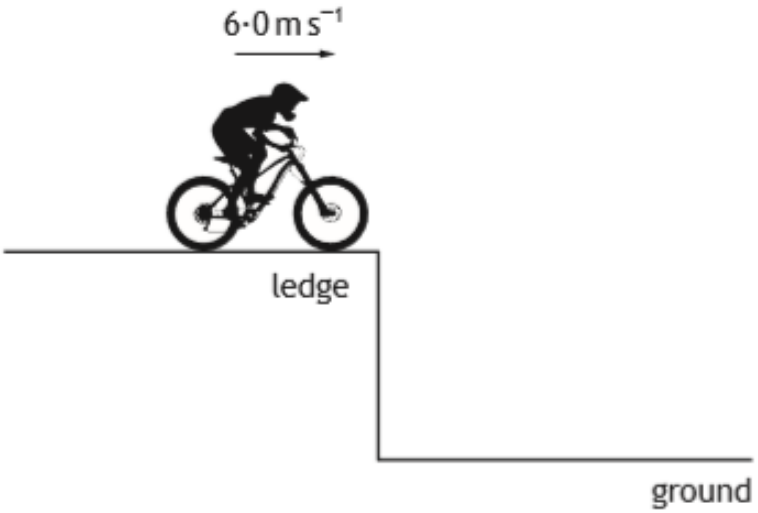
2018 Q 3 c

(c) During another part of the competition, the cyclist and bike travel horizontally at $6{\cdot}0\,m\,s^{-1}$ off a ledge as shown.



(i) On the diagram above, sketch the path taken by the cyclist and bike between leaving the ledge and reaching the ground. **1**

(An additional diagram, if required, can be found on *page 43*.)

(ii) The cyclist and bike reach the ground 0·40 s after leaving the ledge.

Calculate the vertical velocity of the cyclist and bike as they reach the ground.

The effects of air resistance can be ignored. **3**

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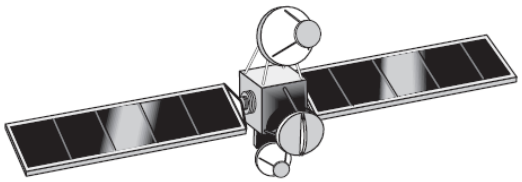
Space

2014 Q 9

9. A communications satellite is used to transmit live television broadcasts from the UK to Canada.

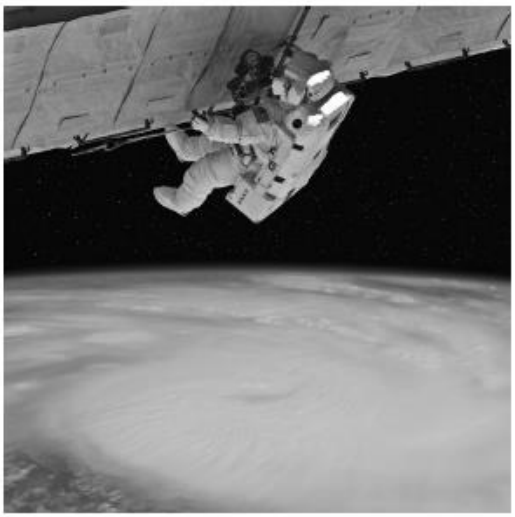


A student states that, to allow the live television broadcasts to be received in Canada, it is important that the satellite does not move.

Use your knowledge of physics to comment on this statement. **3**

2015 Q 10

10. Space exploration involves placing astronauts in difficult environments. Despite this, many people believe the benefits of space exploration outweigh the risks.



Using your knowledge of physics, comment on the benefits and/or risks of space exploration. **3**

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13. Read the passage and answer the questions that follow.

Supernova explosion

The average temperature of the surface of the Sun is 5778 K. In the core of the Sun energy is produced by nuclear fusion. Once the Sun has used all its nuclear fuel it will collapse to form a white dwarf.

A star with a mass much larger than that of the Sun will end its life in an enormous explosion called a supernova. The energy released in a supernova explosion is more than a hundred times the energy that the Sun will radiate over its entire 10 billion year lifetime.

In our galaxy, the star Betelgeuse is predicted to explode in a supernova. Betelgeuse has a mass of around 8 times the mass of the Sun. Even though Betelgeuse is 640 light-years from Earth, the supernova will be as bright as a full moon at night in our sky.

(a) State what is meant by the term *nuclear fusion*. 1

(b) Determine the average temperature of the surface of the Sun in degrees Celsius. 1

(c) Show that the distance from Earth to Betelgeuse is $6{\cdot}1 \times 10^{18}$ m. 3

(d) Betelgeuse may have already exploded in a supernova.
Explain this statement. 1

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2017 Q 12

12. The star Wolf 359 is at a distance of 7·8 light-years from Earth.

A radio signal from Wolf 359 is detected by a radio telescope on Earth.

(a) (i) State the speed of the radio waves. **1**

(ii) Calculate the distance, in metres, from Wolf 359 to Earth. **3**

(b) Another telescope is used to observe the same star in the visible part of the spectrum.

(i) State a suitable detector of visible light that may be used in this telescope. **1**

(ii) State whether the time taken for the visible light from the star to reach Earth is less than, equal to, or greater than the time taken for the radio waves from the star to reach Earth. **1**

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2018 Q 4

4. Within our solar system distances are often measured in astronomical units (AU).

$1\,AU = 1{\cdot}50 \times 10^{11}\,m$.

Mars orbits the Sun at an average distance of 1·52 AU.

(a) (i) Determine the average distance, in metres, at which Mars orbits the Sun. **1**

(ii) Calculate the average time for light from the Sun to reach Mars. **3**

(b) In the future it is hoped that humans will be able to travel to Mars. One challenge of space travel to Mars is maintaining sufficient energy to operate life support systems.

(i) Suggest one solution to this challenge. **1**

(ii) State another challenge of space travel to Mars. **1**

2018 Q 5

5. A group of students are watching a video clip of astronauts on board the International Space Station (ISS) as it orbits the Earth.

One student states, 'I would love to be weightless and float like the astronauts do on the ISS.'

Using your knowledge of physics, comment on the statement made by the student. **3**

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2019 Q 3

3. In 1971, the astronaut Alan Shepard hit a golf ball on the surface of the Moon.

Using your knowledge of physics, comment on the similarities and/or differences between this event and hitting an identical ball on the surface of the Earth. **3**

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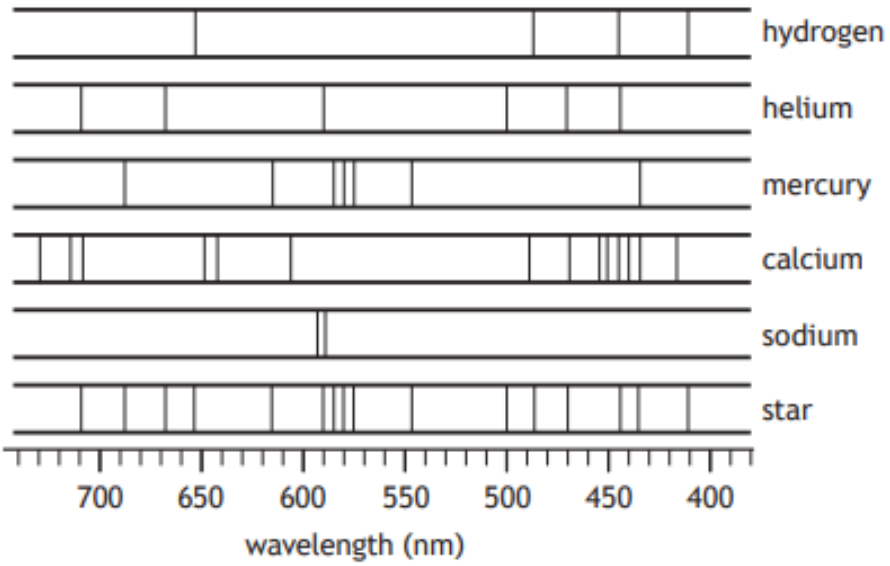
2019 Q 4

4. Astronomers studying a distant star analyse the light from the star that reaches Earth.

The line spectrum from the star is shown, along with the line spectra of the elements hydrogen, helium, mercury, calcium, and sodium.



(a) Determine which of these elements are present in the star. **1**

(b) The star is 97 light-years from Earth.

(i) State what is meant by the term *light-year*. **1**

(ii) Calculate the distance, in metres, from the star to Earth. **3**

Space for working and answer

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(c) Astronomers use satellite-based telescopes to collect information about objects in space.

(i) Suggest an advantage of using satellite-based telescopes such as the Hubble Space Telescope. **1**

(ii) State one **other** use of satellites. **1**

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