Chapter 8 Past Paper Question Booklet One (2861)

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

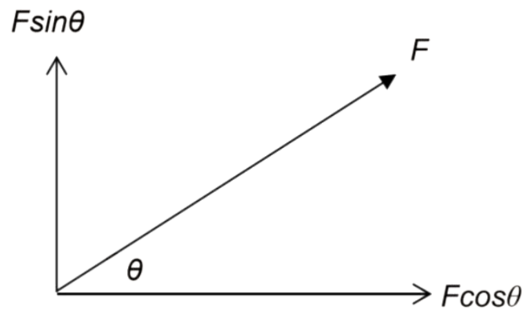
by sketching and interpreting:
(ii) graphs of accelerated motion; slope of s-t and v-t graphs, area underneath the line of a v-t graph
(iii) graphical representation of addition of vectors and changes in vector magnitude and direction

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

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

(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

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

12 This question is concerned with measuring the accelerations of objects.

(a) Name a real situation in which you might wish to measure the acceleration of an object.

.... [1]

(b) For this situation, describe

1. the apparatus you would use,
2. the measurements you would make,
3. how you would use your measurements to determine the acceleration.

[8]

(c) Describe what steps can be taken to ensure that the measurements are as accurate as possible.

[4]

Quality of Written Communication [4]

2 From the window of a train heading south at $30\,\text{m}\,\text{s}^{-1}$ a passenger observes a car moving at $24\,\text{m}\,\text{s}^{-1}$ on a road from east to west (Fig. 2.1).

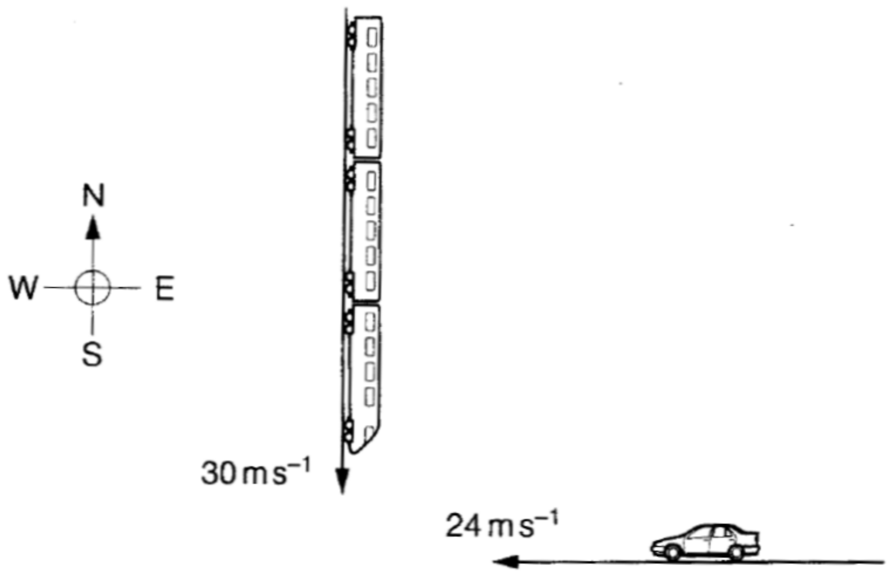


Fig. 2.1

(a) Using information from Fig. 2.1, draw a vector diagram to find the relative velocity at which the car appears to move towards the passenger. Identify the relative velocity on your diagram.

(b) From your diagram, or by calculation, write down the magnitude and direction of the relative velocity.

relative velocity, magnitude = ... $\text{m}\,\text{s}^{-1}$

direction = ... [4]

8 This question is about a golfer driving balls on a horizontal golf course.

In this question the effects of air resistance are to be ignored.

A golfer drives a ball off the tee with an initial velocity of $42\,m\,s^{-1}$ at an angle of 30° to the horizontal. Fig. 8.1 shows the trajectory of the ball through the air.

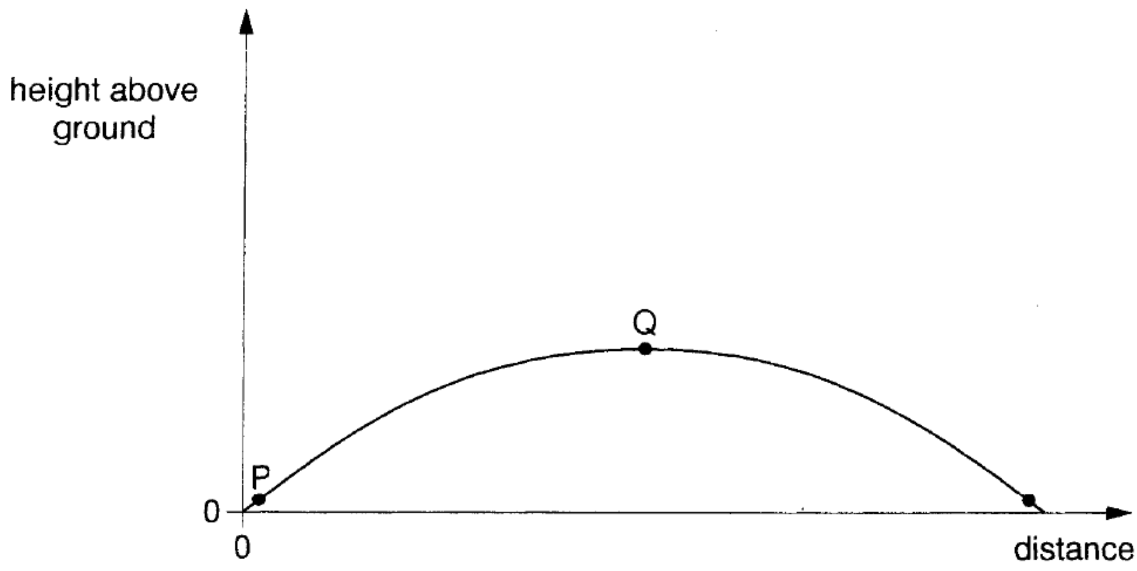


Fig. 8.1

(a) **(i)** Draw below, a vector diagram showing the horizontal and vertical components (including their magnitudes) of the velocity of the ball at the point P.

(ii) State the horizontal and vertical components of the velocity of the ball at Q.

horizontal component velocity = ... $m\,s^{-1}$

vertical component velocity = ... $m\,s^{-1}$

[6]

(b) Calculate

(i) how long the ball is in the air (consider the vertical component of velocity),

time = ... s

(ii) how far the ball travels to its first bounce (consider the horizontal component of velocity).

distance = ...: m

[4]

11 This question is about measuring the distance to a remote object.

(a) Thunder and lightning occur simultaneously. The distance away of a lightning flash can be estimated from measuring the time between seeing the flash and hearing the thunder. Estimate the distance away when the flash is seen 5.0 s before the thunder is heard. (The speed of sound in air is $340\ m\,s^{-1}$.)

[2]

(b) **(i)** Give an example of a remote object.

.... [1]

(ii) For your chosen object, describe how you would measure its distance from you. You should describe

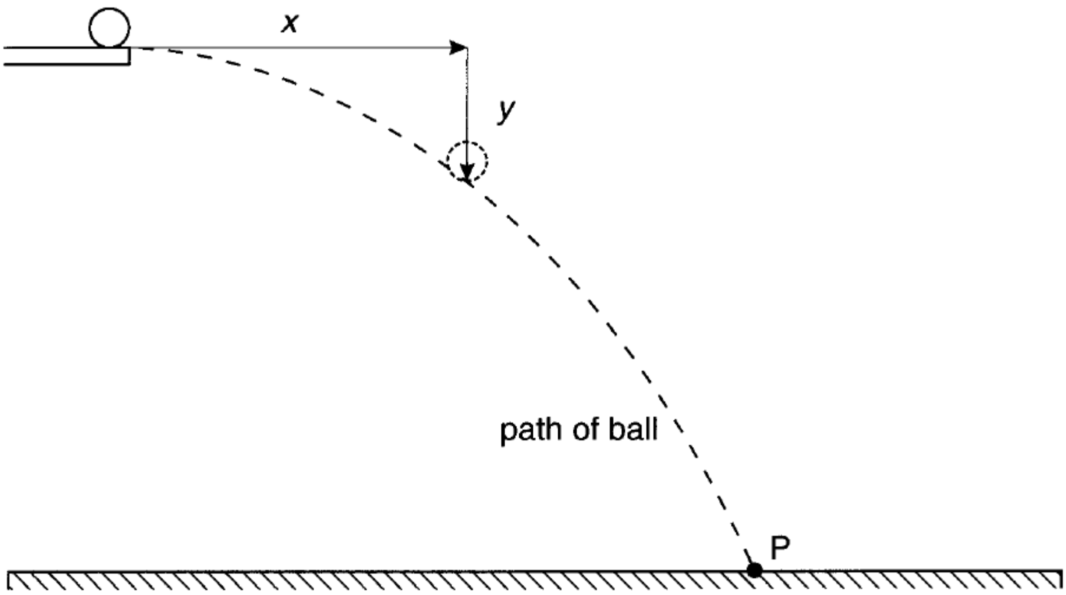
1. the principle on which your measurements would be made,
2. the measurements you would make,
3. how you would combine those measurements to calculate the distance to the object.

[6]

(iii) State two of the uncertainties in your measurements and describe how they affect the error in your value for the distance away of the object.

[4]

4 A heavy ball rolls off a shelf with an initial horizontal velocity v, and lands at point P some time later, as shown below.



The horizontal and vertical displacement of the ball from the edge of the shelf, at any time t during the flight, can be calculated as follows:

horizontal displacement $x = vt$ vertical displacement $y = \frac{1}{2}gt^2$,

where g is the acceleration due to gravity.

Show that the equation describing the path of the ball is given by:

$$y = \frac{gx^2}{2v^2}$$

[2]

6 A coin falls from rest, under gravity, down a deep well. The coin hits the bottom of the well 4.0 s later.

(a) Calculate the depth of the well.

acceleration due to gravity = $9.8\,\text{m}\,\text{s}^{-2}$.

depth = ... m

[2]

(b) In fact, the depth of the well is known to be 70 m.

Suggest a reason for the difference in the values.

[2]

2 Two aircraft, **A** and **B**, are travelling towards each other in level flight along a common flight path, as shown in Fig. 2.1.

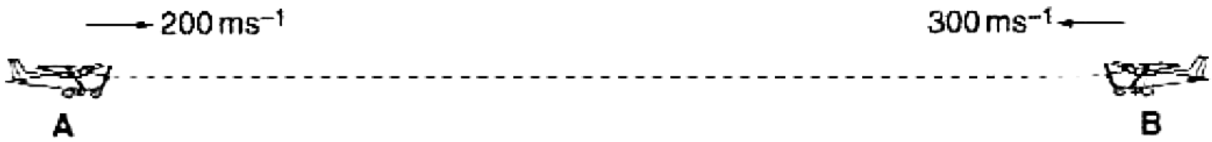


Fig. 2.1

The speeds of the two aircraft, relative to the ground, are $200\,m\,s^{-1}$ and $300\,m\,s^{-1}$ as shown.

(a) Calculate the magnitude of the relative velocity of approach of the two aircraft.

relative velocity = ...$m\,s^{-1}$ [1]

(b) Radar establishes that the two aircraft are 40 km apart. Calculate the time it would take for the aircraft to collide, if avoiding action is not taken.

time = ...s [2]

6 A girl takes up a hand-stand position on the edge of a high board above the water surface in the pool, as shown in Fig. 6.1.

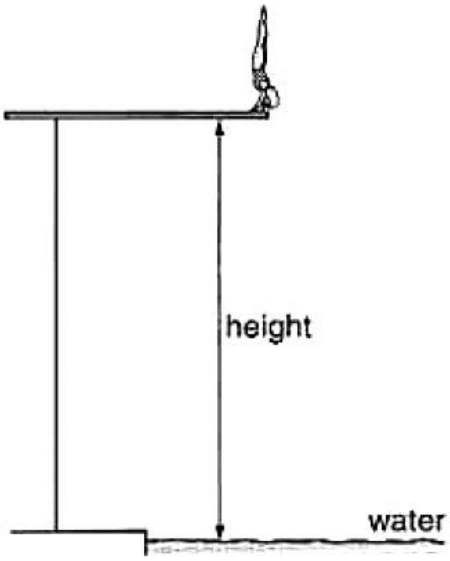


Fig. 6.1

She then dives vertically from rest through the air and enters the water 1.75 s after leaving the board.

Calculate the height of the diving board above the water surface. Neglect any effects of air resistance.

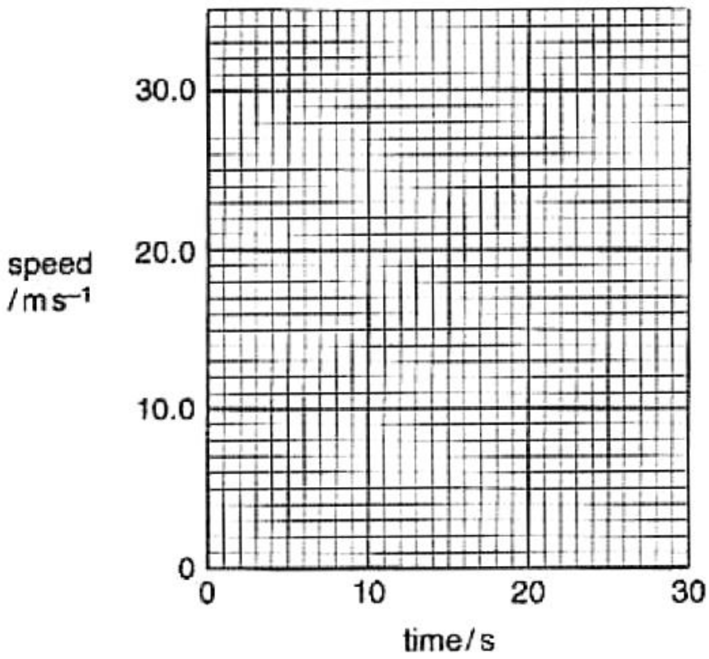
$g = 9.8\,\text{m s}^{-2}$

height = ...m [3]

11 A car of mass 1200 kg accelerates from rest to a speed of 30.0 m s^{-1}. The table below shows the speed of the car at 5 second intervals.

time /s	0	5	10	15	20	25	30
speed /m s^{-1}	0	13.0	21.5	26.5	29.0	30.0	30.0

(a) Plot a graph of speed against time on the axes below.



[2]

(b) **(i)** Calculate the **average** acceleration of the car between 0 s and 25 s. Show how you get your answer.

[2]

(ii) Using the speed-time graph, show that the distance the car travels in the first 25 s is about 500 m.

[2]

10 This question is about a small radio-controlled aircraft.

(b) By means of radio control, flaps on the aircraft are adjusted to make the aircraft start to climb with a vertical component of velocity of $4\,m\,s^{-1}$. The horizontal component of velocity is $10\,m\,s^{-1}$.

(i) In the space below, draw a vector diagram **to scale** showing the vertical and horizontal velocities of the aircraft.

[1]

(ii) By drawing, or by some other method of your choosing, find

1. the magnitude of the resultant velocity of the aircraft

[2]

2. the angle to the horizontal at which the aircraft climbs.

[2]

11 In this question, you are to write a short account of a method to measure the distance to a remote, or inaccessible, object of interest. In such situations, direct measurement of the distance by ruler or tape measure is impossible.

(a) **(i)** Describe the distance measurement to be made.

[1]

(ii) Give an estimate of the distance to be measured.

[1]

(b) **(i)** Draw a diagram to show how the apparatus is to be arranged to make the measurement. Label the important parts of the diagram.

[3]

3 A car travels a distance s in a time t with constant acceleration a. In this time, the velocity of the car increases from an initial velocity u to a final velocity v.

The equations below model the motion.

$$s = \frac{(u + v)t}{2} \qquad \textbf{equation 1}$$

$$v = u + at \qquad \textbf{equation 2}$$

(a) Rearrange each of these equations to make t the subject of the equation.

equation 1	**equation 2**
$t =$	$t =$ ....

[2]

(b) Equate the two expressions for t and hence show that

$$v^2 = u^2 + 2as.$$

[1]

10 This question is about the mathematical modelling of a golf shot.

(a) A golf professional demonstrates how to play an approach shot to a green. When struck, the golf ball follows the path shown from **W**, reaching its greatest vertical height *h* at **X**, and pitches onto the front of the green at **Y** as shown in Fig. 10.1.

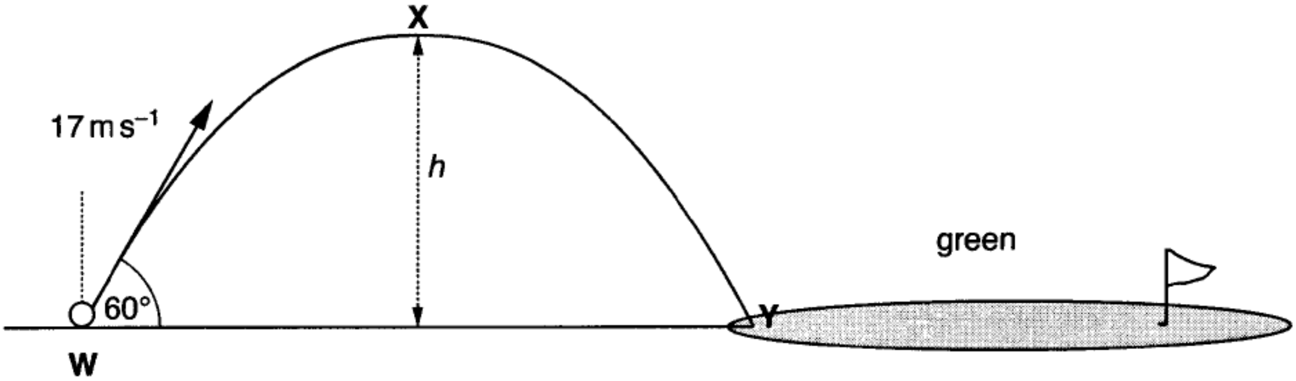


Fig. 10.1

(i) The ball leaves the ground at $17\,\text{m}\,\text{s}^{-1}$ at an angle of 60° to the horizontal.

Show that the initial vertical component of velocity v_y of the ball is $14.7\,\text{m}\,\text{s}^{-1}$.

[1]

(ii) At the highest point **X**, the vertical component of velocity $v_y = 0$.

Explain why the vertical component of velocity has changed.

[1]

(iii) The ball takes 1.5 s to reach its maximum height.

Calculate the maximum vertical height *h* reached by this ball.
$g = 9.8\,\text{m}\,\text{s}^{-2}$

h = ...m [3]

(b) The golf professional plays a second shot from the same position **W** using a different golf club. Again the ball pitches onto the front of the green at the same point **Y**, but the path through the air followed by this ball is quite different, as shown in Fig. 10.2.

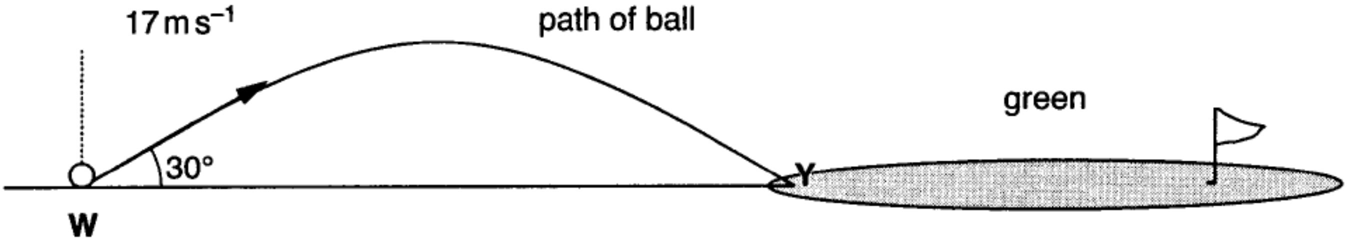


Fig. 10.2

This ball leaves the ground at 17 m s^{-1} as in the first shot, but at an angle of only 30° to the horizontal.

(i) State and explain how the time of flight for this ball travelling from **W** to **Y** compares with that of the first ball.

[2]

(ii) Explain why the horizontal range **WY** can be the same for each shot even though the times of flight are different.

[2]

(iii) Suggest and explain which of the two balls might be expected to travel further across the green after pitching onto it at **Y**.

[2]

11 This question is about **relative** and **resultant** velocities.

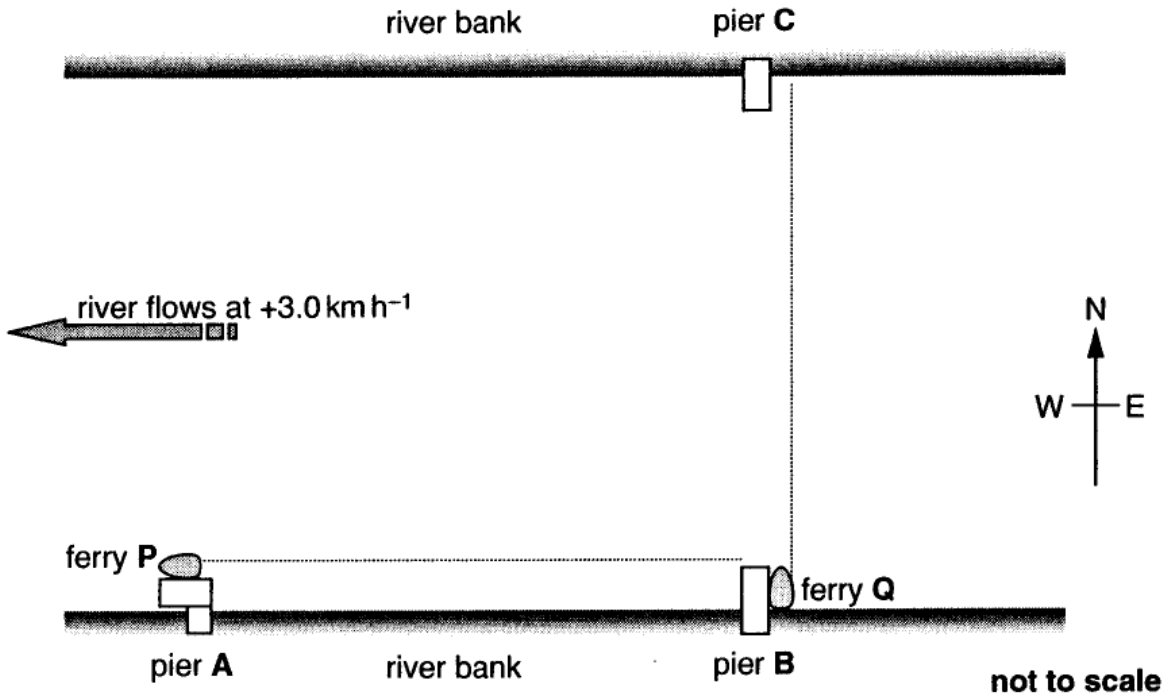


Fig. 11.1

Fig. 11.1 shows part of a wide river on which there are three piers. The river flows from east to west at a constant velocity of $+3.0\,\text{km}\,\text{h}^{-1}$ as shown.

(a) Ferry **P** travels from pier **A** to pier **B**, and then back again. The ferry travels at a speed of $5.0\,\text{km}\,\text{h}^{-1}$ through still water.

(i) Calculate the **velocity** of the ferry relative to the river bank as it sails

1. from **A** to **B**

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

2. from **B** to **A**.

velocity = ... $\text{km}\,\text{h}^{-1}$
[2]

(ii) Piers **A** and **B** are 2.0 km apart.

Show that the total sailing time for a return journey for ferry **P**, sailing from pier **A** to **B** and back again to **A**, is 1.25 hours.
Ignore the time taken for the boat to turn around at pier **B**.

[2]

(b) There is another pier **C** directly across the river from pier B, as shown in Fig. 11.1.

A second ferry **Q** travels between piers **B** and **C** which are 2.0 km apart. This ferry also travels at a speed of 5.0 km h^{-1} through still water.

(i) By scale drawing, or some other method of your choosing, show that ferry **Q** must sail in a direction 37 degrees east of north in order to travel due north across the river, from pier **B** to pier **C**.

[2]

(ii) Show that the resultant velocity of this ferry relative to the river bank is 4.0 km h^{-1} due north.

[2]

(c) Ferry **Q** sets off from pier **B** on an outward bound journey to **C** at the **same time** as ferry **P** sets off from pier **A** towards pier **B**.

Show that the bearing of ferry **Q** from ferry **P** is about 27 degrees east of north, when **Q** just reaches pier **C**.

[2]

3 Fig. 3.1 shows how the speed of a car changes with time during an emergency stop.

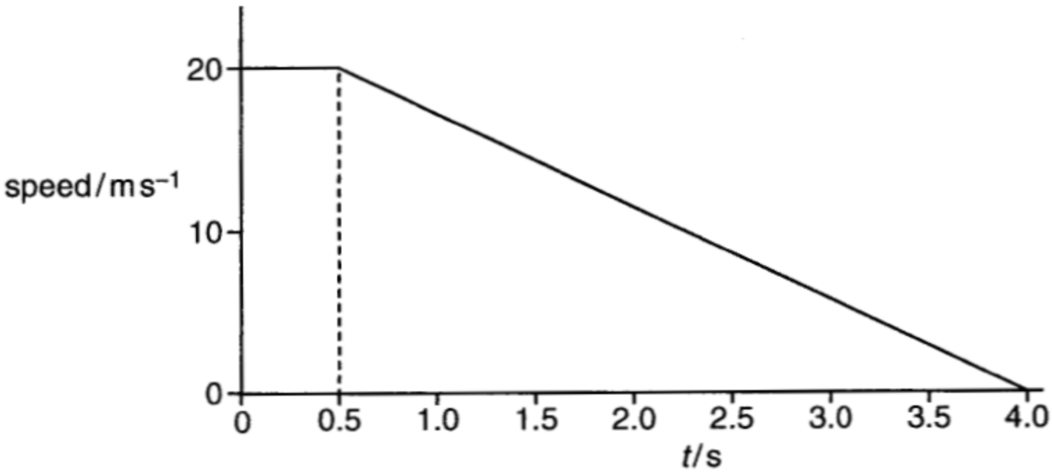


Fig. 3.1

The driver recognises there is a hazard at time $t = 0$, and the car comes to a halt 4.0 seconds later.

Use the graph to find

(a) the initial speed of the car

initial speed = ... m s^{-1} [1]

(b) the time taken for the driver to apply the brakes after seeing the hazard

time = ... s [1]

(c) the total stopping distance of the car.

total stopping distance = ... m [2]

5 Fig. 5.1 shows a human reflex test.

The tester, **A**, holds the top of a £20 note, while the person being tested, **B**, holds his hand still, with thumb and forefinger apart and level with the bottom of the note.

Without warning, **A** releases the note.

B must grasp it before it has passed through his fingers.

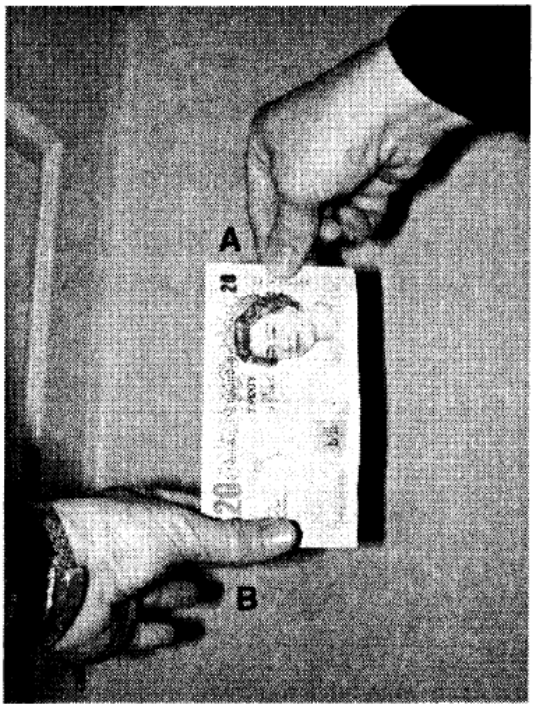


Fig. 5.1

The length of a £20 note is 150 mm.

Show that **B** must react in less than 0.2 s from the release of the note to catch it.
Neglect any effects of air resistance.

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

[3]

12 In this question, you are to write about a method of measuring the distance to a remote or inaccessible object.

(a) **(i)** State the distance measurement to be made.

[1]

(ii) Estimate the distance to be measured.

[1]

(b) **(i)** Draw a clear diagram to show the arrangement of apparatus required to collect data for the measurement of this distance. Label the important items of equipment.

[4]

10 This question is about a simple model of the physics of the long jump.

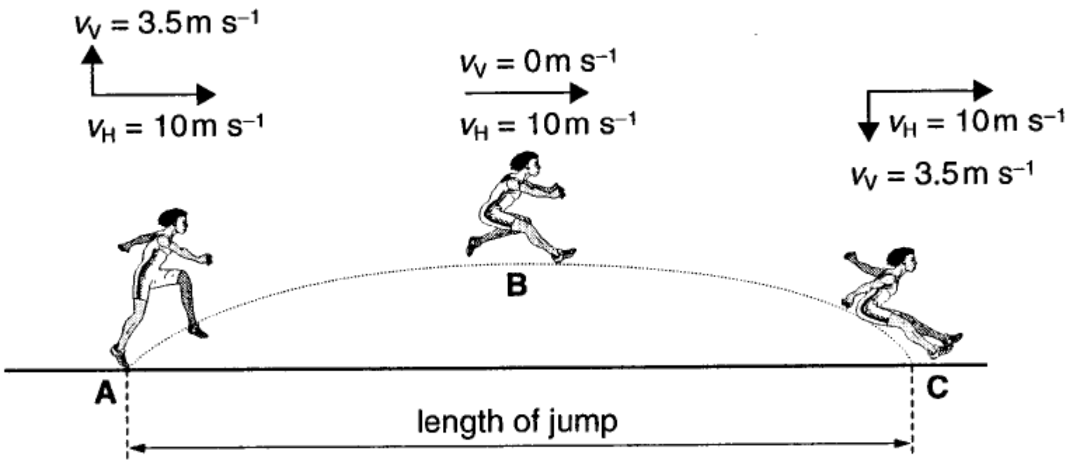


Fig. 10.1

Fig. 10.1 shows a long jumper at three different stages, **A**, **B** and **C**, during the jump. The horizontal and vertical components of velocity at each position are shown.

(a) **(i)** In the model, the horizontal component of velocity v_H is constant at $10\,m s^{-1}$ throughout the jump.

State the assumption that has been made in the model.

[1]

(ii) Without calculation, explain why the vertical component of velocity v_V changes from 3.5 m s^{-1} at **A** to 0 m s^{-1} at **B**.

[2]

(b) **(i)** By considering only the **vertical** motion, show that it takes about 0.4 s for the jumper to reach maximum height at **B** after taking off from **A**.

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

[2]

(ii) Hence, calculate the length of the jump.

length of the jump = ...m [2]

(c) Long jumpers can use this model to help them to improve their performance.

Explain why the length of the jump can be increased by

(i) increasing the horizontal component of velocity v_H, keeping v_V the same

[2]

(ii) increasing the vertical component of velocity v_V, keeping v_H the same.

[2]

4 A motor boat heads directly across a wide river towards the opposite bank. Its speed in still water is 2.0 m s^{-1}.

The river is flowing at 1.5 m s^{-1}, as shown in Fig. 4.1.

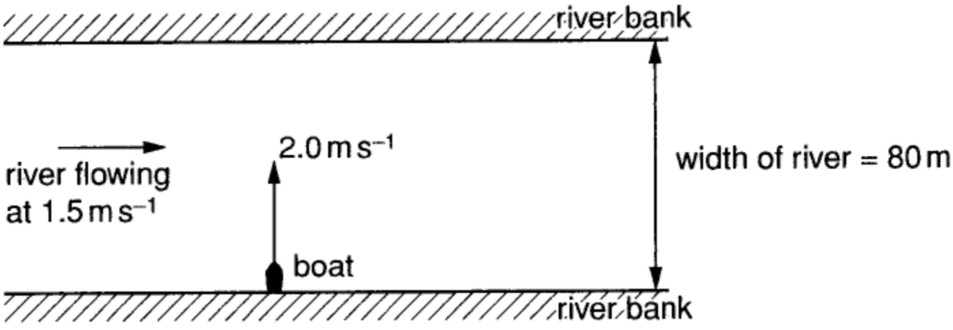


Fig. 4.1

The resultant velocity of the boat is found to be 2.5 m s^{-1} at an angle of 53° to the direction of flow of the river.

(a) By scale drawing, or some other method of your choosing, show how the resultant velocity is found.

[2]

(b) The river is 80 m wide and the boat crosses to the other side in 40 s.

Explain why the speed of flow of the river does **not** affect the time for the boat to cross the river in this case.

[2]

1 Here are three graphs representing different features of the same accelerated motion.

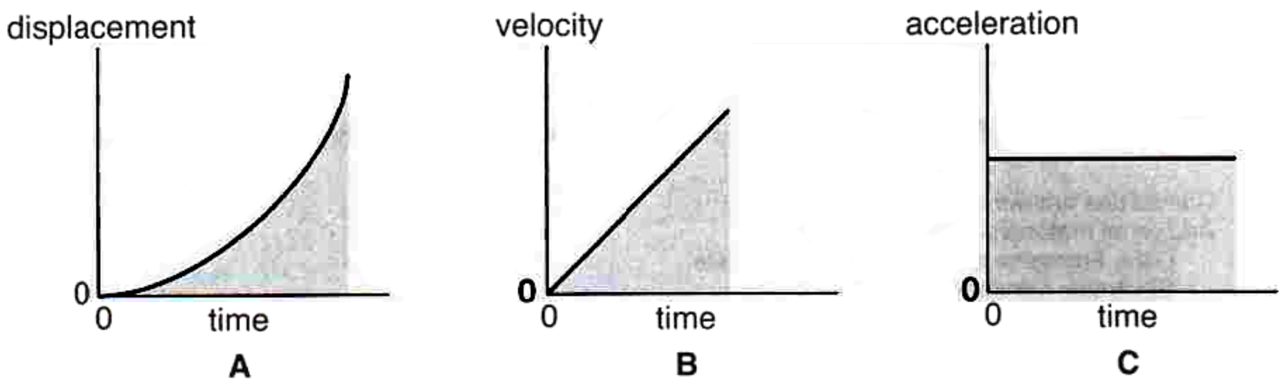


Fig. 1.1

In which graph, **A**, **B**, or **C**, in Fig. 1.1, does

(a) the gradient represent the acceleration

answer ....[1]

(b) the gradient represent the velocity

answer ....[1]

(c) the shaded area represent the distance travelled?

answer ....[1]

2 This question is about a car attempting an overtaking manoeuvre.

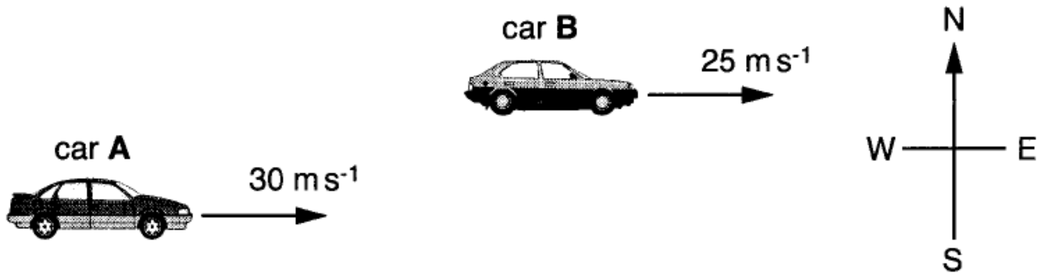


Fig. 2.1

Fig. 2.1 shows two cars travelling in an easterly direction.
Car **A** is attempting to overtake car **B** on a straight, level road.

(a) Calculate the magnitude and direction of the relative velocity of approach of car **A** to car **B**, as seen from car **B**.

magnitude = ... $m\,s^{-1}$ direction ....[2]

(b) At the instant shown in Fig. 2.1, car **A** is still some distance behind car **B**.
In order to complete the overtaking safely, car **A** must move forwards a distance of 35 m relative to car **B**.

Using your answer to **(a)**, calculate how long it will take for car **A** to reach this relative position.

time = ... s [1]

(c) Calculate the distance moved by car **B** in this time.

distance = ... m [1]

4 A stone is dropped down a well which is 6.80 m deep.

The time from releasing the stone to hearing the sound of it hitting the bottom of the well is 1.20 s.

(a) A student calculates the time for the stone to reach the bottom of the well and finds that it is less than 1.20 s.

Carry out the calculation to show that the time is less than 1.20 s.
Ignore any effects of air resistance.
Give your answer to **three** significant figures.

$g = 9.81\ \text{m}\,\text{s}^{-2}$

time = ... s [2]

(b) The student realises that the difference between these times is the time it takes for the sound caused by the stone hitting the bottom to travel back up the well. This allows him to estimate the velocity of sound in the well.

Calculate the velocity of sound in the well.

velocity of sound = ... $\text{m}\,\text{s}^{-1}$ [2]

6 A projectile is launched horizontally at a speed of $0.5\,m\,s^{-1}$ above the surface of the Moon.

The velocity of the projectile, at equal time intervals, is represented in magnitude and direction by the arrows shown in Fig. 6.1.

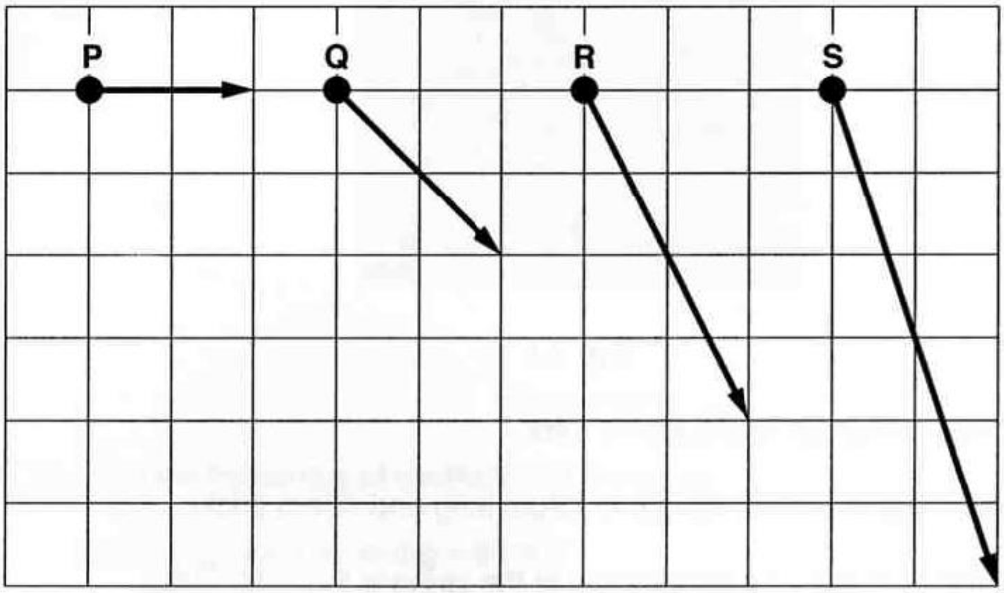


Fig. 6.1

(a) **(i)** Construct arrows on the diagram to represent the **vertical** component of velocity for each of the vectors **Q**, **R** and **S**. [1]

(ii) The grid on the diagram is drawn to the scale: 1 division represents $0.25\,m\,s^{-1}$.

Complete the table below.

velocity vector	P	Q	R	S
vertical component of velocity / $m\,s^{-1}$	0			

[1]

(b) The velocity vectors of the projectile are shown at 0.3 s intervals.

Using the information from **(a)**, calculate the acceleration due to gravity on the Moon.

acceleration = ... $m\,s^{-2}$ [2]

6 A motorcycle stunt rider, moving at constant speed, takes off horizontally from a launch point 2.0 m above the ground, as shown in Fig. 6.1.

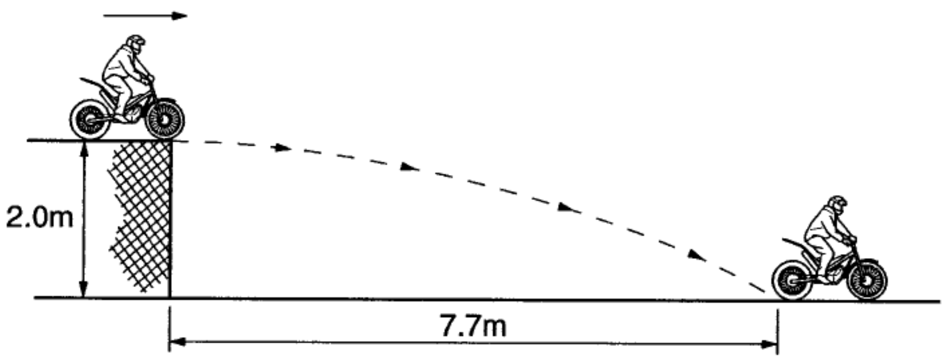


Fig. 6.1

He lands on the ground 7.7 m away as shown.

(a) By considering his vertical motion only, show that the time taken to reach the ground after he has taken off is about 0.6 s. Neglect the effects of any resistive forces.

acceleration due to gravity = $9.8\,m\,s^{-2}$

[2]

(b) Calculate the horizontal velocity at which he leaves the launching point.

velocity = ... $m\,s^{-1}$ [2]

10 This question is about relative velocity.

Fig. 10.1 shows two aircraft **K** and **L**, in level flight at the same altitude, approaching a radar beacon at **M**.

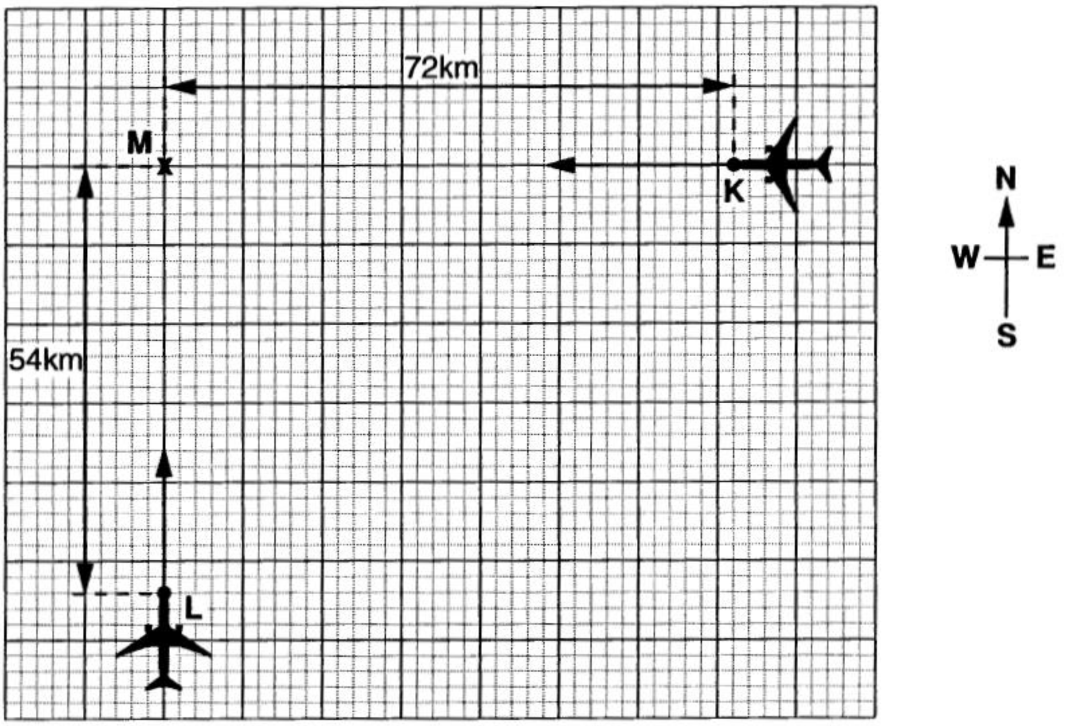


Fig. 10.1

(a) Use the information on the diagram to show that the **displacement** of aircraft **K** from aircraft **L** is 90 km, 53° East of North, when the aircraft are in the positions shown. You may find it helpful to draw a diagram in the space below.

[2]

(b) Aircraft **L** is flying due North at 900 km h^{-1} and aircraft **K** is flying due West at 1200 km h^{-1}. The magnitudes and directions of the velocity vectors are drawn to scale on Fig. 10.1. Scale: 1 cm represents 500 km h^{-1}.

(i) At the instant shown, the magnitude of the relative velocity of approach of aircraft **L** to aircraft **K** is 1500 km h^{-1} in a direction directly towards aircraft **K**.

Confirm this either by scale drawing on Fig. 10.1, or by some other method of your choosing.

[4]

(ii) Describe the position of aircraft **L** when aircraft **K** passes over point **M**, if the aircraft go on flying at their present velocities.

[1]

(c) Air traffic control rules do not permit aircraft to fly on paths like those shown in Fig. 10.1 at distances closer than 60 km.

Calculate the time taken for the aircraft to reach a position 60 km apart, from the instant shown in Fig. 10.1. Express your answer in seconds.

time = ... s [3]

7

Fig. 7.1

Two boats **X** and **Y** are travelling towards each other along the centre of a canal in still water. The speeds of the boats are 0.7 m s^{-1} and 1.2 m s^{-1} respectively, as shown in Fig. 7.1.

(a) Calculate the magnitude of the relative velocity of approach of the two boats.

relative velocity = ... m s^{-1} [1]

(b) The boats are 57 m apart at the instant shown in Fig. 7.1.

Calculate the time before the boats would collide if avoiding action is not taken.

time = ... s [2]

10 This question is about skydiving.

(a) A skydiver falls from a stationary balloon high above the surface of the Earth.
Air resistance can be neglected at this height since the density of the air is low.

Show that the time taken for the falling skydiver to accelerate to the speed of sound after leaving the balloon is more than 30 s.

speed of sound = 330 m s^{-1}
acceleration due to gravity = 9.8 m s^{-2}

[3]

(b) As the skydiver descends towards the Earth the density of the air increases.

Fig. 10.1 shows how the velocity of the skydiver changes with time as he falls towards Earth, before opening his parachute.

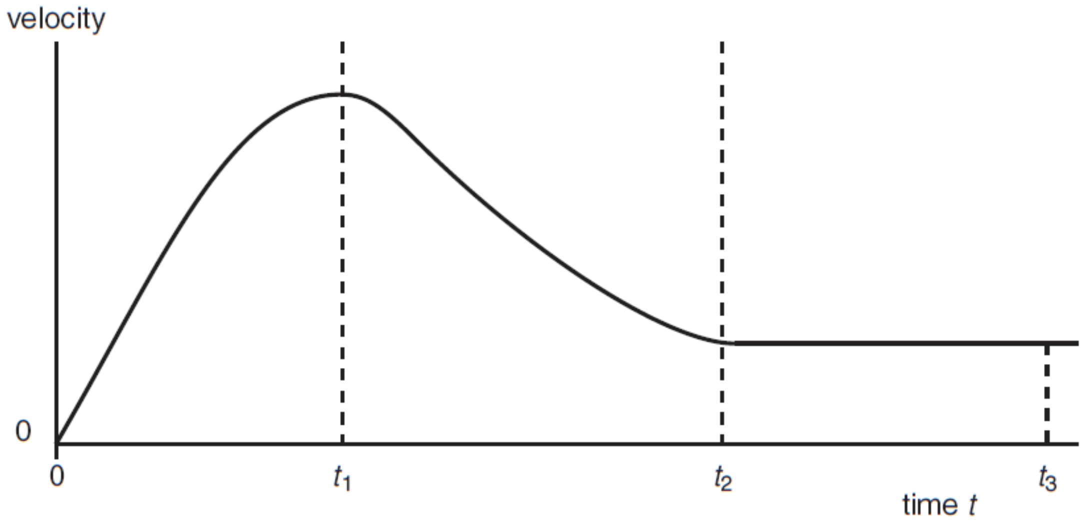


Fig. 10.1

(i) Complete the following statements.

1 The area under a velocity-time graph represents

....

2 The gradient of a velocity-time graph at any time represents

.... [2]

(ii) The graph shows three distinct stages of the skydiver's descent.

Using information from the graph, describe the motion of the skydiver in each of the time intervals shown on the graph.

$t = 0$ to $t = t_1$

$t = t_1$ to $t = t_2$

$t = t_2$ to $t = t_3$

[3]

(c) A camera man, in freefall alongside the skydiver, films every moment of the skydiver's descent.

An image has been removed due to third party copyright restrictions

Details: An image of a camera man in freefall alongside a skydiver

camera man skydiver

At $t = t_3$ the skydiver finally opens his parachute. The camera man continues in freefall. The film of the event shows the skydiver apparently accelerating upwards.

Explain this observation.

[2]

1 The cheetah is the fastest animal on land.
The highest speed reached by a cheetah is recorded as 114 km per hour.

(a) Show that 114 km per hour is about $32\,\mathrm{m\,s^{-1}}$.

[1]

(b) The cheetah can accelerate from rest to 114 km per hour in 8.4 s.

Calculate the average acceleration of the cheetah. Express your answer in $\mathrm{m\,s^{-2}}$.

average acceleration = ... $\mathrm{m\,s^{-2}}$ [2]

3 The conventional filament bulbs used for brake lights in cars are being replaced by light emitting diodes (LEDs). This question looks at one benefit of this technology.

Fig. 3.1

In a test two cars, **A** and **B,** are driven at a constant velocity of 30 m s^{-1} in the same direction along a level road, as shown in Fig. 3.1. The driver of the second car **B** is instructed to apply the brakes as quickly as he can after seeing the brake lights of car **A** come on.

(a) Assuming the reaction time of the driver is 0.6 s, calculate the distance travelled forward by car **B** during the reaction time of the driver.

distance = ... m [1]

(b) An LED takes only one microsecond (1 μs) to light after brakes are pressed, but a filament bulb takes 0.27 seconds. In the test the drivers do not know whether LEDs or filament bulbs have been fitted as brake lights in car **A**.

Calculate the **minimum** distance that the driver of car **B** ought to allow between the cars in order to avoid a collision when the brakes of car **A** are applied in this test.
Explain your reasoning.

distance = ... m [2]

9 This question is about the motion of a cricket ball from a bowling machine.

(a) A bowling machine launches a cricket ball horizontally from a height of 3.0 m above the ground, as shown in Fig. 9.1.

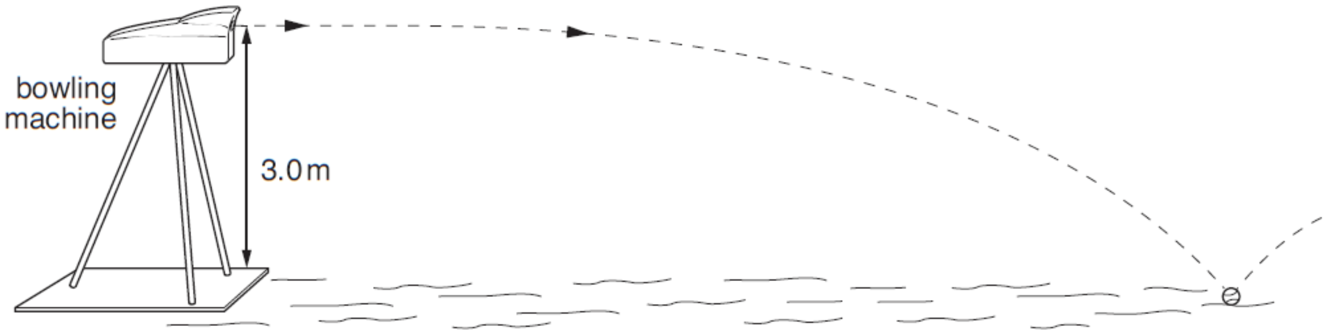
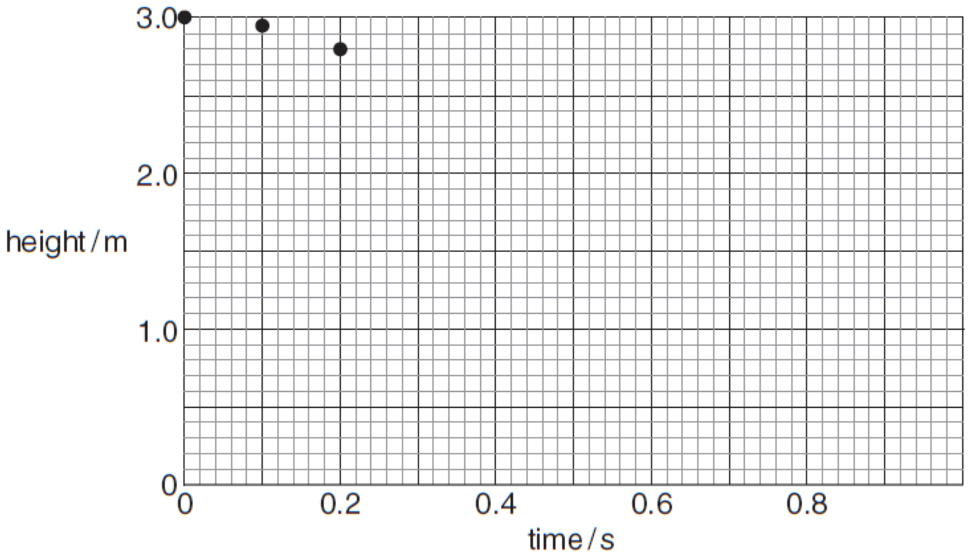


Fig. 9.1

The table shows the height and the horizontal displacement of the ball at various times.

time/s	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7
height/m	3.00	2.95	2.80	2.56	2.22	1.78	1.24	0.60
horizontal displacement/m	0.0	2.5	4.8	6.9	8.8	10.5	12.1	13.6

(i) On the axes of Fig. 9.2 draw a graph to show how the height of the ball above the ground varies with time. The first three points have been plotted for you.



[2]

Fig. 9.2

(ii) State the feature of the graph that shows that the ball is accelerating as it falls. Explain your reasoning.

[2]

(iii) Calculate the time taken for the cricket ball to fall vertically to the ground from a height of 3.0 m, neglecting air resistance.

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

time = ... s [2]

(iv) Use the **graph** to show that the vertical motion of the ball is hardly affected at all by air resistance forces.

[1]

(v) Use information from the **table** to show that the horizontal motion of the ball **is significantly** affected by air resistance forces.

[2]

(b) The vertical and horizontal components of velocity of the cricket ball as it reaches the ground are $7.6\,\mathrm{m\,s^{-1}}$ and $14\,\mathrm{m\,s^{-1}}$ respectively.

Find the angle to the horizontal at which the ball strikes the ground. Show your working.

angle to horizontal = ... degrees [2]

3 In 1966 John Stapp became the fastest man on Earth.
He was propelled along a track on a vehicle that reached a top speed of 1011 km h^{-1}.

(a) Show that the vehicle travels almost 300 m in 1 second at this speed.
Show your working.

[2]

(b) The vehicle was brought to rest from top speed in 1.4 s.

Show that the average deceleration was about 20*g*.
acceleration due to gravity g = 9.8 m s^{-2}

[2]

9 This question is about the motion of a sphere in a viscous liquid.

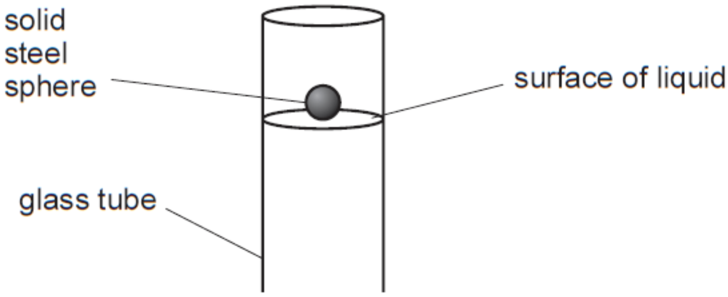


Fig. 9.1

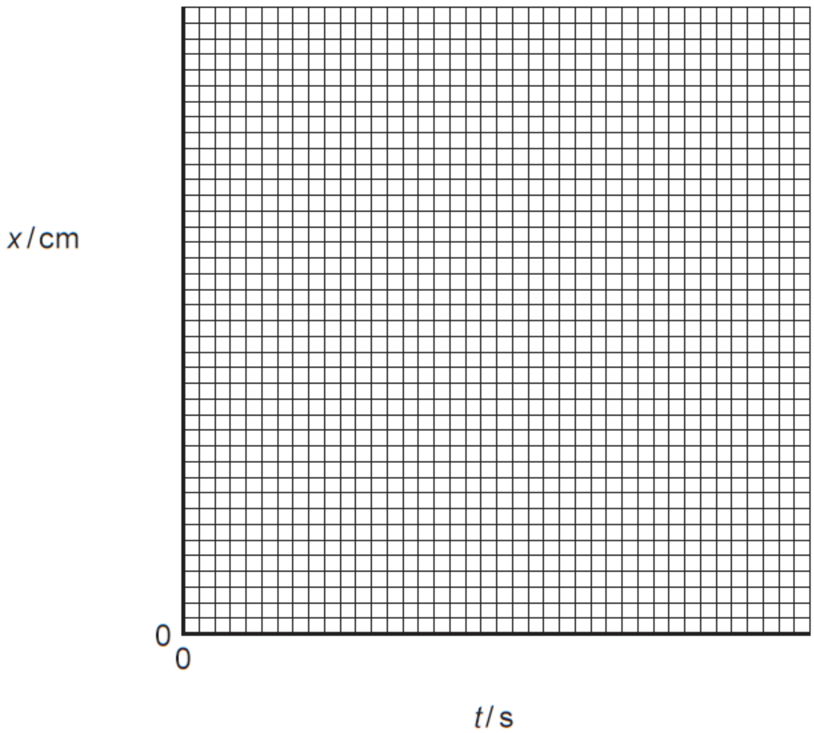
(a) A solid steel sphere is released from rest at the surface of a transparent liquid in a cylindrical glass tube, as shown in Fig. 9.1

The time *t* taken for the sphere to fall to different distances *x* below the surface of the liquid is recorded in Fig. 9.2.

x /cm	0	20	40	60	80	100	120
t /s	0.0	1.6	2.4	3.0	3.4	3.8	4.2

Fig. 9.2

(i) On the axes below, draw a graph to show how the distance *x* travelled by the sphere varies with time *t* from the moment of release (*t* = 0).



[3]

(ii) Describe the motion of the sphere between $t = 0$ and $t = 4$ s. Make your reasoning clear.

[3]

(b) A student attempts to use the data in Fig. 9.2 to obtain an estimate of the speed v of the falling sphere at different distances x below the liquid surface.
The data are processed as shown in Fig. 9.3.

x/cm	t /s	Δx /cm	Δt /s	$v = \Delta x / \Delta t$ /cm s^{-1}
0	0	-	-	-
20	1.6	(40 – 0) = 40	(2.4 – 0) = 2.4	40 / 2.4 = 17
40	2.4	(60 – 20) = 40	(3.0 – 1.6) = 1.4	40 / 1.4 = 29
60	3.0	(80 – 40) = 40	(3.4 – 2.4) = 1.0	40 / 1.0 = 40
80	3.4	(100 – 60) = 40	(3.8 – 3.0) = 0.8	40 / 0.8 = 50
100	3.8	(120 – 80) = 40	(4.2 – 3.4) = 0.8	40 / 0.8 = 50
120	4.2	-	-	-

Fig. 9.3

(i) Explain what the student has done to get a value for the speed v of the sphere at $x = 100$ cm.

[2]

(ii) Explain why calculating the value of v in this way gives a good estimate of the speed of the sphere at depth 100 cm, but gives an inaccurate estimate for the speed at depth 40 cm.

[2]

13 In this question you are to describe how to make an accurate measurement of the acceleration of a trolley moving down a ramp.

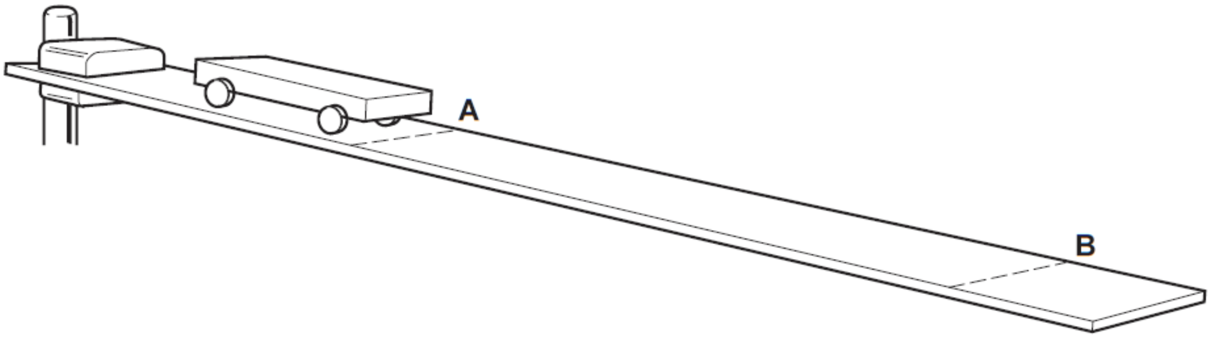


Fig. 13.1

One end of the ramp is firmly supported above the bench in the position shown in Fig. 13.1. The trolley is released from rest at **A** and accelerates down the ramp through **B**.

(a) State the quantities that would need to be measured in order to be able to calculate the average acceleration of the trolley between **A** and **B**.

[2]

(b) Describe and explain how you would make accurate measurements of the quantities you stated in **(a)**.

[4]

(c) Show how the quantities would be used to find a value for the average acceleration.

[2]

(d) **(i)** State **two** different factors that can introduce uncertainty into the measurement of the acceleration by this method.

1.

2.

[2]

(ii) Explain how the uncertainty might be reduced.

[2]

2 In Acapulco, Mexico, a common sport is to dive into the sea from a cliff 28 m above the water surface.

Calculate the maximum velocity a diver could reach just before entering the water. State any assumption that you make.

acceleration due to gravity = 9.8 m s^{-2}

working

maximum velocity = ... m s^{-1}

assumption

[3]

3 Fig. 3.1 shows a man running with an umbrella through the rain.

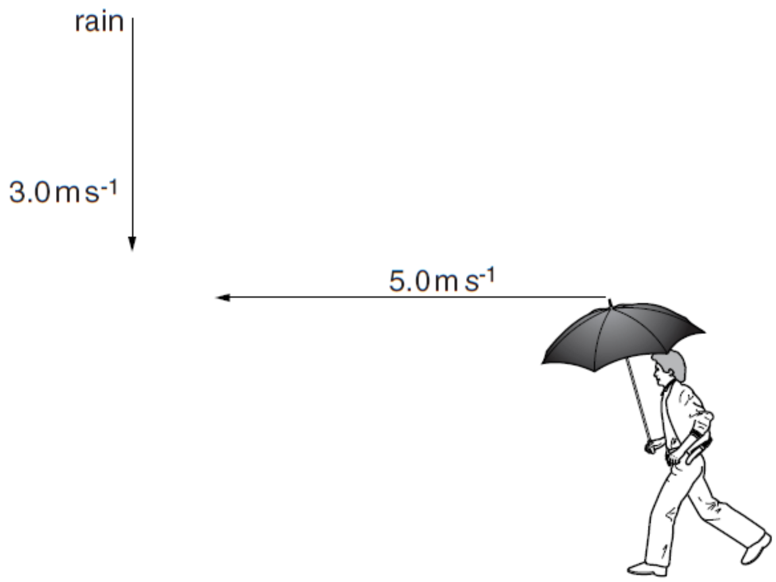


Fig. 3.1

The rain is falling vertically at a speed of $3.0\,\mathrm{m\,s^{-1}}$ and the horizontal speed of the man is $5.0\,\mathrm{m\,s^{-1}}$, as shown.

By scale drawing, or by some other method of your choosing, show that the velocity of the rain relative to the umbrella is $5.8\,\mathrm{m\,s^{-1}}$ at an angle of about 60° to the vertical.

[3]

7 An ultrasonic 'tape measure' is used to measure the depth of a deep well.

The device sends pulses of ultrasound down the well to the water surface and electronically measures the time for the pulse to return.

In one measurement the pulse returns after 0.67 s.

Calculate the depth of the well.

speed of ultrasound in air = $330\,m\,s^{-1}$

depth of the well = ... m **[3]**

9 This question is taken from an investigation into bouncing balls.

Ignore any effects of air resistance in this question.

(a) A steel ball is dropped from rest at a height of 3.0 m above a horizontal surface.

(i) Show that the time taken for the ball to reach the surface is about 0.8 s.

acceleration due to gravity = $9.8\,\text{m}\,\text{s}^{-2}$

[2]

(ii) Calculate the vertical speed of the ball as it strikes the surface after falling 3.0 m.

vertical speed = ... $\text{m}\,\text{s}^{-1}$ **[2]**

(iii) 16% of the energy of the ball is absorbed in every vertical impact with the surface.

Show that about 70% of the initial energy of the ball will have gone after **seven** successive bounces.

[2]

(b) The same ball is then projected horizontally with a speed *v* from a height of 3.0 m and strikes the surface after travelling a horizontal distance of 2.2 m, as shown in Fig. 9.1.

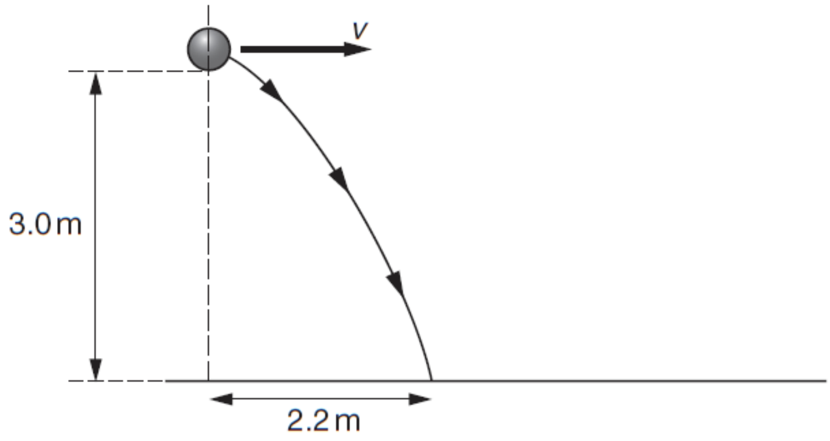


Fig. 9.1

(i) Show that *v* equals 2.8 m s^{-1}.

[1]

(ii) By scale drawing, or by some other method of your choosing, calculate the magnitude and direction of the resultant velocity of this ball on impact with the surface.

magnitude of resultant velocity = ... m s^{-1}

direction = ...

[3]

Notes

Notes