Chapter 8 Past Paper Question Booklet Two (G492)

8.1 Graphs of Motion
8.2 Vectors
8.3 Modelling Motion
8.4 Kinematic Equations

Describe and explain:
(i) the use of vectors to represent displacement, velocity and acceleration
(ii) measurement of displacement, velocity and acceleration

Make appropriate use of:
(i) the terms: displacement, speed, velocity, acceleration, vector, scalar

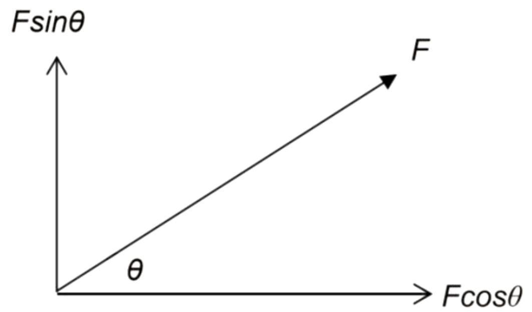
by sketching and interpreting:
(ii) graphs of accelerated motion; slope of s-t and v-t graphs, area underneath the line of a v-t graph
(iii) graphical representation of addition of vectors and changes in vector magnitude and direction

Make calculations and estimates involving:
(i) the resolution of a vector into two components at right angles to each other
(ii) the addition of two vectors, graphically and algebraically (two perpendicular vectors only)
(iii) the equations for constant acceleration derivable from: a = (v-u)/t and average velocity = (v+u)/2

$$v = u + at \qquad s = ut + \tfrac{1}{2}at^2 \qquad v^2 = u^2 + 2as$$

(iv) modelling changes of displacement and velocity in small discrete time steps, using a computational model or graphical representation of displacement and velocity vectors. (constant force only).

components of a vector in two perpendicular directions

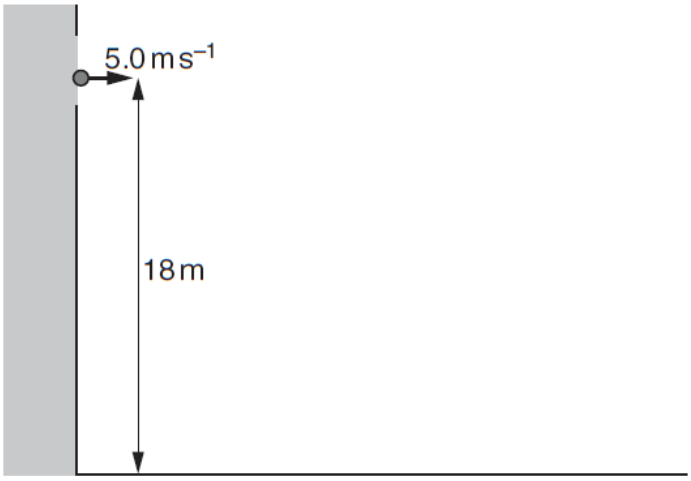


equations for uniformly accelerated motion

$$s = ut + \tfrac{1}{2}at^2$$
$$v = u + at$$
$$v^2 = u^2 + 2as$$

4 A ball is thrown out of a window 18 m above the ground.

It is thrown horizontally at $5.0\,\mathrm{m\,s^{-1}}$.



(a) Show that it takes about 2 seconds to reach the ground.

$g = 9.8\,\mathrm{m\,s^{-2}}$

[2]

(b) Calculate the distance from the bottom of the building to the place where the ball hits the ground.

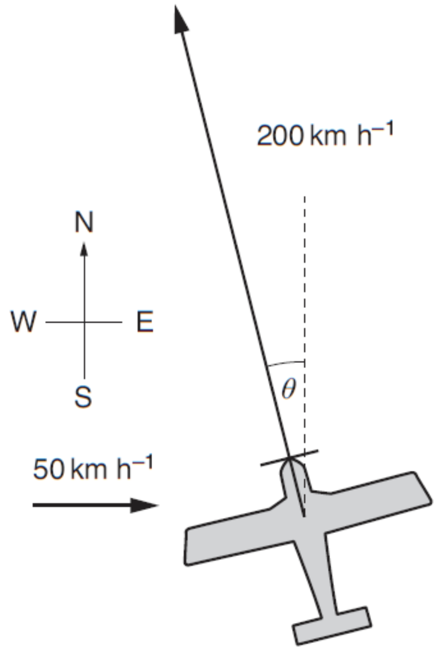
distance = ... m **[1]**

3 A small aircraft flies at a velocity of 200 $km\,h^{-1}$ relative to the ground.

There is a wind blowing at 50 $km\,h^{-1}$ from the west.

The pilot wishes to reach a destination due north of the starting point.
Find the resultant speed v of the aircraft, and the angle θ, west of north, which it must take.

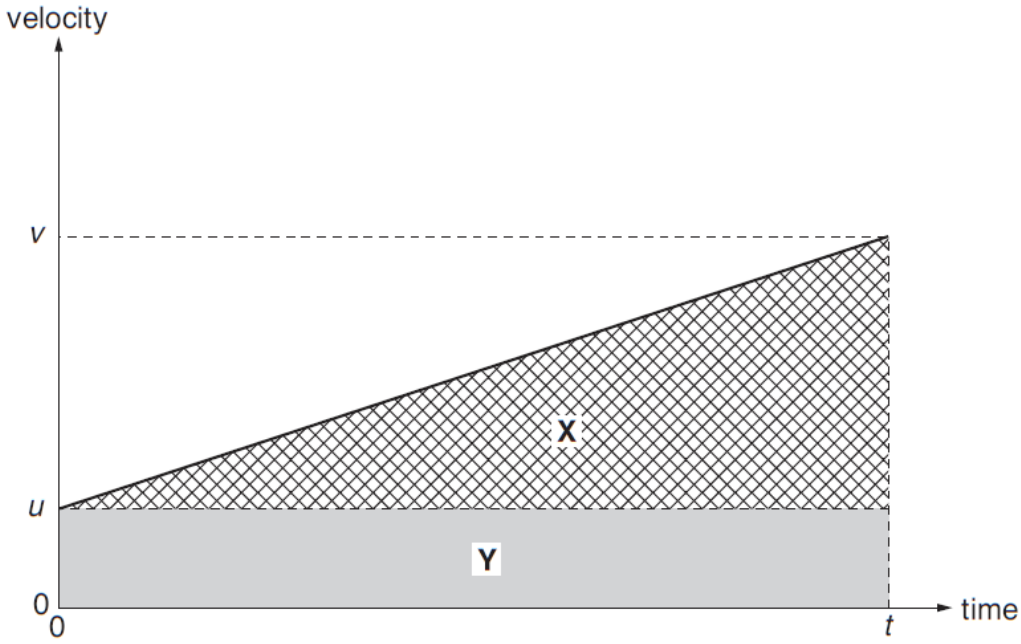
Show your working clearly.
You may wish to draw a vector diagram.



v = ... $km\,h^{-1}$

θ = ...°W of N **[3]**

4 The velocity-time graph below is for an object undergoing constant acceleration *a*.



Which of the following statements about the areas **X** and **Y** are correct?

Put ticks (✓) in the **two** correct boxes.

X = ut ☐

X = $\frac{1}{2}ut$ ☐

X = $\frac{1}{2}at^2$ ☐

Y = ut ☐

Y = $\frac{1}{2}vt$ ☐

Y = $\frac{1}{2}at^2$ ☐ **[2]**

8 In the 2008 Beijing Olympics, the Jamaican sprinter Usain Bolt won both the 100 metres and 200 metres races in record times.

Fig. 8.1 is the velocity-time graph for Usain in one of these two races.

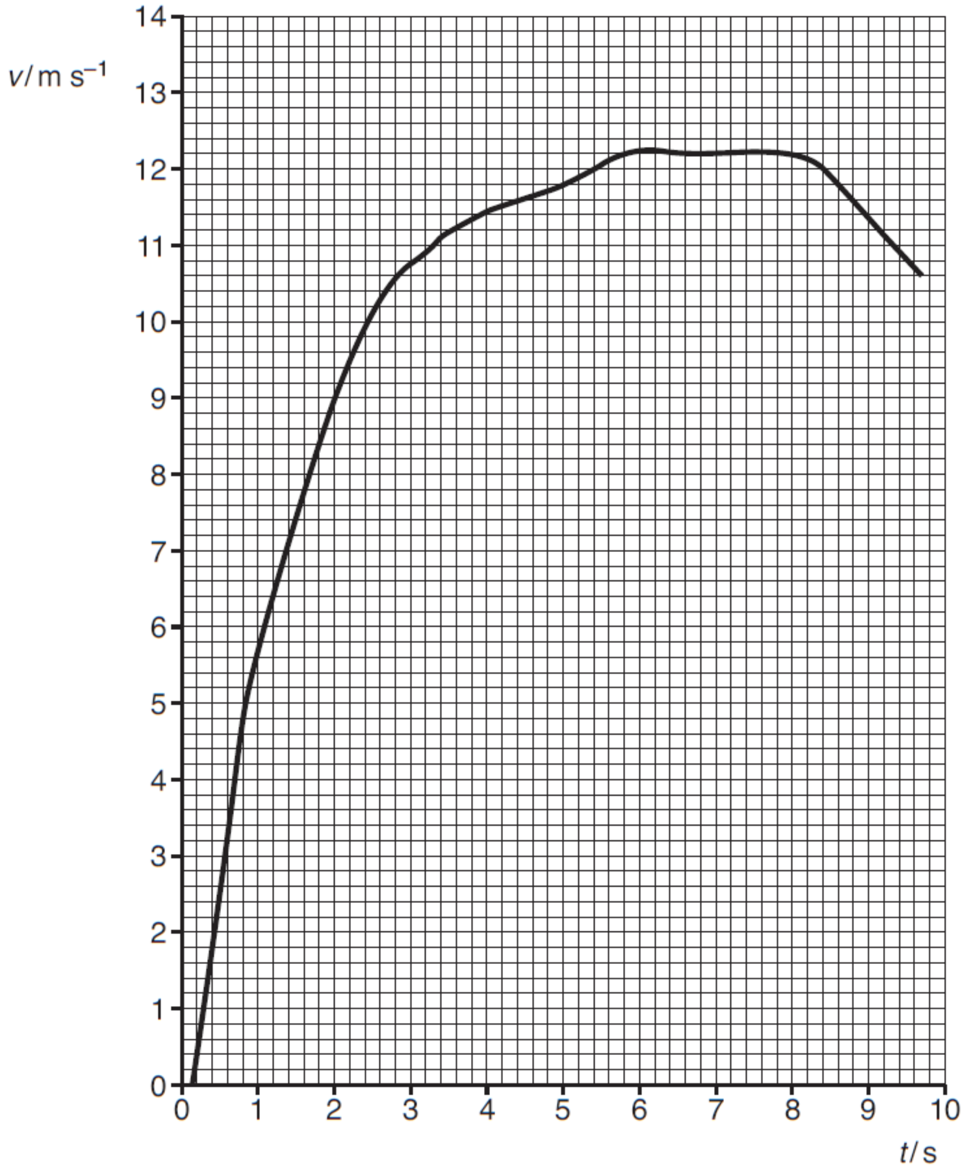


Fig. 8.1

(a) (i) The starting gun was fired at the time $t = 0$.
Use the graph to estimate Usain's reaction time to the starting gun.

reaction time = ... s **[1]**

(ii) Use data from both axes of the graph to show that this was the 100 m race.

[2]

(b) **(i)** Use the graph to estimate the horizontal force with which Usain pushed back on the starting block as he began to run.

mass of Usain Bolt = 88 kg

force = ...N **[3]**

(ii) Explain why this answer cannot be more than an estimate.

[1]

(c) Commentators describing this race noted that Usain seemed to relax once he knew he could not be passed, and that this happened about 20 metres from the end.
Use data from the graph to check this statement.

You should ensure that you use data from the graph and explain your findings clearly.

[3]

11 This question is about a computational model for the path of a projectile thrown horizontally at a speed of $5\,\text{m}\,\text{s}^{-1}$.
In this model, equal time intervals of 0.2 seconds are used.

(a) Explain why the horizontal displacement Δx during each time interval is constant at 1.0 m.

[2]

(b) The computer program for the model produces the graph of Fig. 11.1.

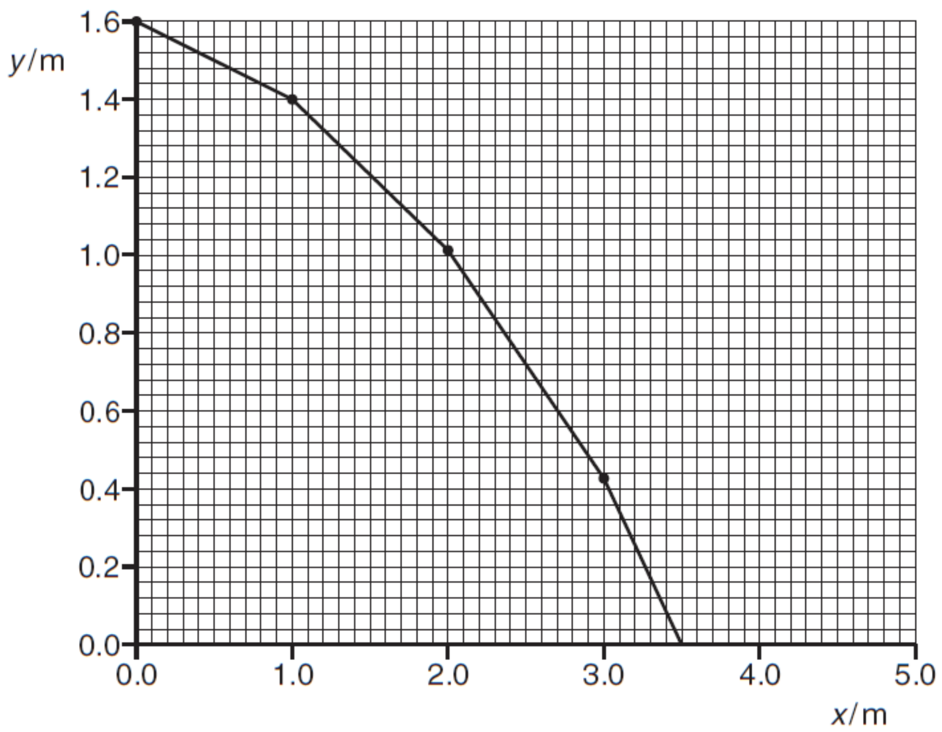


Fig. 11.1

(i) The model makes the assumption that the vertical component of velocity does not change during each time interval.
Explain clearly how the graph shows this.

[2]

(ii) State how the graph shows that the projectile should hit the ground at about 0.7 s after it is thrown.

[2]

(iii) Do a calculation to show that the time taken for a real object to fall vertically from rest through a distance of 1.6 m is significantly less than 0.7 s.

$g = 9.8\,\mathrm{m\,s^{-2}}$

[2]

(iv) The answers to **(ii)** and **(iii)** above show that the computational model produces vertical components of velocity which are too small.
Explain why this is the case.

[1]

(c) Suggest and explain a change which could be made to the model to produce a graph which more accurately matches the curve produced by a real projectile.

[2]

6 A high-performance car has an acceleration of $0.86g$.

(a) Calculate the time it takes to reach a velocity of $27\,m\,s^{-1}$ (60 miles $hour^{-1}$).

$g = 9.8\,m\,s^{-2}$

time = ... s **[2]**

(b) The car can brake from $27\,m\,s^{-1}$ to rest in a distance of 35 m.
Calculate the mean force exerted by the brakes.

mass of car = 1600 kg

mean force = ... N **[2]**

Water rockets

The use of water rockets is a popular way to study force and motion in A-Level physics. This article describes an experiment carried out by students with a particular water rocket on the school playing fields. A plastic drinks bottle is used with a toy rocket kit that involves filling the bottle one-third to a half full with water (Fig. 2). This is then attached to a foot pump via a valve and tube. As air is pumped into the bottle the internal pressure increases. When the pressure inside the bottle exceeds the maximum capacity of the valve, the valve and tube are forced free and the rocket takes off.

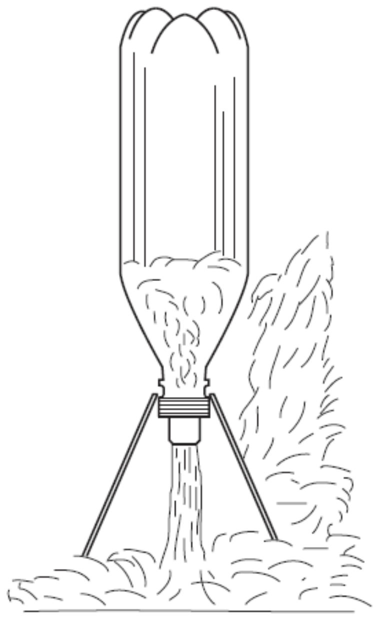


Fig. 2

Due to the internal pressure, the water is forced out in a downward direction. An equal and opposite force is exerted on the rocket which accelerates it upwards. The water is all released very quickly and the rocket continues upwards until it reaches its maximum height. From here it falls back to the ground.

The students found it very difficult to make measurements and eventually settled on using a digital video camera with a freeze-frame facility to measure the height of the rocket every 0.5 seconds.

The following table contains an average of several trials. In each case, the rocket was fired vertically into the air.

time /s	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00
height /m	0.0	12.4	19.9	24.2	26.4	28.1	27.9	24.4	20.0

The students carried out a second set of experiments later the same day, using exactly the same experimental arrangements. This time, however, there was a horizontal wind which affected the overall path of the water rocket. The rocket now travelled a mean distance of 37 m away from the original launch position, although the maximum height and time of flight were similar to the earlier experiments.

13 This question is based on the article *Water rockets.*

(a) The graph in Fig. 13.1 shows the way in which the mean height of the water rocket varies with time.

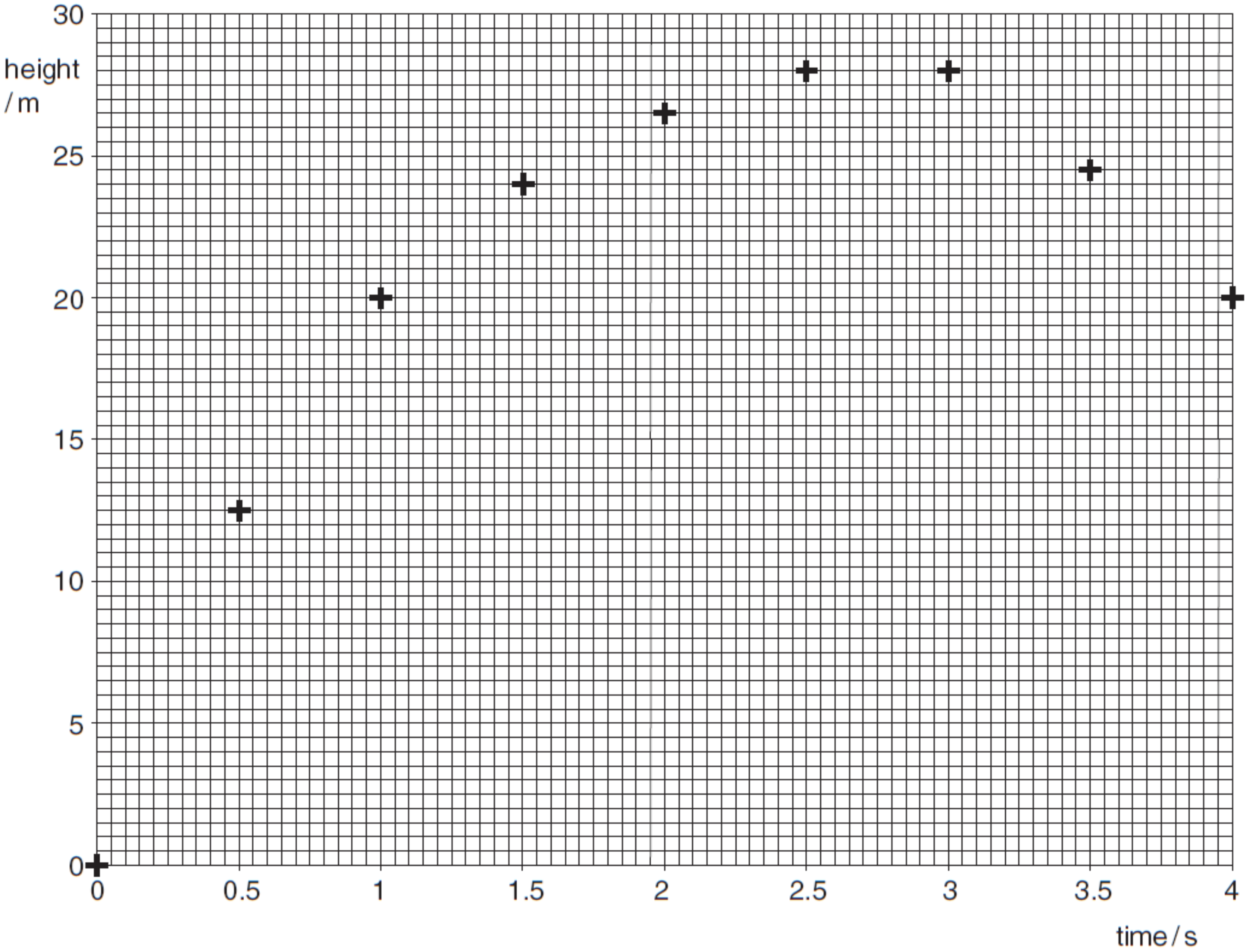


Fig. 13.1

(i) Draw a best-fit curve through the points and use the graph to obtain a value for the maximum height reached by the water rocket.

maximum height = ... m **[1]**

(ii) Use the graph to show that the initial velocity of the rocket is about 25 $m\,s^{-1}$.

[2]

(iii) Explain how the graph shows that the rocket has an acceleration downwards for its entire flight.

[2]

(b) **(i)** Use the equations for uniformly accelerated motion to show that a maximum height of about 30 m can be reached by an object projected vertically with an initial vertical velocity of $25\,\mathrm{m\,s^{-1}}$.

$g = 9.8\,\mathrm{m\,s^{-2}}$

[3]

(ii) Suggest and explain one reason why the rocket did not reach the maximum height calculated in **(b)(i)**.

[2]

(c) This question refers to the second set of results where the students' experiment was affected by a horizontal wind.

(i) Explain why the height reached by the water rocket was not affected by the wind.

[2]

(ii) Use data from the graph of Fig. 13.1 to estimate the speed of the wind which resulted in the rocket landing 37 m from its launch position.

[2]

7 A stone is thrown vertically upwards at $12\,\mathrm{m\,s^{-1}}$.

(a) Calculate the speed v of the stone when it is 3.0 m above the point of projection.

$g = 9.8\,\mathrm{m\,s^{-2}}$

v = ... $\mathrm{m\,s^{-1}}$ **[3]**

(b) When the equation $s = ut + \frac{1}{2}at^2$ is used to calculate the time taken to reach a point 3.0 m above the point of projection, two answers of 0.28 s and 2.2 s are obtained.
Explain, without calculation, how the displacement can be the same at two different times.

[1]

9 In one extreme sport, BASE jumping, people jump off structures such as buildings or bridges. They open a parachute as late as they dare (Fig. 9.1).

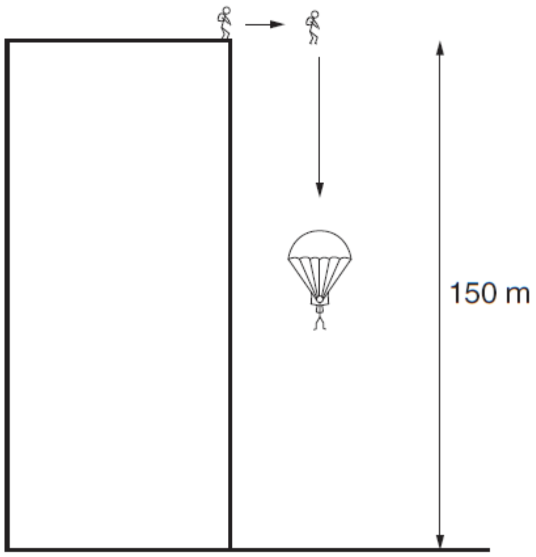


Fig. 9.1

(a) In one BASE jump, the building used is 150 m high.
In a simple model of the jump, a jumper accelerates uniformly with $a = g$ before she opens her parachute.

(i) Show that it takes a little over 1 s for the free-falling BASE jumper to reach a speed of $12\,\mathrm{m\,s^{-1}}$.

$g = 9.8\,\mathrm{m\,s^{-2}}$

[1]

(ii) Show that the distance fallen by the BASE jumper before she reaches a speed of $12\,\mathrm{m\,s^{-1}}$ is about 7 m.

[2]

(iii) Assume that her parachute opens instantly after the first 7 m of free-fall, and that she then falls at a steady speed of 6.0 m s^{-1} for the rest of the fall.
Calculate the **total** time she takes to reach the ground.

total time = ... s **[2]**

(b) The graph for the jump described by the model in **(a)** is shown in Fig. 9.2.

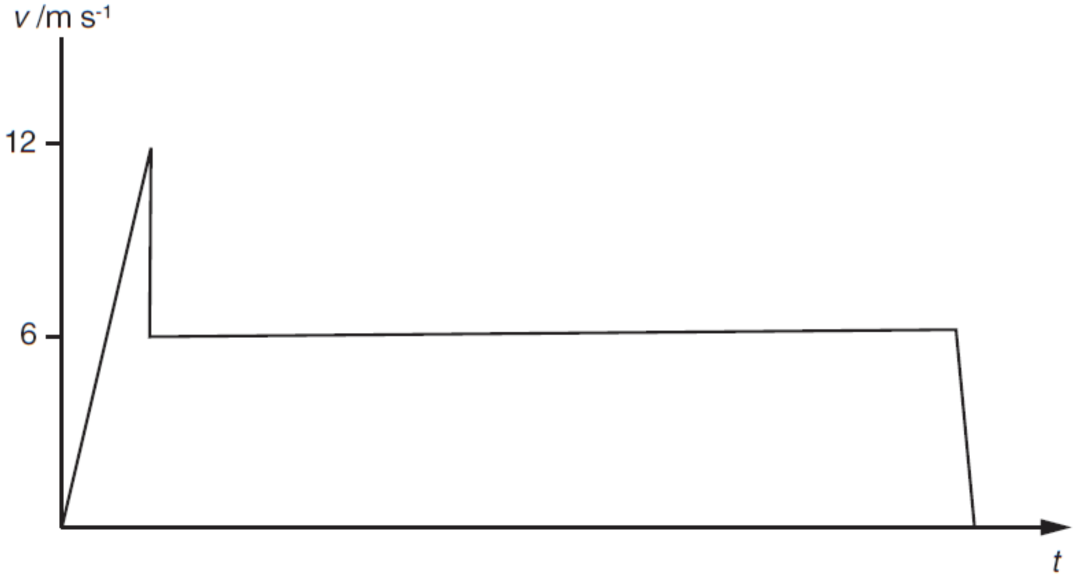


Fig. 9.2

Sketch on Fig. 9.2 the actual curve you would expect for the BASE jumper. When the parachute is opened, her terminal velocity is 6.0 m s^{-1}.

[2]

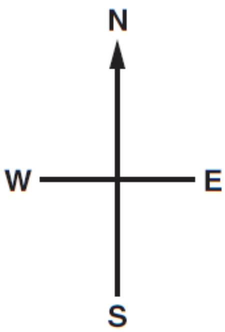
7 A treasure map states:

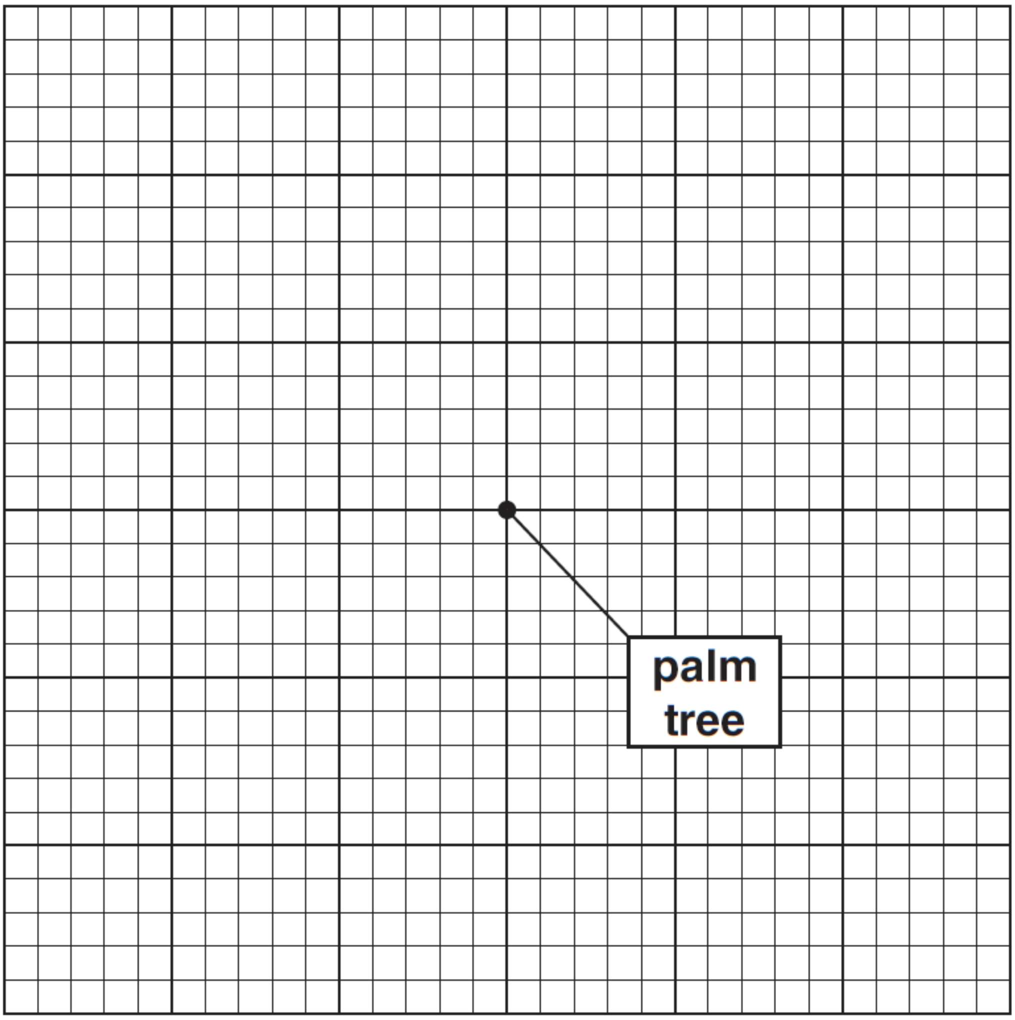
- from the palm tree, go 15 paces north,
- then go 7 paces west
- the treasure is buried 3 paces south.

By calculation or drawing, find the magnitude and direction of the displacement of the treasure from the palm tree.

The central dot represents the palm tree.

Each small square on the grid below represents one pace.





displacement = ... paces

in a direction .... **[3]**

1 Here is a list of quantities.

energy **force** **power** **speed** **velocity**

(a) Which two quantities can have the same units?

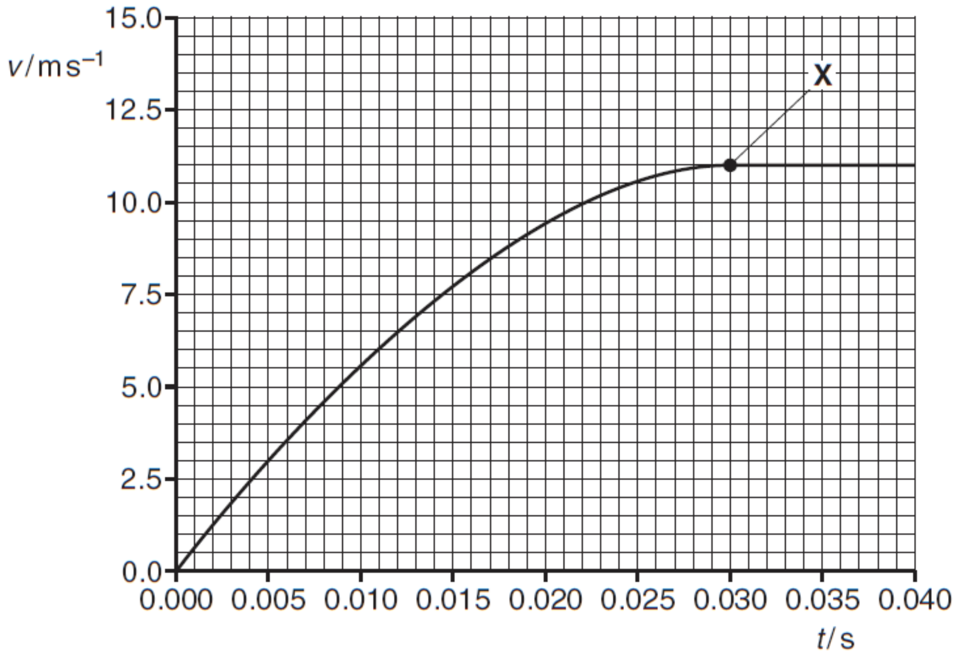
.... and .... **[1]**

(b) Which two quantities are vectors?

.... and .... **[1]**

7 The graph shows the velocity of a stone being launched from a catapult.

The stone loses contact with the catapult at the point marked **X**.



Use the graph to calculate the distance the stone moved while in contact with the catapult.
Make your working clear on the graph and in this space.

distance = ... m **[3]**

11 This question is about the vector nature of velocity and acceleration.
At time $t = 0$, an object is moving in the x-direction at $5.0\,\text{m s}^{-1}$ as shown in Fig. 11.1.
Two seconds later, it is moving at $40°$ to that direction, but at the same speed.

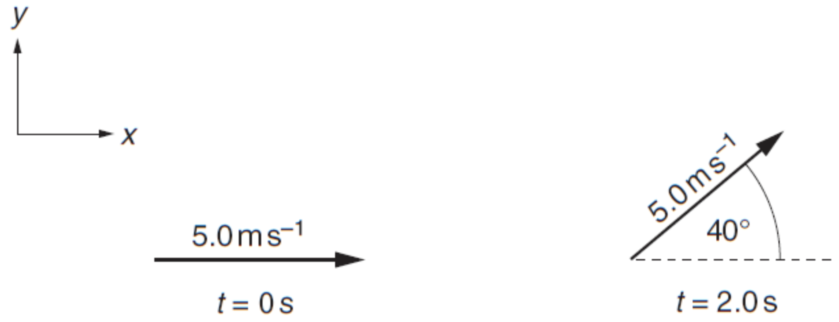


Fig. 11.1

(a) **(i)** Show that the x-component of velocity at time $t = 2.0\,\text{s}$ is about $4\,\text{m s}^{-1}$ and that the y-component of velocity at this time is about $3\,\text{m s}^{-1}$.

[2]

(ii) Show that the mean x-component of acceleration during the 2.0 s is about $-0.6\,\text{m s}^{-2}$.

[2]

(b) The mean y-component of acceleration during the 2.0 s is $+ 1.6\,\text{m s}^{-2}$.

Choosing an appropriate scale, draw the two vector components of acceleration on the grid of Fig. 11.2 opposite and determine the magnitude and direction of the resultant acceleration.

magnitude of acceleration = ... m s^{-2}

direction of acceleration = ... °

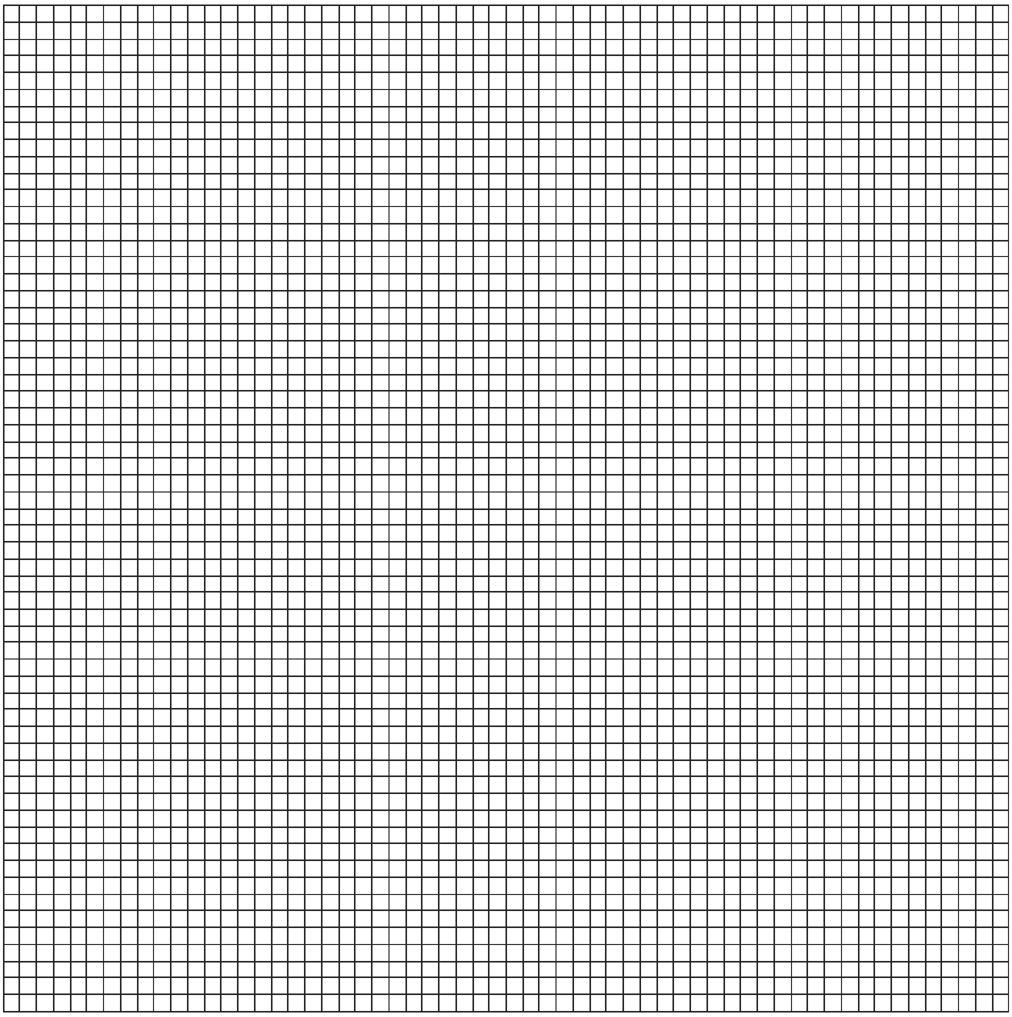


Fig. 11.2

[4]

Measuring g by freefall

A direct measurement of g, the acceleration due to gravity, can be made by timing an object in freefall. An example of the method using standard school equipment is shown in Fig. 2. The break-to-start and break-to-stop contacts are connected to an electronic timer.

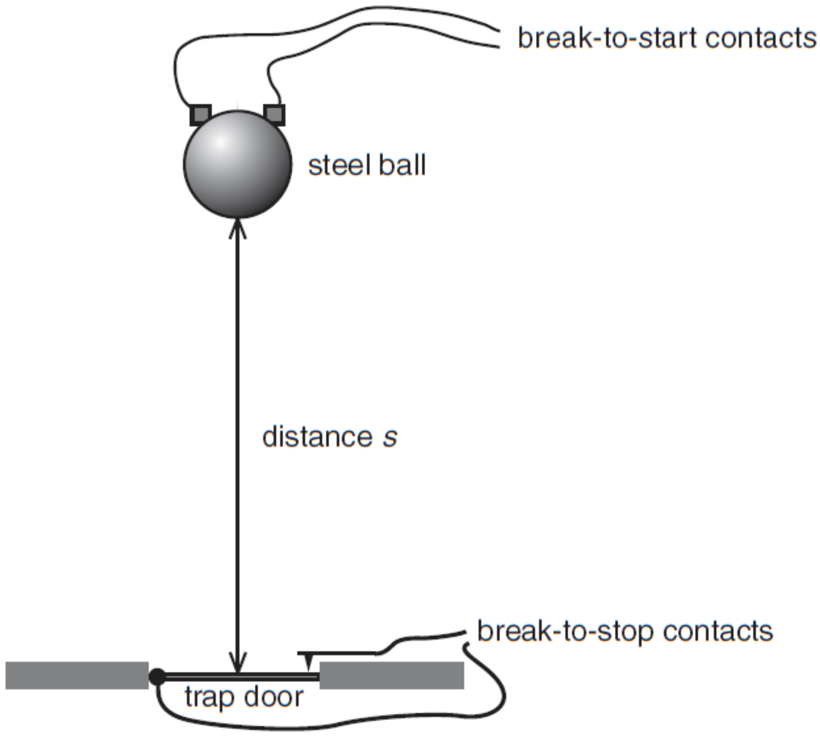


Fig. 2

As the steel ball bearing is released, the electronic timer starts. The ball falls a distance s before it hits a hinged metal 'trap door'. The trap door opens, breaks the circuit and stops the timer. The time t can be measured to the nearest 0.01 of a second and the distance s is measured with a tape measure to the nearest centimetre. This procedure can be repeated to give a mean time t for this value of s.

The values of t and s can be substituted into the equation $s = ut + \frac{1}{2}at^2$ to find the acceleration. However, it is best not to rely upon the mean time t for one particular distance s. A more accurate and reliable value for g can be obtained by taking measurements at different values of s and then plotting a suitable straight line graph. Such a graph may also reveal any systematic errors in the experiment.

A set of readings obtained in this way is given in the table below.

s/m	mean t/s
0.40	0.27
0.50	0.31
0.60	0.34
0.70	0.38
0.80	0.41
0.90	0.43
1.00	0.45
1.20	0.50

13 This question is about the article *Measuring g by freefall*.

A student carries out an experiment to measure g in the classroom using the equipment described in the article and shown in Fig. 13.1.

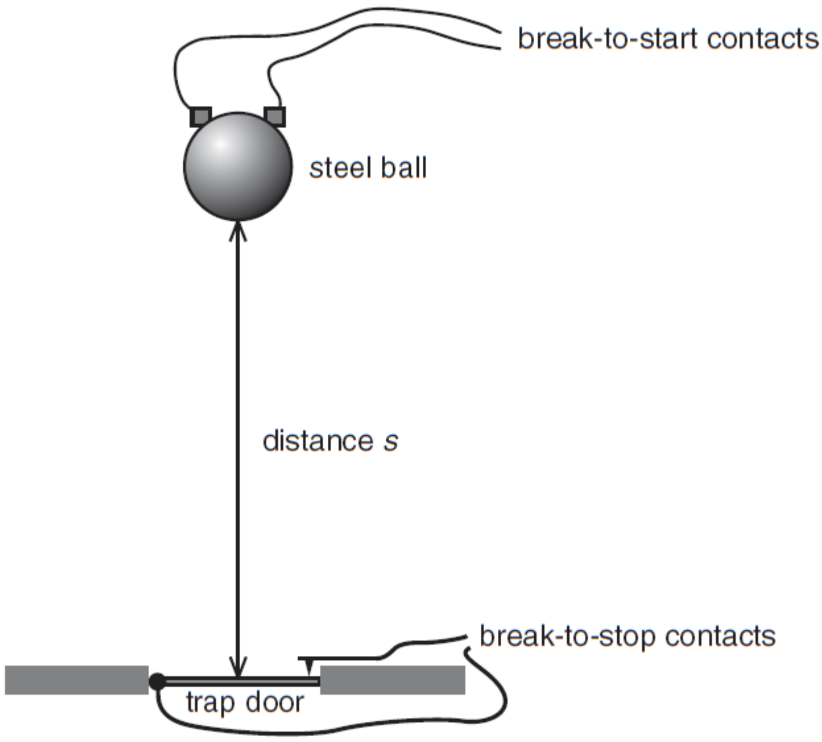


Fig. 13.1

She sets up the equipment and judges the uncertainty in the two measurements. The timing device measures to within 0.01 s and the distance s is measured to within 0.01 m.

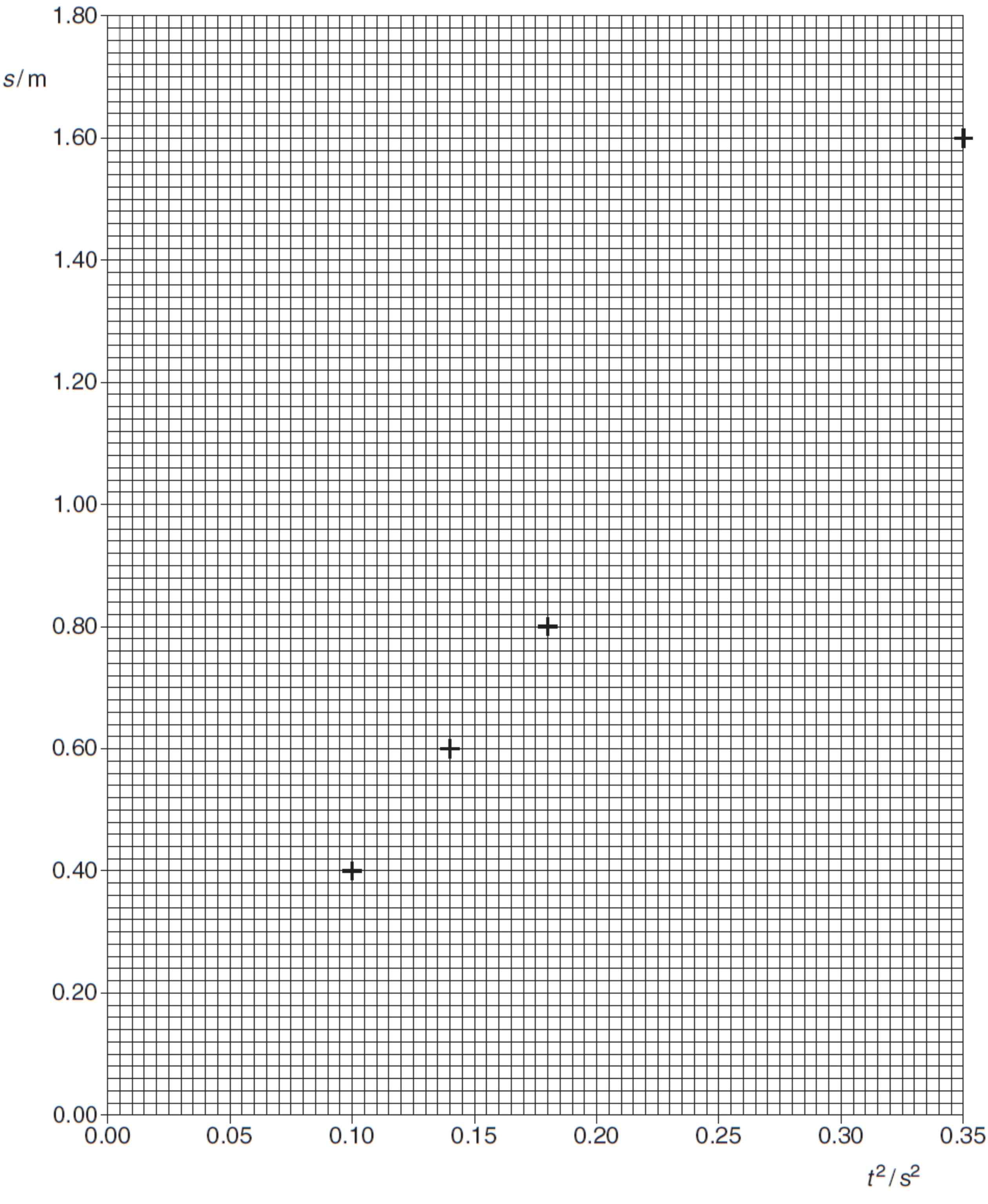
(a) The student records the following data for a range of distances, averaging the time t at each distance s over several drops. She intends to plot a graph of s against t^2.

(i) Complete the table.

s/m	mean t/s	t^2/s^2
0.40	0.31	0.10
0.60	0.38	0.14
0.80	0.42	0.18
1.00	0.47	
1.20	0.51	
1.40	0.55	
1.60	0.59	0.35

[2]

(ii) Using your values from the table, complete the graph of s against t^2 opposite and draw a straight line of best fit.



[3]

(b) **(i)** Explain why the equation $s = ut + \frac{1}{2}at^2$ would lead you to expect the graph to go through the origin.

[2]

(ii) Calculate the gradient of the graph.
Show your working clearly on the graph or in this space.

gradient = ... **[2]**

(iii) Use your answer to **(ii)** to obtain a value for the acceleration due to gravity, g.

g = ... unit ....**[2]**

(c) (i) The graph does not pass through the origin. Suggest one way in which this may have come about, and what effect it would have on the recorded values.

[2]

(ii) Explain whether this source of systematic error would affect the value of g obtained as in **(b)(iii)**.

[2]

10 This question is about the vector nature of displacement, velocity and acceleration.

(a) An object moves in the x–y plane along a semi-circular path from **A** to **C** as shown in Fig. 10.1. **B** is mid-way between **A** and **C**. The radius of the path is 3.0 m and the object moves at a constant speed of $5.0\,\text{m}\,\text{s}^{-1}$.

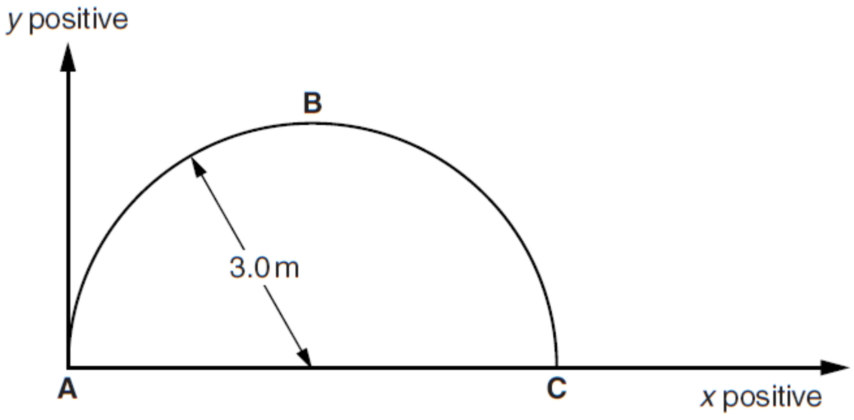


Fig. 10.1

(i) Show that it takes about 2 seconds for the object to travel from **A** to **C**.

[1]

(ii) Write down the values of the x- and y-components of the **velocity** of the object when at **A**, **B** and **C** in the table below.

	velocity at **A** / $\text{m}\,\text{s}^{-1}$	velocity at **B** / $\text{m}\,\text{s}^{-1}$	velocity at **C** / $\text{m}\,\text{s}^{-1}$
x-component			
y-component			

[2]

(iii) Write down the values of the x- and y-components of the **displacement** of the object from **A** when at **B** and **C** in the table below.

	displacement from **A** to **B** / m	displacement from **A** to **C** / m
x-component		
y-component		

[2]

(b) A car travels around a roundabout at a constant speed of $12\,\mathrm{m\,s^{-1}}$.
Its direction changes by 40° when moving from **D** to **E**, as shown in Fig. 10.2.

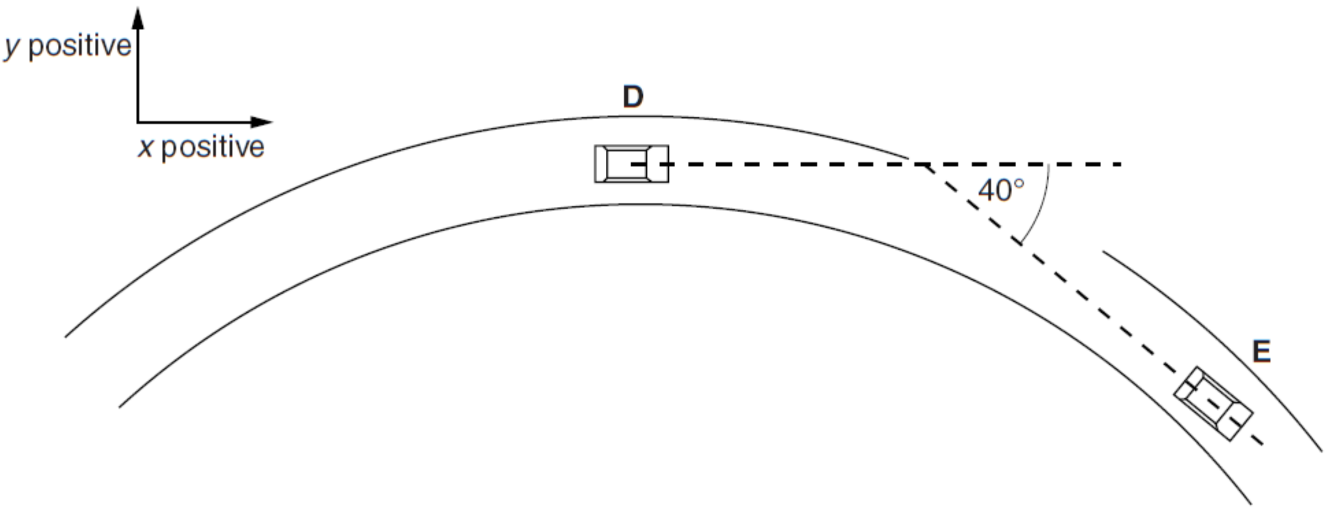


Fig. 10.2

Because the velocity vector changes, the car has an acceleration.
The car takes 1.6 s to travel from **D** to **E**.
Calculate the mean values of the *x*- and *y*-components of acceleration between **D** and **E**.
Show your working clearly.

x-component	*y*-component
mean *x*-acceleration = ... $\mathrm{m\,s^{-2}}$	mean *y*-acceleration = ... $\mathrm{m\,s^{-2}}$

[4]

3 Fig. 3.1 shows the velocity–time graph for the motion of a car.

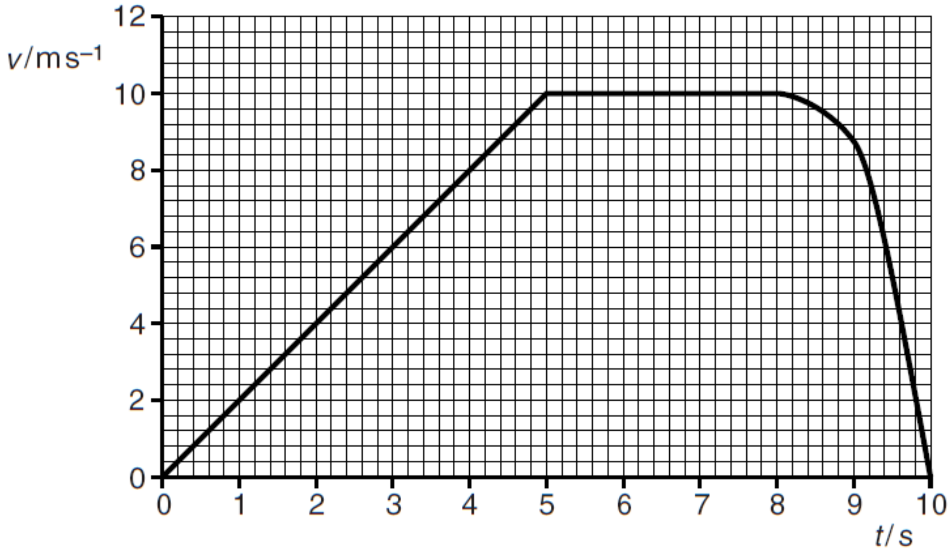


Fig. 3.1

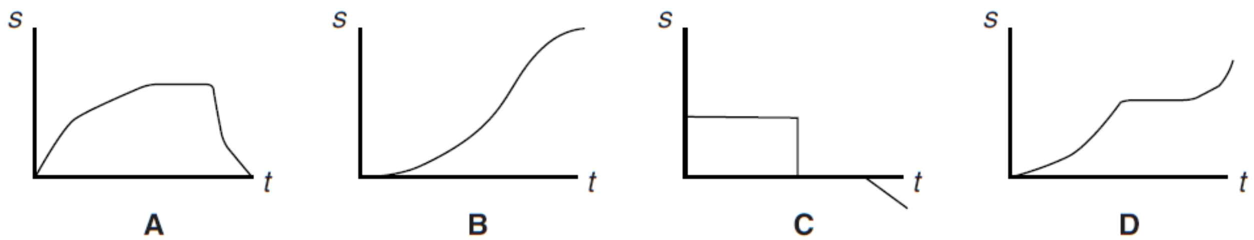
(a) Calculate the distance travelled by the car in the first 8 seconds.
You should show your working.

distance = ... m **[2]**

(b) Use the graph to estimate the deceleration of the car at t = 9.0 s.
You should show your working on the graph and in this space.

deceleration = ... m s^{-2} **[2]**

(c) Which sketch graph, **A**, **B**, **C** or **D**, best represents the displacement–time graph for this journey?



answer .... **[1]**

8 After a natural disaster, aeroplanes are often used to drop emergency supplies to people who cannot be reached by other means.
Fig. 8.1 shows the trajectory of a pack of supplies dropped in this way.

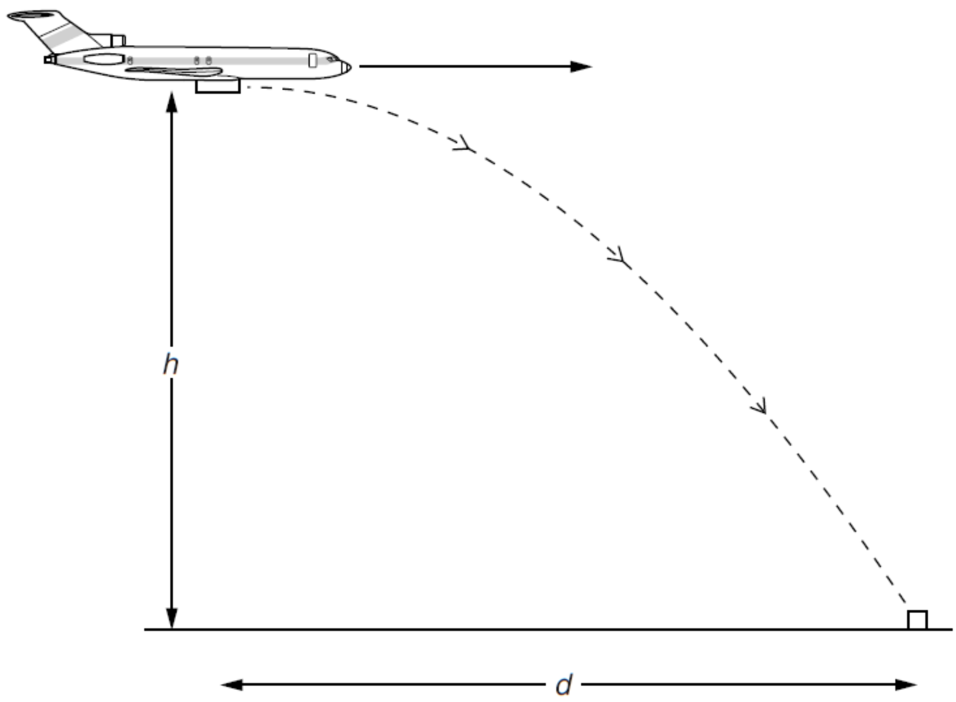


Fig. 8.1

(a) In this part of the question, you should ignore air resistance.

(i) Show that it would take a pack of supplies a time t of about 3 s to land, falling from a height h of 50 m.
$g = 9.8\,\mathrm{m\,s^{-2}}$

[2]

(ii) Explain why the horizontal distance d travelled by the pack while it falls for a time t is given by

$$d = vt$$

where v is the horizontal speed of the plane at the time of release of the pack.

[2]

(iii) Calculate the value of d for a plane travelling at a speed of $120\,\text{m}\,\text{s}^{-1}$ at a height of $50\,\text{m}$.

d = ... m **[1]**

(b) For certain supplies, it is essential that they land at a much lower speed, so a parachute is used.

A parachute cannot be used for a pack dropped from heights below 200 m.

Suggest an item which would need to be dropped by parachute. Discuss why using a parachute and dropping the pack from a height above 200 m might prevent the pack reaching its intended destination.

In your answer you should consider different factors which may prevent the pack reaching its intended destination.

[4]

9 This question is about the modelling of an object falling freely under gravity without air resistance. Use $g = 9.8\,\mathrm{m\,s^{-2}}$ wherever it is needed.

(a) **(i)** Calculate the speed of the object, falling from rest, after 0.3 s.

Show your working.

speed = ... $\mathrm{m\,s^{-1}}$ **[1]**

(ii) Show that the distance fallen in 0.3 s is more than 0.4 m.

[2]

(b) A computer program is used to model this fall.

The computer produces the following data.

Time t/s	**Velocity v/$\mathrm{m\,s^{-1}}$**	**Displacement s/m**
0.0	0.00	0.000
0.1	0.98	0.000
0.2	1.96	0.098
0.3	2.94	0.294

(i) How do the **velocity** data in the table show that the acceleration is **uniform**?

[1]

(ii) How do the **displacement** data in the table show that the object is accelerating between 0.1 s and 0.3 s?

[1]

(c) Each set of data is calculated by the computer model using the following steps.

- The object starts at time $t = 0$ with $s = 0$ and $v = 0$.
- Calculations are made at equal time intervals of $\Delta t = 0.1$ s.
- During each time interval, the velocity is assumed to be constant at the value it had at the beginning of that time interval.
- At the end of each time interval, the velocity is increased by an amount $g\Delta t$.
- At the end of each time interval, the displacement is increased by an amount calculated from the value of velocity at the beginning of that time interval.

(i) Use this information to explain why the displacement at $t = 0.1$ s is still zero according to the model.

[1]

(ii) Explain why the distance fallen in 0.3 s given by the model is less than the correct value calculated in **(a)(ii)**.

[2]

(iii) Explain how a change to the value of Δt used could improve the accuracy of the model.

[2]

Trolley down a ramp

You may wish to try out these ideas in the laboratory so that you know in advance what the difficulties might be, how the experiment works and how the data can be used.

A trolley released from rest accelerates down a ramp. Its final velocity v is measured at a light gate. The simple arrangement of Fig. 2 can be used to carry out the practical task.

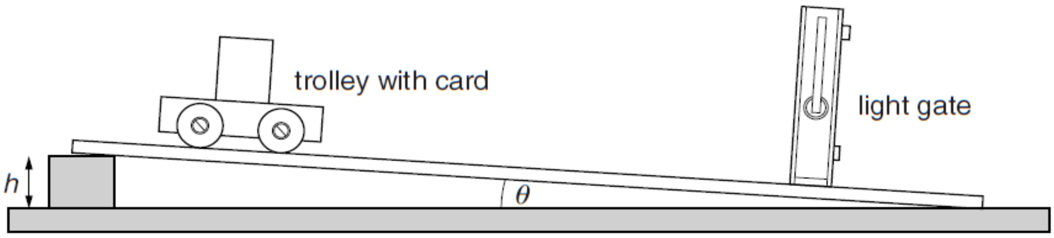


Fig. 2

The height h of the ramp can be raised to alter the angle θ of the ramp with respect to the horizontal.

The equation $v^2 = u^2 + 2as$ can be applied to the situation and used to determine a value for g, the acceleration due to gravity.

Factors that impact on the experiment and the consequent calculation of a value for g should all be considered. These could include friction on the trolley, energy loss, precision of the velocity measurement and measurement of the angle θ.

12 This question is about the article *Trolley down a ramp*.

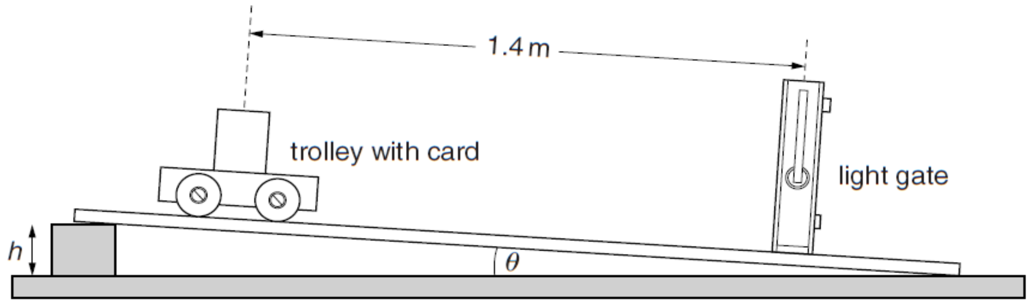


Fig. 12.1

(a) (i) In a particular experiment the angle θ of the ramp is increased in 5° steps from 10° to 40°. The trolley released from rest accelerates down the ramp, travelling a distance of 1.4 m. The final velocity v is measured at the light gate. Values for the final velocity are recorded in the table below. Values for v^2 and $\sin\theta$ have been tabulated.

Add the three missing values to the table.

v / m s^{-1}	v^2 / m^2 s^{-2}	θ / degree	$\sin\theta$
2.13		10	0.17
2.72	7.40	15	0.26
3.06	9.36	20	0.34
3.38	11.42	25	0.42
3.69	13.62	30	0.50
3.92	15.37	35	
4.16		40	0.64

[2]

(ii) Plot these new values on the graph of Fig. 12.2 and draw a line of best fit.

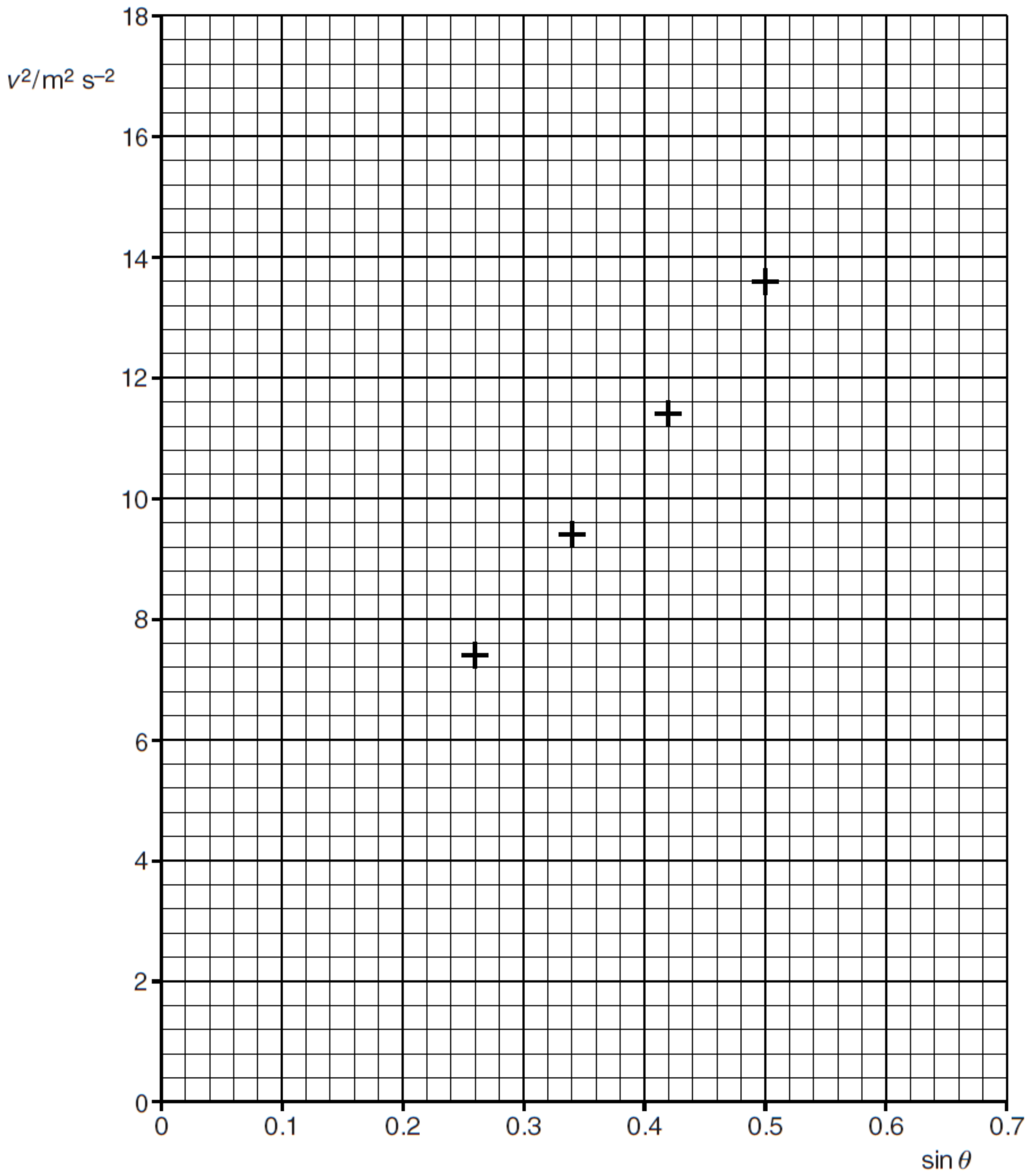


Fig. 12.2

[3]

(b) (i) Use data from the graph to calculate a value of the gradient of the graph.

gradient = ... unit .... **[3]**

(ii) Assuming no friction, Fig. 12.1 can be simplified to Fig. 12.3.

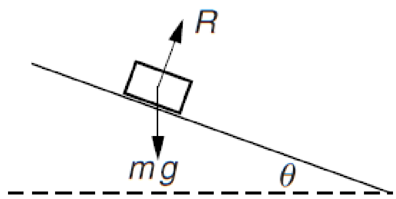


Fig. 12.3

Explain why the acceleration a down the ramp is given by $a = g \sin \theta$.

[2]

(iii) By using the relationships $v^2 = u^2 + 2as$ and $a = g \sin \theta$, show that the gradient of the graph of Fig. 12.2 is equal to $2.8g$.

[2]

(iv) Calculate a value for g.

g = ... $\mathrm{m\,s^{-2}}$ **[1]**

(c) Suggest and explain **two** experimental factors that may affect the value of g obtained by this method.

You should make clear the effect of each on the calculated value of g.

[4]

6 An aircraft is in level flight through still air.

It has the following components of velocity:

north-south: $50\,\mathrm{m\,s^{-1}}$ towards the south

east-west: $35\,\mathrm{m\,s^{-1}}$ towards the east

(a) Using a suitable scale, draw these components on the grid below.
Hence or otherwise find the speed and direction of flight of the aircraft.

speed = ... $\mathrm{m\,s^{-1}}$

direction = ...

[4]

(b) A wind later acts upon the aircraft, changing the aircraft's direction so that it travels due south.
Deduce the speed and direction of this wind.

speed = ... $\mathrm{m\,s^{-1}}$

direction = ...

[2]

11 This question is about a person diving into a swimming pool from a springboard.
Fig. 11.1 shows the sequence of events.

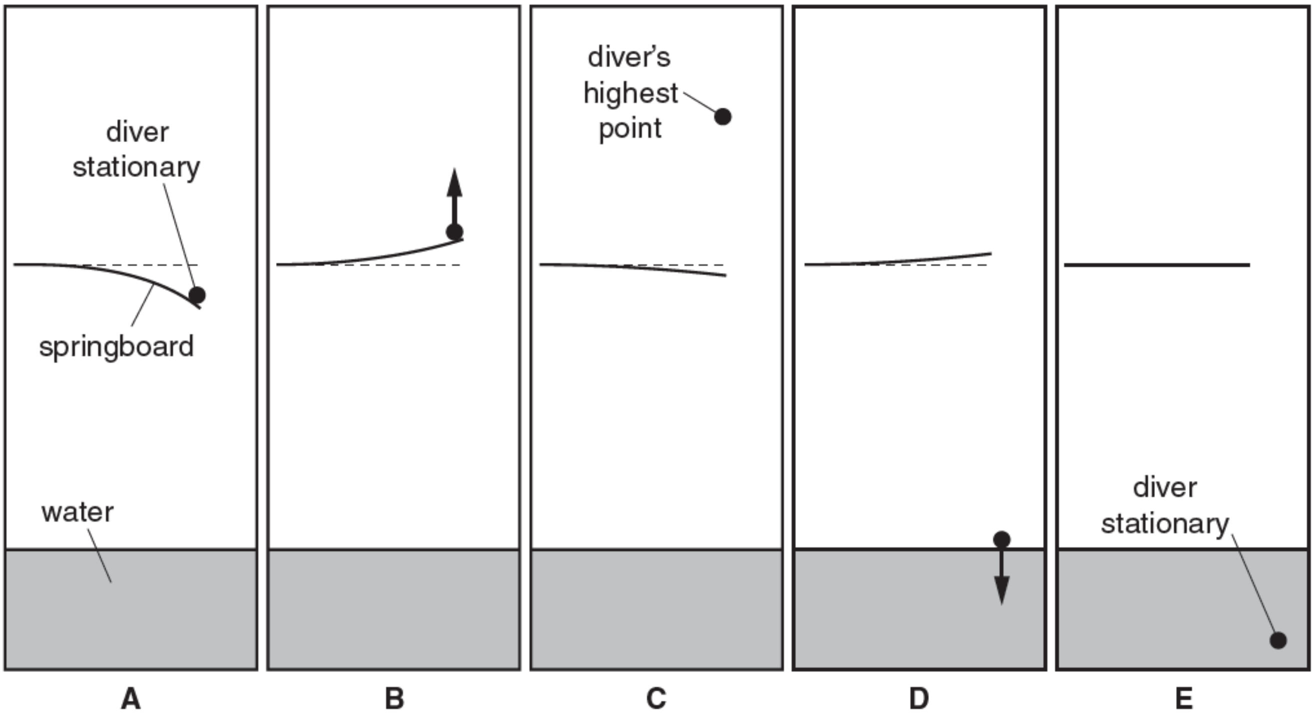


Fig. 11.1

In this simplified model, the diver is shown as a point and the horizontal outwards component of the diver's velocity is ignored, so only vertical motion is shown.

The diver jumps vertically at the end of the springboard and then lands on it, bending it downwards to the position shown in **A**. This is the time $t = 0$. The board then accelerates the diver upwards as it springs back, launching the diver upwards (time **B**). On leaving the board, the diver is in free-fall, rising to his highest point (time **C**), until he hits the water (time **D**). He then decelerates to a stop (time **E**).

Fig. 11.2 shows the velocity-time graph for the diver's vertical motion with the times **A** to **E** shown.

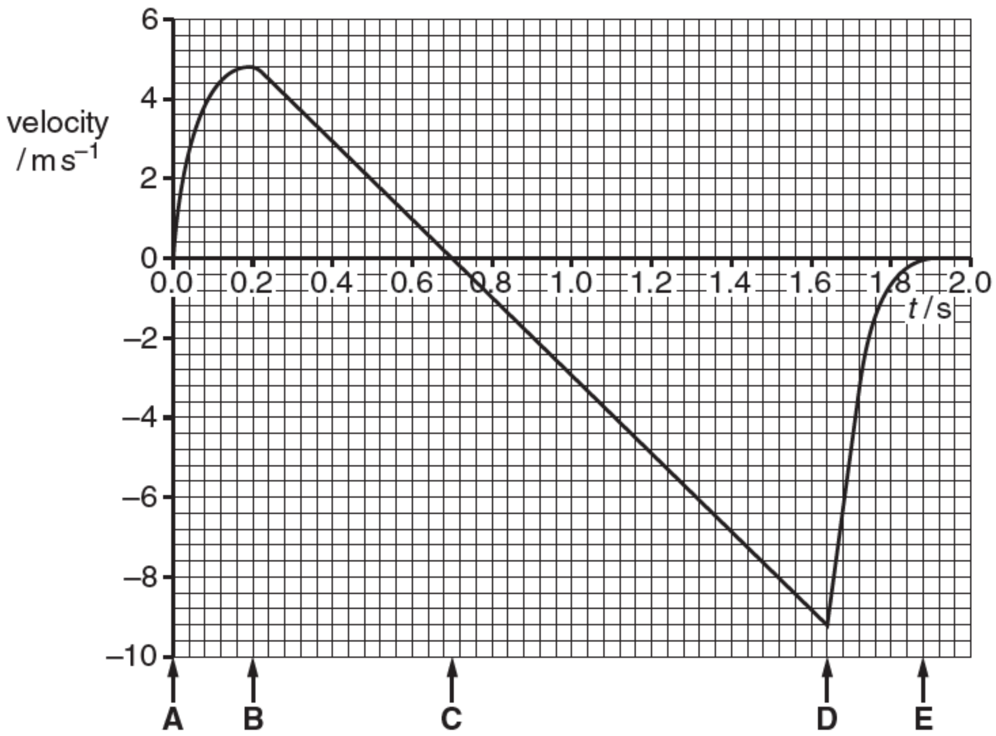


Fig. 11.2

(a) Explain how the graph of Fig. 11.2 shows that the force exerted on the diver by the springboard between times **A** and **B** is greatest at the start.

[2]

(b) Explain how the graph shows that:

(i) The diver leaves the board at time **B**,

[1]

(ii) The diver is at his highest point at time **C**.

[1]

(c) (i) State what the area between the graph and the time axis between **B** and **C** represents.

[1]

(ii) Use data from Fig. 11.2 to calculate the distance fallen by the diver between **C** and **D**.

Show your working clearly.

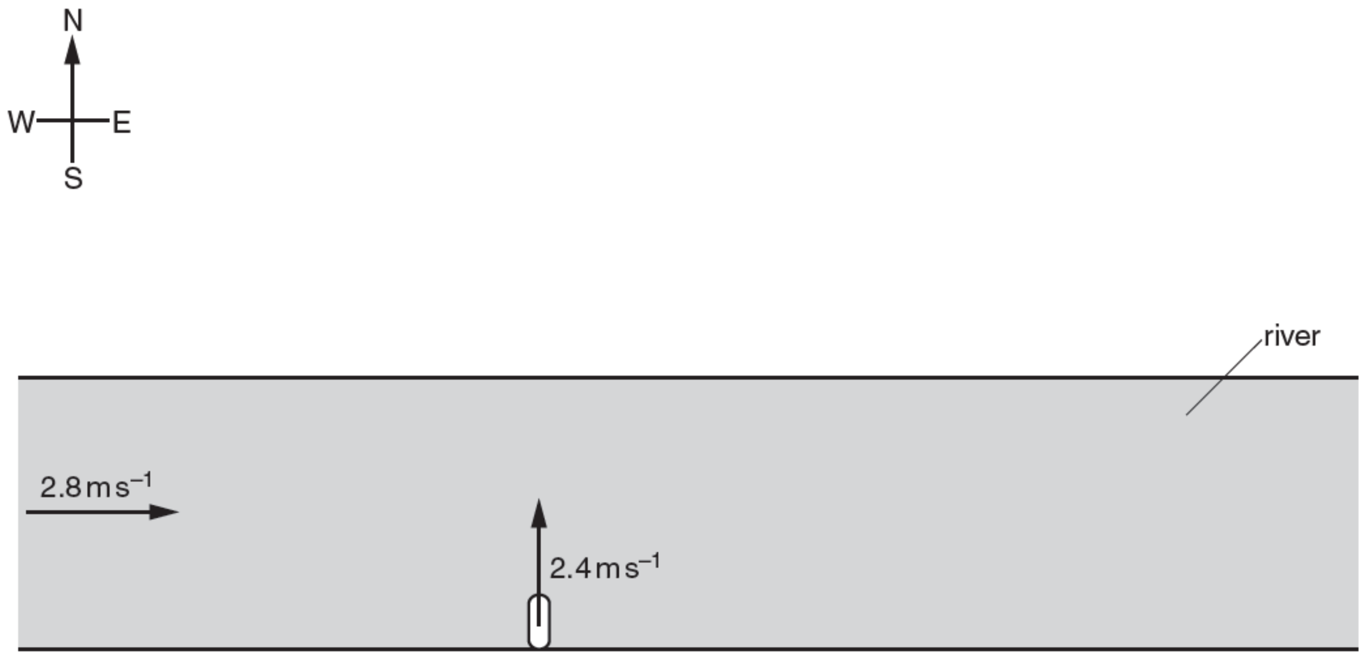
distance = ... m **[2]**

(d) Use information from Fig. 11.2 to describe how the resultant force upon the diver changes between **D** and **E**.

Suggest why the force changes in this way.

[2]

5 A boat heads out north to cross a river as shown in the diagram.



The boat moves at 2.4 m s^{-1} in still water. The river is flowing due east at 2.8 m s^{-1}.

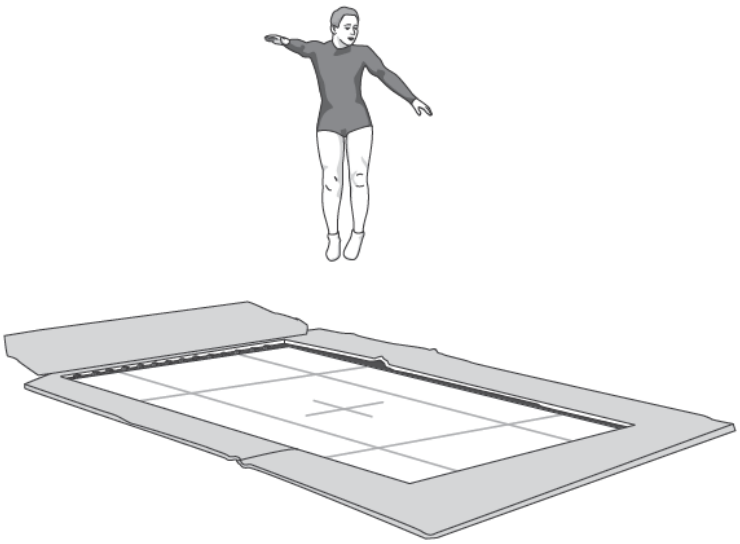
By scale drawing or by calculation, find the resultant velocity of the boat.

magnitude = ... m s^{-1}

direction = ...

[3]

6 A gymnast leaves the surface of a trampoline with an initial vertical velocity of $12\,\text{m}\,\text{s}^{-1}$.

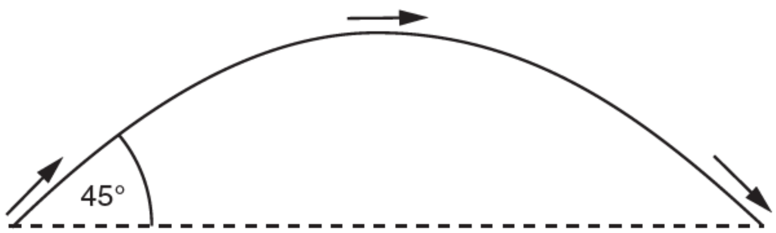


Calculate the height into the air that she rises. State any assumption that you make.

$g = 9.8\,\text{m}\,\text{s}^{-2}$

height = ... m **[3]**

7 A ball thrown at 45° to the horizontal follows the path shown in the diagram.



On the diagram, sketch the path the ball may take when it is thrown at the same speed but at an angle greater than 45° (and less than 90°) to the horizontal. **[2]**

10 In October 2012, the Austrian skydiver Felix Baumgartner jumped from a balloon more than 36 km above the Earth's surface. He fell freely for over four minutes before opening his parachute.

Fig. 10.1 shows how his velocity changed during that time.

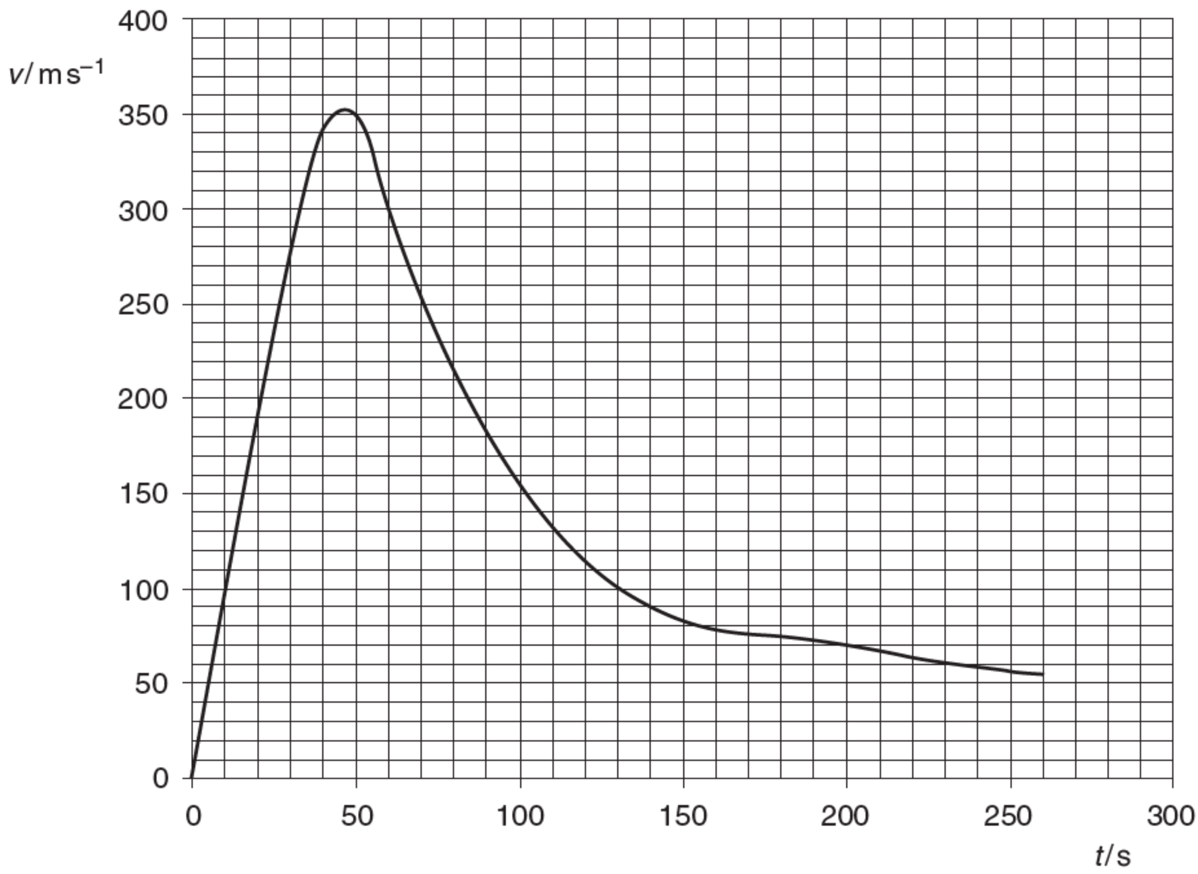


Fig. 10.1

(a) At the height from which Baumgartner jumped, the atmosphere is of very low density. As he fell, the air became denser.

(i) Using the graph of Fig. 10.1 show that, 30 s after he started to fall, his acceleration was about 7 m s^{-2}. Show your working clearly.

[2]

(ii) Calculate the upward force F acting on Baumgartner at this point.

total mass of Baumgartner = 95 kg

$g = 9.8\,\text{m}\,\text{s}^{-2}$

force = ... N **[3]**

(b) Describe the shape of the graph between 30 s and 70 s. Explain the velocity changes in terms of changes in the air through which Baumgartner was falling. You may wish to label any point(s) of interest on Fig. 10.1.

[3]

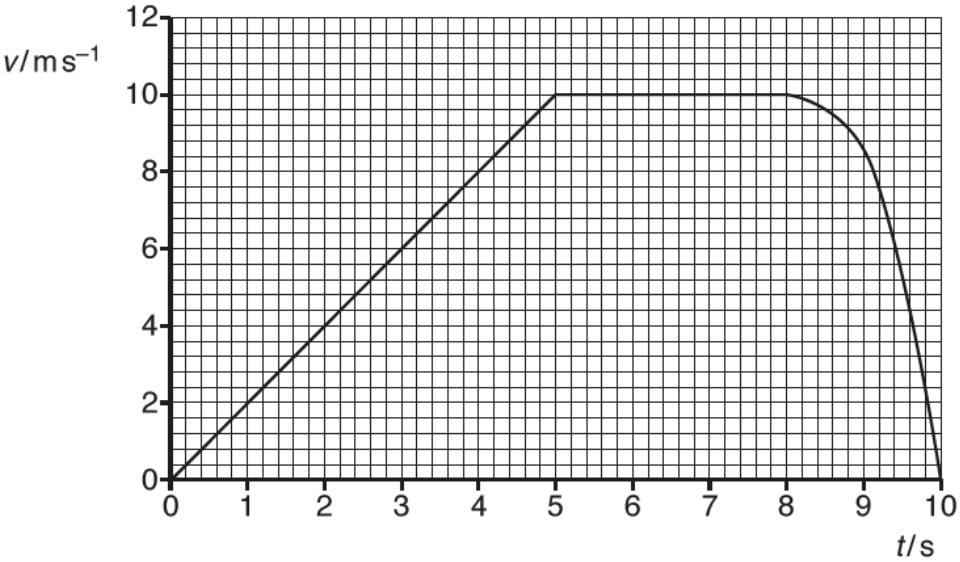
(c) It has been claimed that Baumgartner fell more than 35 km in the 260 seconds before he opened the parachute.

Use the graph of Fig. 10.1 to check whether this claim is correct.

Show your method clearly.

[3]

6 The velocity-time graph describes the motion of a car.



(a) Calculate the distance travelled by the car in the first 6 seconds.
You should show your working.

distance = ... m **[2]**

(b) Use the graph to estimate the deceleration of the car at $t = 8.5$ s.
You should show your working.

deceleration = ... m s^{-2} **[3]**

9 This question is about a projectile.
Fig. 9.1 shows a multi-flash picture of the motion of a dried pea fired horizontally from a pea-shooter in a classroom. The effect of air resistance is negligible.

Fig. 9.1

(a) The time interval between successive flashes is constant. At each flash, the new position of the pea is shown on the picture as a bright image on the dark background.

The horizontal displacement of the pea increases by equal amounts between flashes but the vertical displacement increases by increasing amounts.

Explain these observations.

[2]

(b) Describe how the multi-flash picture would have differed from Fig. 9.1 if the pea were replaced with a sphere made of low-density material such as polystyrene foam.

In your answer, you should consider the effect on both the horizontal and the vertical motion observed at regular time intervals.

[4]

(c) The pea is fired horizontally at a speed v from a vertical distance y above the floor.
It strikes the ground a time t later after travelling a horizontal distance x, as shown in Fig. 9.2.

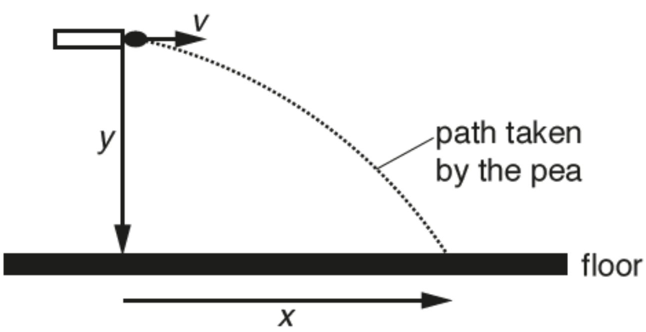


Fig. 9.2

The horizontal range x and the vertical distance fallen y are given by the equations

$$x = vt \qquad \text{and} \qquad y = \frac{1}{2}gt^2$$

where g is the acceleration due to gravity.

Show that these two equations can be combined to give the range x of the pea:

$$x = v\sqrt{\frac{2y}{g}}$$

[2]

(d) The pea-shooter is fired horizontally from a height of 1.5 m above the ground.

Calculate the speed v at which the dried pea must leave if it is to hit the bottom of a waste bin 2.6 m away.

$g = 9.8\,\text{m s}^{-2}$

v = ... m s^{-1} **[2]**

Notes