KINEMATICS WORKSHEET
AS Level Physics 9702

MJ24/21/Q2

1 **(a)** Define velocity.

....

.... [1]

(b) A student throws a ball over a vertical wall of height h, as shown in Fig. 2.1.

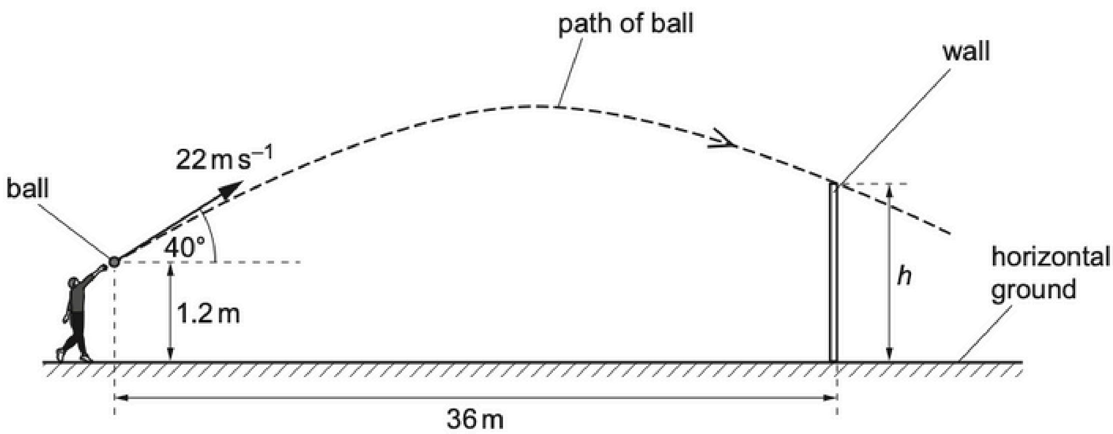

Fig. 2.1 (not to scale)

The ball leaves the hand of the student at a height of 1.2 m above the horizontal ground.
The ball has an initial velocity of $22\,\text{m}\,\text{s}^{-1}$ at an angle of 40° to the horizontal.
The wall is a horizontal distance of 36 m from where the student releases the ball.

Air resistance is negligible.

(i) Determine the time taken for the ball to reach the wall.

time taken = ... s [2]

(ii) Calculate the vertical component *u* of the initial velocity of the ball.

u = ... $m s^{-1}$ [1]

(iii) The ball just goes over the wall.

Calculate the height *h* of the wall.

h = ... m [3]

[Total: 7]

2 A skydiver jumps from an aircraft at time t = 0 and falls vertically downwards. The variation with t of her velocity v is shown in Fig. 2.1.

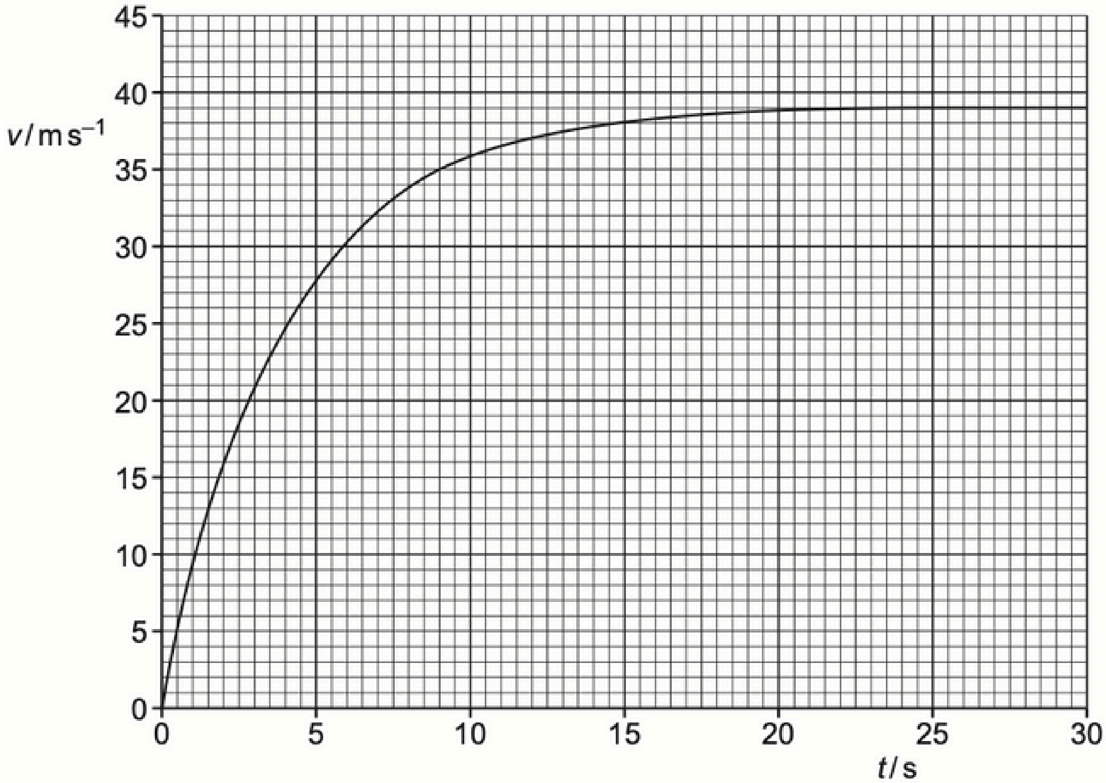

Fig. 2.1

(a) **(i)** Using Fig. 2.1, state the terminal velocity of the skydiver.

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

(ii) By drawing a suitable line on Fig. 2.1, determine the acceleration of the skydiver at time t = 9.0 s.

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

(b) The mass of the skydiver and her equipment is 68 kg. The upthrust on the skydiver is negligible.

After reaching terminal velocity, the skydiver opens her parachute at time t_1. A total drag force of 1800 N acts on the skydiver.

Determine the magnitude and direction of the acceleration of the skydiver at time t_1.

acceleration = ... $m s^{-2}$

direction = ...
[3]

(c) The parachute is fully open at time t_2. At a later time t_3 the skydiver reaches a constant velocity of $5.7 m s^{-1}$.

(i) Describe and explain the variation with time of the magnitude of her acceleration between time t_2 and time t_3.

....

....

....

....

.... [2]

Q3 **(a)** Define displacement from a point.

....

.... [1]

(b) An object is projected horizontally at a speed of $6.0\,m\,s^{-1}$ from a slope, as shown in Fig. 2.1.

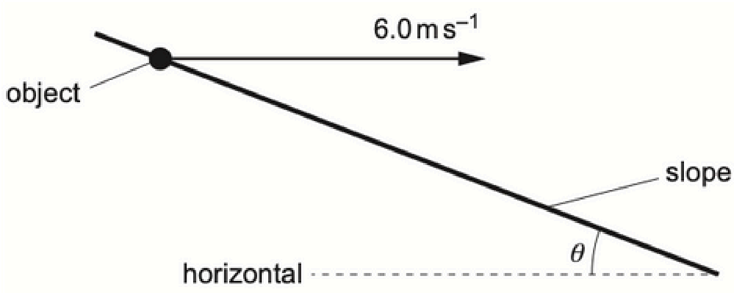

Fig. 2.1 (not to scale)

The slope is at an angle θ to the horizontal. Air resistance is negligible.

The object lands on the slope a time of 0.71 s later and stops without rolling or bouncing.

(i) Determine the horizontal distance travelled by the object.

distance = ... m [1]

(ii) Determine the vertical distance travelled by the object.

distance = ... m [2]

(iii) Use your answers in **(b)(i)** and **(b)(ii)** to calculate θ.

θ = ... ° [2]

(iv) Determine the magnitude of the displacement of the object from its original position.

displacement = ... m [2]

Q4 (a) Define acceleration. **March24/22/Q2**

....

.... [1]

(b) An Olympic diver stands on a platform above a pool of water, as shown in Fig. 2.1.

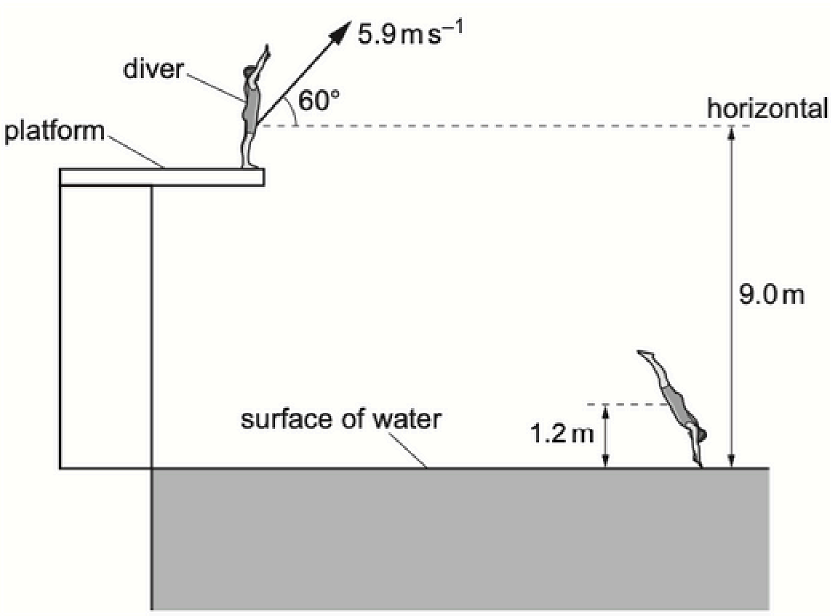

Fig. 2.1 (not to scale)

When the diver is on the platform his centre of gravity is a vertical height of 9.0 m above the surface of the water. The diver jumps from the platform with a velocity of 5.9 m s^{-1} at an angle of 60° to the horizontal.

Air resistance is negligible.

When the diver hits the surface of the water, his centre of gravity is a vertical height of 1.2 m above the surface of the water.

Calculate the speed of the diver at the instant he hits the surface of the water.

speed = ... m s^{-1} [3]

Q5 **(a)** In the following list, underline **all** quantities that are SI base quantities. **ON23/22/Q1**

charge electric current force time [1]

(b) Under certain conditions, the distance *s* moved in a straight line by an object in time *t* is given by

$$s = \frac{1}{2}at^2$$

where *a* is the acceleration of the object.

State **two** conditions under which the above expression applies to the motion of the object.

1 ....

2 ....
[2]

(c) The variation with time *t* of the velocity *v* of a car that is moving in a straight line is shown in Fig. 1.1.

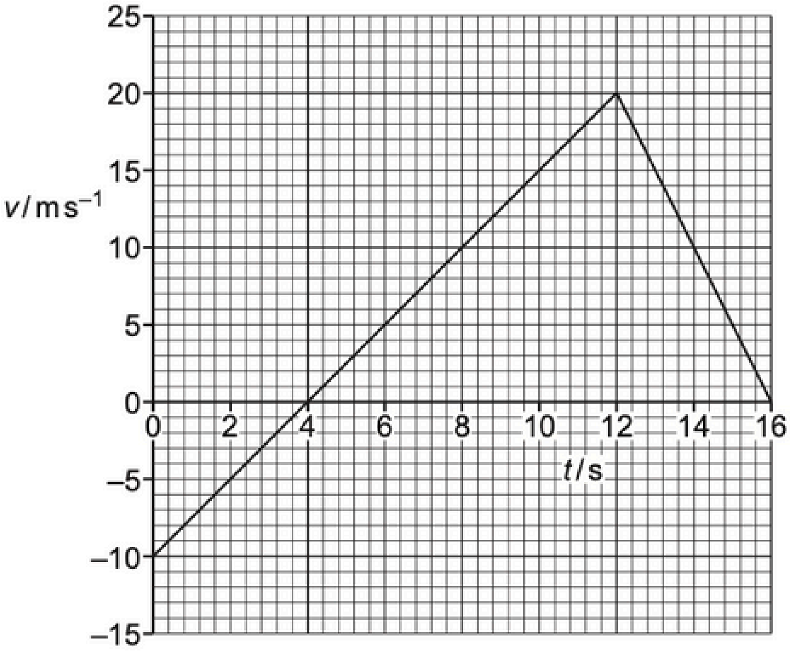

Fig. 1.1

(i) Compare, qualitatively, the acceleration of the car at time $t = 8.0$ s and at time $t = 14.0$ s in terms of:

- magnitude

....

....

- direction.

....

.... [2]

(ii) Determine the magnitude of the acceleration of the car at time $t = 4.0$ s.

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

(iii) The car is at point X at time $t = 0$.

Determine the magnitude of the displacement of the car from X at time $t = 12.0\,s$.

displacement = ... m [2]

[Total: 9]

ON23/23/Q2

Q6 A ball on horizontal ground is kicked towards a vertical wall. Fig. 2.1 shows the path of the ball.

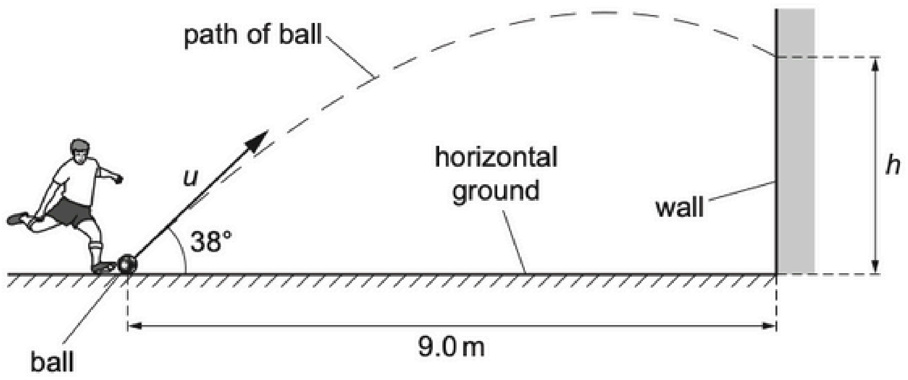

Fig. 2.1 (not to scale)

The ball has an initial velocity u at an angle of 38° to the ground. The ball travels a horizontal distance of 9.0 m before striking the wall at a height h above the ground. The horizontal component u_H of the initial velocity of the ball is $9.5\,m\,s^{-1}$.

Air resistance is negligible.

(a) **(i)** Show that the time t for the ball to reach the wall is 0.95 s.

[1]

(ii) Calculate the vertical component u_V of the initial velocity of the ball.

u_V = ... $m s^{-1}$ [2]

(iii) Determine h.

h = ... m [2]

MJ23/23/Q1

Q7 A well has a depth of 36 m from ground level to the surface of the water in the well, as shown in Fig. 1.1.

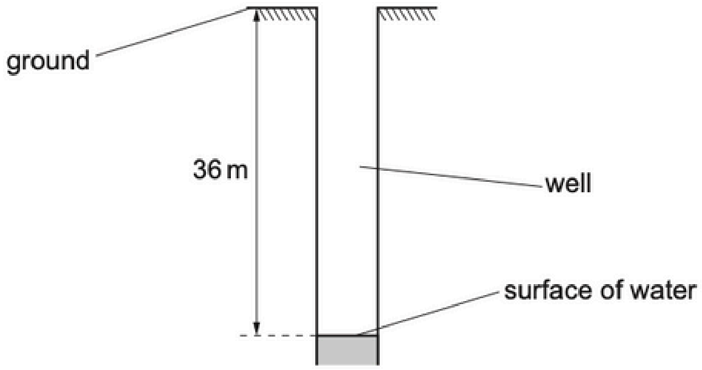

Fig. 1.1 (not to scale)

A student wishes to find the depth of the well. The student plans to drop a stone down the well and record the time taken from releasing the stone to hearing the splash made by the stone as it enters the water.

(a) Assume that air resistance is negligible and that the stone is released from rest.

Calculate the time taken for the stone to fall from ground level to the surface of the water.

time = ... s [2]

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(b) The time recorded by the student using a stop-watch is not equal to the time in **(a)**.

Suggest **three** possible reasons, other than the effect of air resistance, for this difference.

1 ....

....

2 ....

....

3 ....

....
[3]

(c) The student repeats the experiment three times and uses the results to calculate the depth of the well. The values are shown in Table 1.1.

Table 1.1

	1st experiment	2nd experiment	3rd experiment
depth/m	54.4	53.9	54.1

The true depth of the well is 36.0 m. Explain why these results may be described as precise but not accurate.

....

....

....

.... [2]

[Total: 7]

March 2023/22/Q1

Q8 **(a)** Underline **all** the SI base units in the following list.

ampere coulomb current kelvin newton [1]

(b) A toy car moves in a horizontal straight line. The displacement *s* of the car is given by the equation

$$s = \frac{v^2}{2a}$$

where *a* is the acceleration of the car and *v* is its final velocity.

State **two** conditions that apply to the motion of the car in order for the above equation to be valid.

1 ....

2 ....
[2]

(c) An experiment is performed to determine the acceleration of the car in **(b)**. The following measurements are obtained:

$s = 3.89\,\text{m} \pm 0.5\%$
$v = 2.75\,\text{m}\,\text{s}^{-1} \pm 0.8\%$.

(i) Calculate the acceleration *a* of the car.

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

(ii) Determine the percentage uncertainty, to two significant figures, in *a*.

percentage uncertainty = ... % [2]

(iii) Use your answers in **(c)(i)** and **(c)(ii)** to determine the absolute uncertainty in the calculated value of *a*.

absolute uncertainty = ... $\text{m}\,\text{s}^{-2}$ [1]

[Total: 7]

Q9 A steel ball is projected horizontally from the top of a table, as shown in Fig. 2.1.

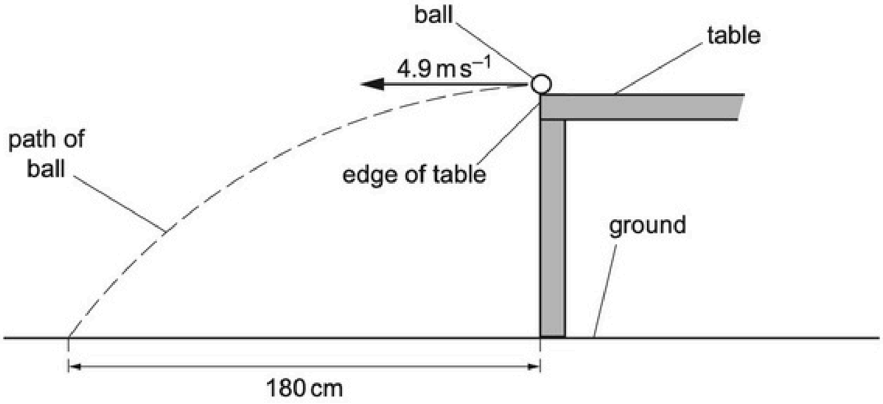


Fig. 2.1 (not to scale)

The ball is projected horizontally at a speed of $4.9\,\text{m s}^{-1}$. The ball lands on the ground a horizontal distance of 180 cm from the edge of the table.

Assume that air resistance is negligible.

(a) **(i)** Calculate the time taken for the ball to reach the ground.

time = ... s [1]

(ii) Calculate the vertical component of the velocity of the ball as it hits the ground.

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

(iii) Determine the magnitude and the angle to the horizontal of the velocity of the ball as it hits the ground.

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

angle to the horizontal = ... °

[3]

(b) The ball is projected by means of a compressed spring which is attached to a fixed block as shown in Fig. 2.2.

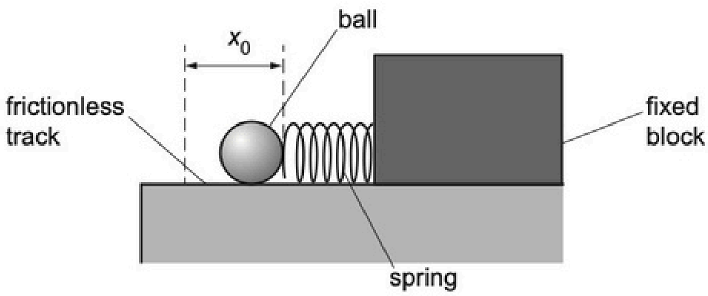
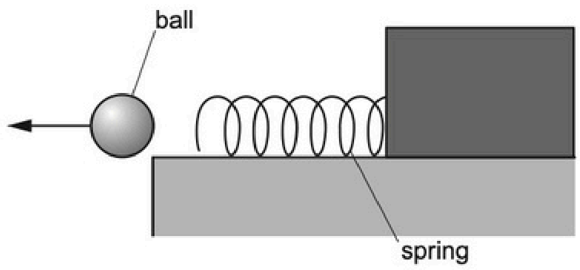


Fig. 2.2

The ball is placed on a frictionless track in front of the spring. The ball is then pulled back so that the spring has compression x_0.

When the spring is released, the ball is projected horizontally as shown in Fig. 2.3.



The variation with compression x of the applied force F for the spring is shown in Fig. 2.4.

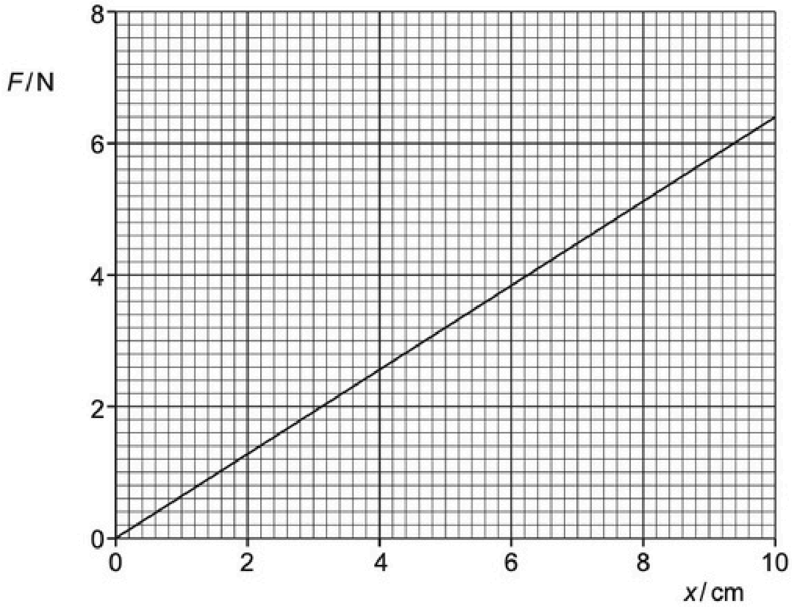


Fig. 2.4

The ball is a uniform sphere of steel of diameter 0.016 m and mass 0.017 kg.

(i) Calculate the density of the steel.

density = ... $kg\,m^{-3}$ [3]

(ii) All of the elastic potential energy in the spring is converted into kinetic energy of the ball. The speed of the ball as it leaves the spring is $4.9\,m\,s^{-1}$.

Show that the maximum elastic potential energy of the spring is 0.20 J.

[2]

(iii) Use Fig. 2.4 to determine the spring constant k of the spring.

k = ... Nm^{-1} [2]

(iv) Use your answer in **(b)(iii)** and the value of energy given in **(b)(ii)** to determine the compression x_0 of the spring.

x_0 = ... m [2]

(c) The steel ball is replaced by a polystyrene ball of the same diameter but of much lower mass. The spring is given compression x_0 and is then released.

Air resistance on this ball is **not** negligible after it leaves the spring.

Explain:

(i) why this ball leaves the spring with a greater speed than that of the steel ball

....

....

.... [1]

(ii) why this ball takes a longer time to reach the ground than the steel ball.

....

....

.... [1]

[Total: 17]

Q10 A man standing on a wall throws a small ball vertically upwards with a velocity of $5.6\,m\,s^{-1}$. The ball leaves his hand when it is at a height of 3.1 m above the ground, as shown in Fig. 3.1.

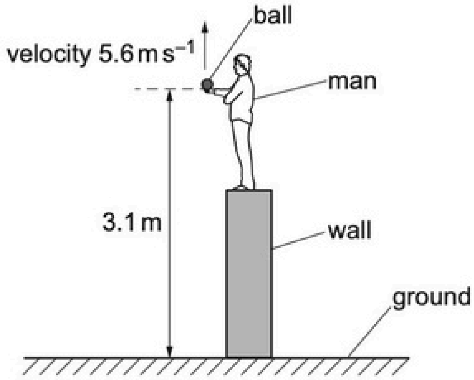


Fig. 3.1 (not to scale)

Assume that air resistance is negligible.

(a) Show that the ball reaches a maximum height above the ground of 4.7 m.

[2]

(b) The man does not catch the ball as it falls.

Calculate the time taken for the ball to fall from its maximum height to the ground.

time taken = ... s [2]

(c) The ball leaves the man's hand at time $t = 0$ and hits the ground at time $t = T$.

On Fig. 3.2, sketch a graph to show the variation of the velocity v of the ball with time t from $t = 0$ to $t = T$. Numerical values of v and t are not required. Assume that v is positive in the upward direction.

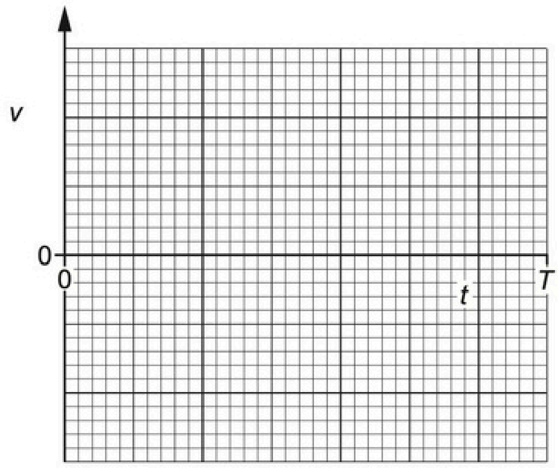


Fig. 3.2

[3]

(d) State what is represented by the gradient of the graph in **(c)**.

.... [1]

(e) The man now throws a second ball with the same velocity and from the same height as the first ball. The mass of the second ball is greater than that of the first ball. Assume that air resistance is still negligible.

For the first and second balls, compare:

(i) the magnitudes of their accelerations

.... [1]

(ii) the speeds with which they hit the ground.

.... [1]

[Total: 10]

Q11 **(a)** Define velocity.

....

.... [1]

(b) A rock of mass 7.5 kg is projected vertically upwards from the surface of a planet. The rock leaves the surface of the planet with a speed of $4.0\,m\,s^{-1}$ at time t = 0. The variation with time t of the velocity v of the rock is shown in Fig. 1.1.

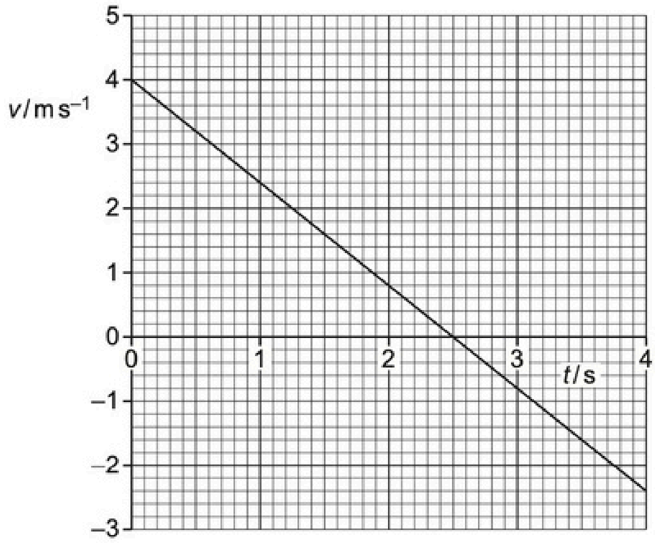


Fig. 1.1

Assume that the planet does not have an atmosphere and that the viscous force acting on the rock is always zero.

(i) Determine the height of the rock above the surface of the planet at time t = 4.0 s.

height = ... m [3]

(ii) Determine the change in the momentum of the rock from time $t = 0$ to time $t = 4.0\,s$.

change in momentum = ... N s [2]

(iii) Determine the weight W of the rock on this planet.

W = ... N [2]

(c) In practice, the planet in **(b)** does have an atmosphere that causes a viscous force to act on the moving rock.

State and explain the variation, if any, in the resultant force acting on the rock as it moves vertically upwards.

....

....

....

.... [2]

[Total: 10]

Q12 Water leaves the end of a hose pipe at point P with a horizontal velocity of $6.6\,m\,s^{-1}$, as shown in Fig. 2.1.

FM22/22/Q2

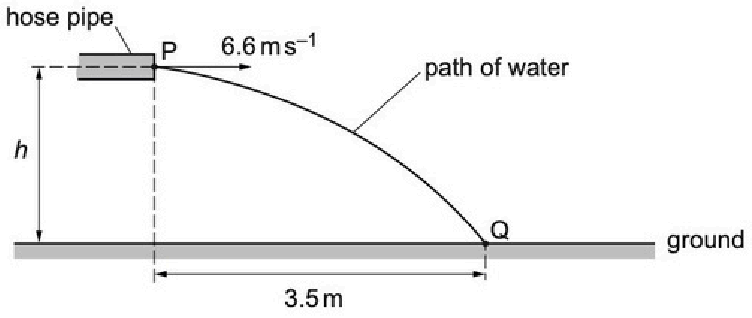


Fig. 2.1 (not to scale)

Point P is at height h above the ground. The water hits the ground at point Q. The horizontal distance from P to Q is 3.5 m.

Air resistance is negligible. Assume that the water between P and Q consists of non-interacting droplets of water and that the only force acting on each droplet is its weight.

(a) Explain, briefly, why the horizontal component of the velocity of a droplet of water remains constant as it moves from P to Q.

....

.... [1]

(b) Show that the time taken for a droplet of water to move from P to Q is 0.53 s.

[1]

(c) Calculate height h.

h = ... m [2]

(d) For the movement of a droplet of water from P to Q, state and explain whether the displacement of the droplet is less than, more than or the same as the distance along its path.

....

....

.... [1]

(e) Calculate the magnitude of the displacement of a droplet of water that moves from P to Q.

displacement = ... m [2]

[Total: 7]

F/M/21/22/Q1

Q13 **(a)** Complete Table 1.1 by stating whether each of the quantities is a vector or a scalar.

Table 1.1

quantity	vector or scalar
acceleration	
power	
work	

[2]

(b) The variation with time *t* of the velocity *v* of an object is shown in Fig. 1.1.

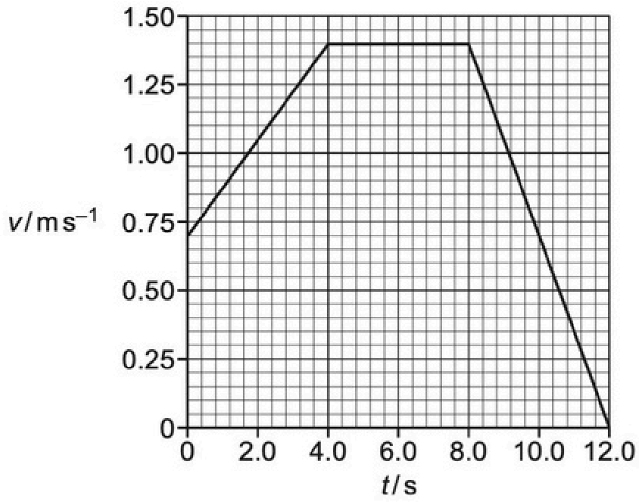


Fig. 1.1

(i) Determine the acceleration of the object from time $t = 0$ to time $t = 4.0$ s.

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

(ii) Determine the distance moved by the object from time $t = 0$ to time $t = 4.0$ s.

distance = ... m [2]

M/J/21/22/Q2

Q14 A ball is thrown vertically downwards to the ground, as illustrated in Fig. 2.1.

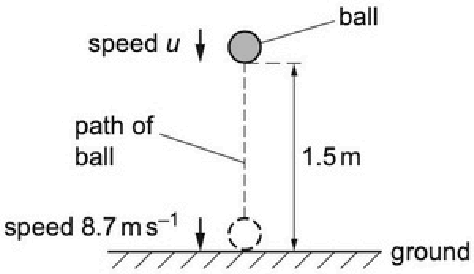


Fig. 2.1

The ball is thrown with speed u from a height of 1.5 m. The ball then hits the ground with speed 8.7 m s^{-1}. Assume that air resistance is negligible.

Calculate speed u.

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

Q15 A ball is fired horizontally with a speed of $41.0\,m\,s^{-1}$ from a stationary cannon at the top of a hill. The ball lands on horizontal ground that is a vertical distance of 57 m below the cannon, as shown in Fig. 3.1.

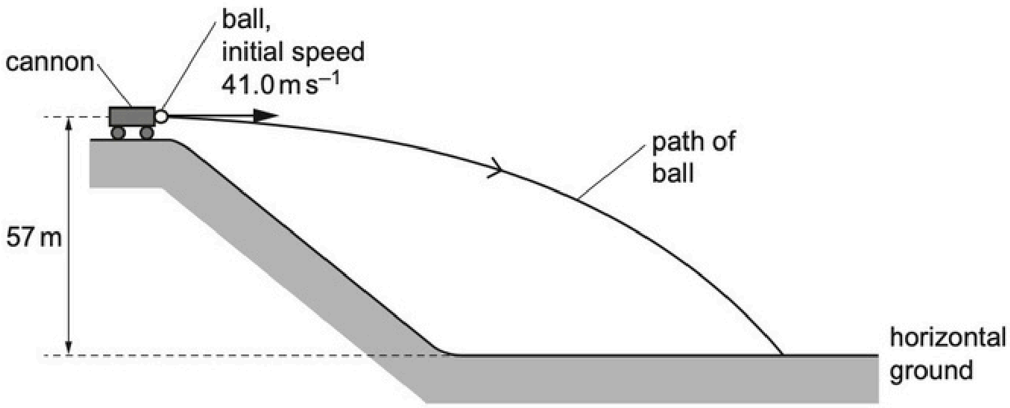


Fig. 3.1 (not to scale)

Assume air resistance is negligible.

(a) Show that the time taken for the ball to reach the ground, after being fired, is 3.4 s.

[2]

(b) Calculate the horizontal distance of the ball from the cannon at the point where the ball lands on the ground.

horizontal distance = ... m [1]

(c) Determine the magnitude of the displacement of the ball from the cannon at the point where the ball lands on the ground.

displacement = ... m [2]

(d) The ball leaves the cannon at time $t = 0$.

On Fig. 3.2, sketch a graph to show the variation of the magnitude v of the vertical component of the velocity of the ball with time t from $t = 0$ to $t = 3.4$ s.
Numerical values are not required.

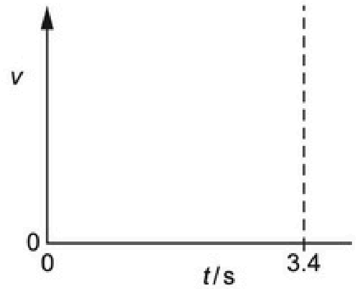


Fig. 3.2

[1]

O/N/20/22/Q1

Q16 (a) A toy train moves along a straight section of track. Fig. 1.1 shows the variation with time t of the distance d moved by the train.

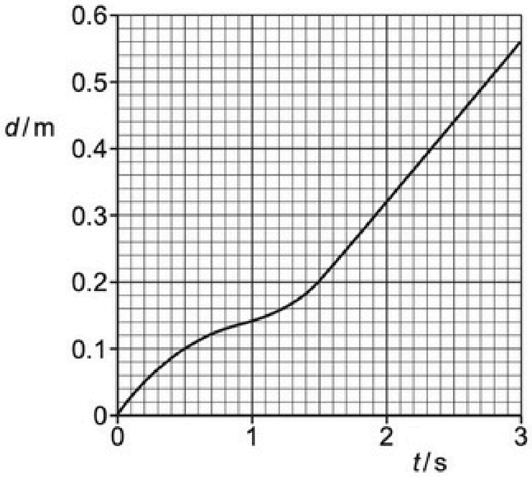


Fig. 1.1

(i) Describe qualitatively the motion of the train between time $t = 0$ and time $t = 1.0$ s.

....

.... [1]

(ii) Determine the speed of the train at time $t = 2.0\,s$.

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

(b) The straight section of track in **(b)** is part of the loop of track shown in Fig. 1.2.

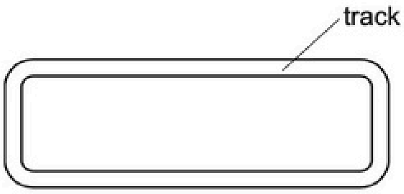


Fig. 1.2

The train completes exactly one lap of the loop.

State and explain the average velocity of the train over the one complete lap.

....

....

.... [1]

Q17 A small block is lifted vertically upwards by a toy aircraft, as illustrated in Fig. 2.1. *O/N/20/21/Q2*

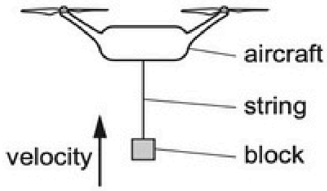


Fig. 2.1

As the block is moving upwards, the string breaks at time t = 0. The block initially continues moving upwards and then falls and hits the ground at time t = 0.90 s. The variation with time t of the velocity v of the block is shown in Fig. 2.2.

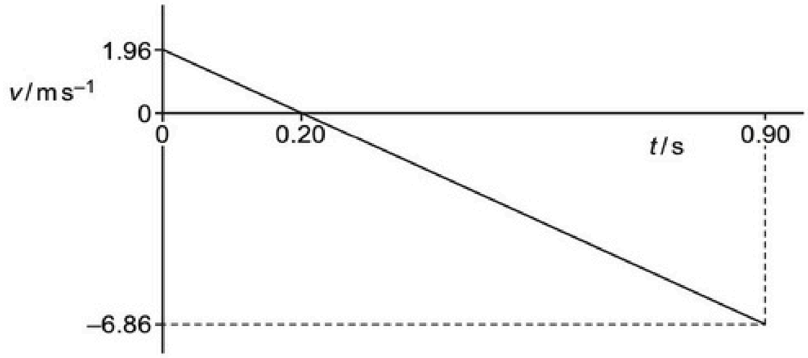


Fig. 2.2

Air resistance is negligible.

(a) State the feature of the graph in Fig. 2.2 that shows the block has a constant acceleration.

.... [1]

(b) Use Fig. 2.2 to determine the height of the block above the ground when the string breaks at time t = 0.

height = ... m [3]

Q18 (a) State Newton's first law of motion. *M/J/20/23/Q2*

....

.... [1]

(b) A skier is pulled in a straight line along horizontal ground by a wire attached to a kite, as shown in Fig. 2.1.

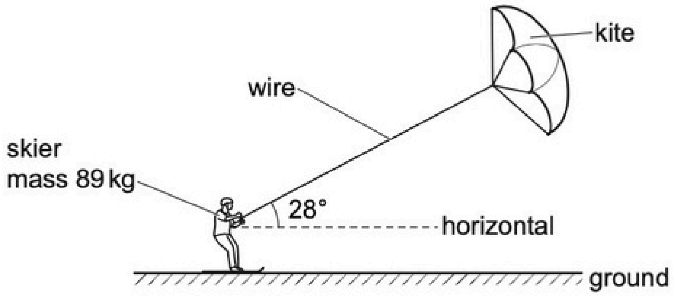


Fig. 2.1 (not to scale)

The mass of the skier is 89 kg. The wire is at an angle of 28° to the horizontal. The variation with time t of the velocity v of the skier is shown in Fig. 2.2.

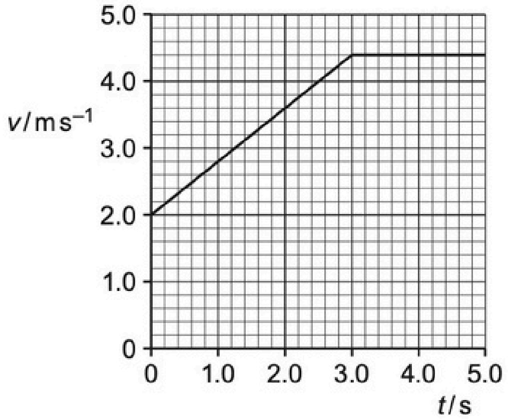


Fig. 2.2

(i) Use Fig. 2.2 to determine the distance moved by the skier from time $t = 0$ to $t = 5.0$ s.

distance = ... m [2]

(ii) Use Fig. 2.2 to show that the acceleration *a* of the skier is 0.80 m s^{-2} at time *t* = 2.0 s.

[2]

(iii) The tension in the wire at time *t* = 2.0 s is 240 N.

Calculate:

1. the horizontal component of the tension force acting on the skier

horizontal component of force = ... N [1]

2. the total resistive force *R* acting on the skier in the horizontal direction.

R = ... N [2]

(iv) The skier is now lifted upwards by a gust of wind. For a few seconds the skier moves horizontally through the air with the wire at an angle of 45° to the horizontal, as shown in Fig. 2.3.

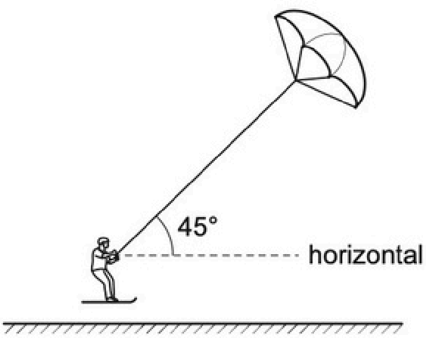


Fig. 2.3 (not to scale)

By considering the vertical components of the forces acting on the skier, determine the new tension in the wire when the skier is moving horizontally through the air.

tension = ... N [2]

Q19 **(a)** Fig. 2.1 shows the velocity–time graph for an object moving in a straight line. *M/J/20/22/Q2*

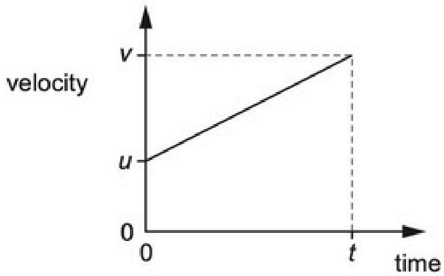


Fig. 2.1

(i) Determine an expression, in terms of u, v and t, for the area under the graph.

area = ... [1]

(ii) State the name of the quantity represented by the area under the graph.

.... [1]

(b) A ball is kicked with a velocity of $15\,\text{m}\,\text{s}^{-1}$ at an angle of 60° to horizontal ground. The ball then strikes a vertical wall at the instant when the path of the ball becomes horizontal, as shown in Fig. 2.2.

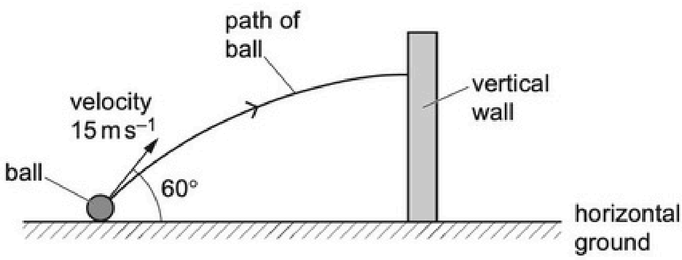


Fig. 2.2 (not to scale)

Assume that air resistance is negligible.

(i) By considering the vertical motion of the ball, calculate the time it takes to reach the wall.

time = ... s [3]

(ii) Explain why the horizontal component of the velocity of the ball remains constant as it moves to the wall.

....

.... [1]

(iii) Show that the ball strikes the wall with a horizontal velocity of 7.5 m s^{-1}.

[1]

O/N/18/22/Q1

Q20 A golfer strikes a ball so that it leaves horizontal ground with a velocity of 6.0 m s^{-1} at an angle θ to the horizontal, as illustrated in Fig. 1.1.

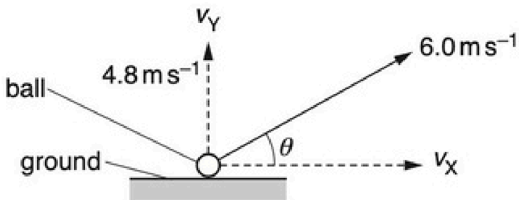


Fig. 1.1 (not to scale)

The magnitude of the initial vertical component v_Y of the velocity is 4.8 m s^{-1}.
Assume that air resistance is negligible.

(a) Show that the magnitude of the initial horizontal component v_X of the velocity is 3.6 m s^{-1}.

[1]

(b) The ball leaves the ground at time $t = 0$ and reaches its maximum height at $t = 0.49$ s.

On Fig. 1.2, sketch separate lines to show the variation with time t, until the ball returns to the ground, of

(i) the vertical component v_Y of the velocity (label this line Y), [2]

(ii) the horizontal component v_X of the velocity (label this line X). [2]

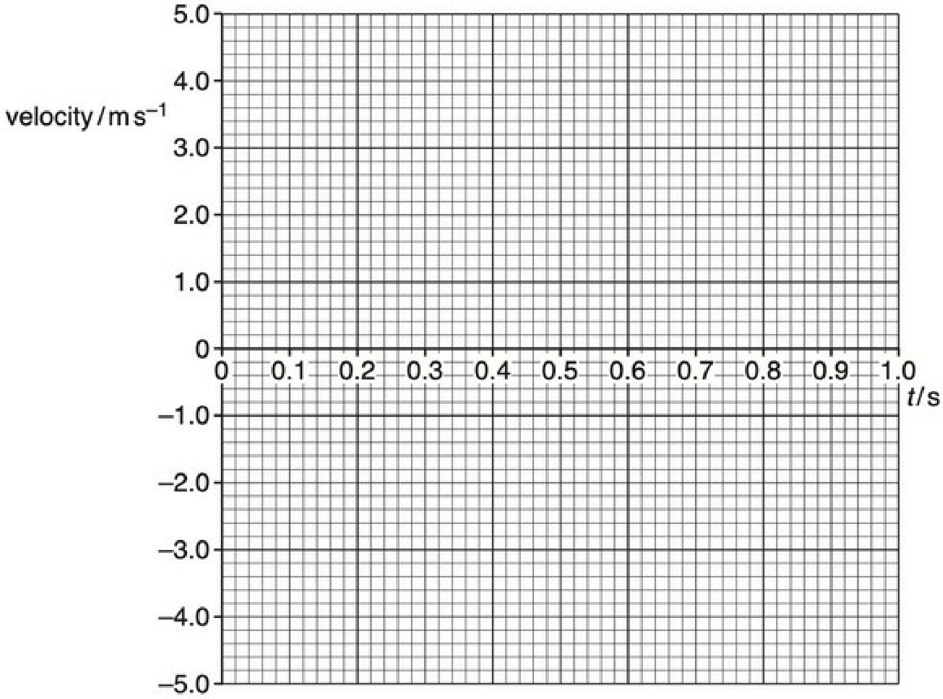


Fig. 1.2

(c) Calculate the maximum height reached by the ball.

maximum height = ... m [2]

M/J/18/22/Q3

Q21 A child on a sledge slides down a steep hill and then travels in a straight line up an ice-covered slope, as illustrated in Fig. 3.1.

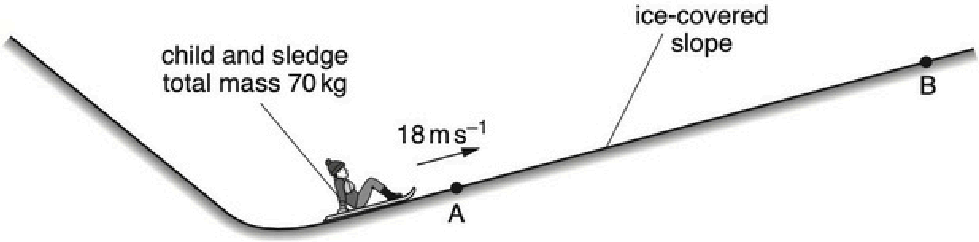


Fig. 3.1 (not to scale)

The sledge passes point A with speed $18\,\mathrm{m\,s^{-1}}$ at time $t = 0$ and then comes to rest at point B. The child applies a brake to the sledge at point B. The brake does not keep the sledge stationary and it immediately slides back down the slope towards A.

The variation with time t of the velocity v of the sledge from $t = 0$ to $t = 24\,\mathrm{s}$ is shown in Fig. 3.2.

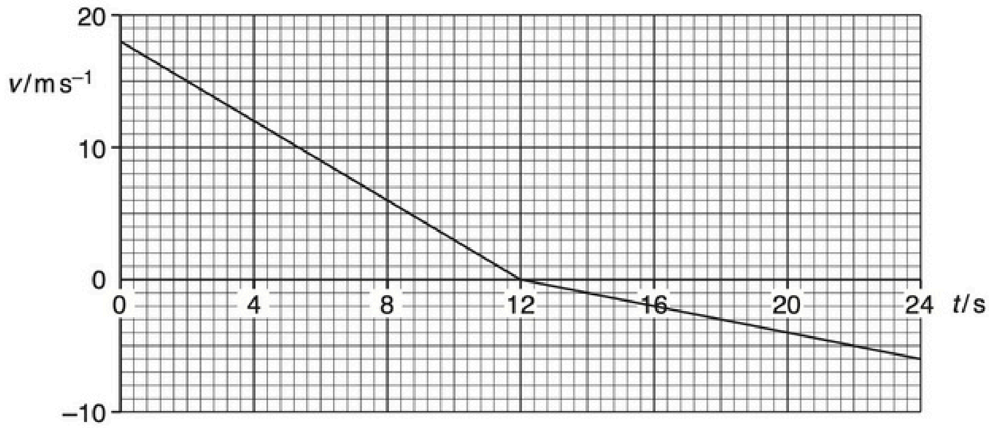


Fig. 3.2

(a) State the time taken for the sledge to travel from A to B.

time = ... s [1]

(b) Determine the displacement of the sledge up the slope from point A at time $t = 24$ s.

displacement = ...m [3]

(c) Show that the acceleration of the sledge as it moves from B back towards A is $0.50\,\text{m}\,\text{s}^{-2}$.

[2]

(d) The child and sledge have a total mass of 70 kg. The component of the total weight of the child and sledge that acts down the slope is 80 N.

Determine

(i) the frictional force on the sledge as it moves from B towards A,

frictional force = ... N [2]

(ii) the angle θ of the slope to the horizontal.

Q22 **(a)** Define *acceleration*. F/M/16/22/Q2

....

.... [1]

(b) A ball is kicked from horizontal ground towards the top of a vertical wall, as shown in Fig. 2.1.

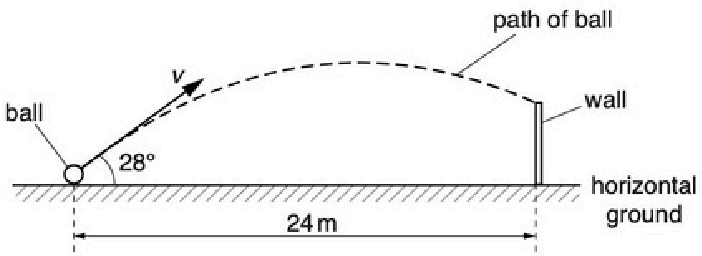


Fig. 2.1 (not to scale)

The horizontal distance between the initial position of the ball and the base of the wall is 24 m. The ball is kicked with an initial velocity v at an angle of 28° to the horizontal. The ball hits the top of the wall after a time of 1.5 s. Air resistance may be assumed to be negligible.

(i) Calculate the initial horizontal component v_X of the velocity of the ball.

v_X = ... $m s^{-1}$ [1]

(ii) Show that the initial vertical component v_Y of the velocity of the ball is $8.5 m s^{-1}$.

[2]

(iii) Calculate the time taken for the ball to reach its maximum height above the ground.

(iv) The ball is kicked at time $t = 0$. On Fig. 2.2, sketch the variation with time t of the vertical component v_Y of the velocity of the ball until it hits the wall. It may be assumed that velocity is positive when in the upwards direction.

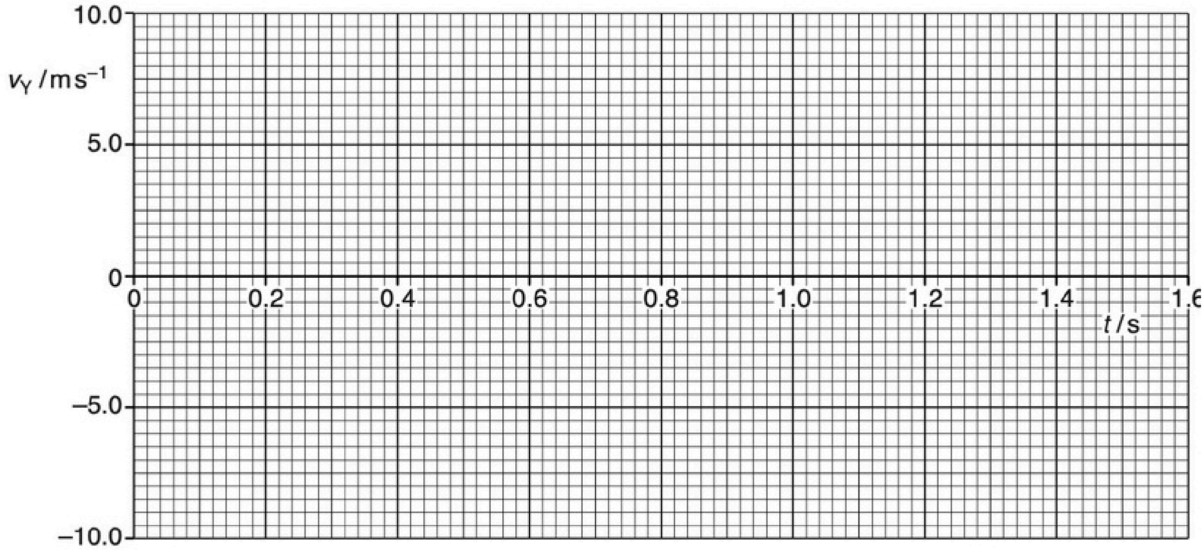


Fig. 2.2

[2]

(c) (i) Use the information in **(b)** to determine the maximum height of the ball above the ground.

maximum height = ... m [2]

(ii) The maximum gravitational potential energy of the ball above the ground is 22 J. Calculate the mass of the ball.

mass = ... kg [2]

(d) A ball of greater mass is kicked with the same velocity as the ball in **(b)**.
State and explain the effect, if any, of the increased mass on the maximum height reached by the ball. Air resistance is still assumed to be negligible.

....

US ISHAQ
S
.... [1]

Q23 **(a)** Define *velocity*. M/J/17/22/Q2

....

....[1]

(b) A ball of mass 0.45 kg leaves the edge of a table with a horizontal velocity *v*, as shown in Fig. 2.1.

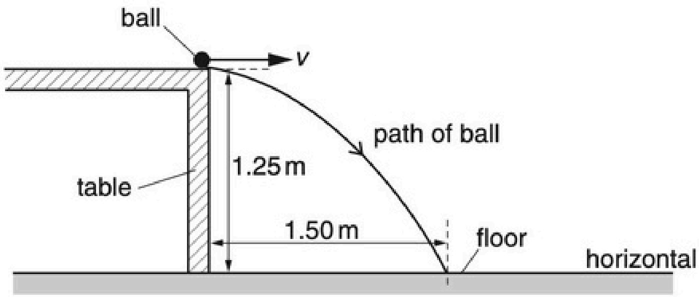


Fig. 2.1

The height of the table is 1.25 m. The ball travels a distance of 1.50 m horizontally before hitting the floor.

Air resistance is negligible.

Calculate, for the ball,

(i) the horizontal velocity *v* as it leaves the table,

v = ... $m s^{-1}$ [3]

(ii) the velocity just as it hits the floor,

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

angle to the horizontal = ... °

[4]

Q24 **(a)** Define: *F/M/19/22/Q2*

(i) *displacement*

....

....[1]

(ii) *acceleration.*

....

....[1]

(b) A man wearing a wingsuit glides through the air with a constant velocity of 47 m s^{-1} at an angle of 24° to the horizontal. The path of the man is shown in Fig. 2.1.

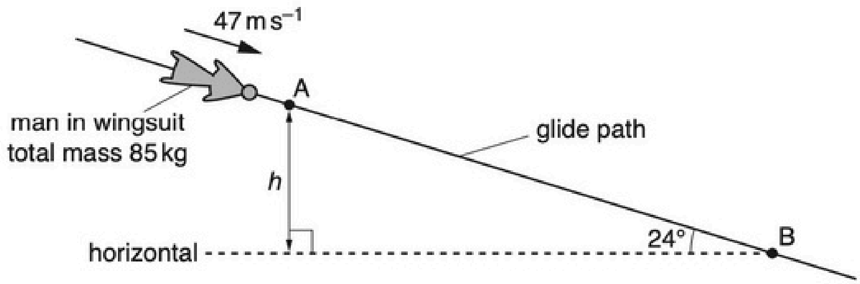


Fig. 2.1 (not to scale)

The total mass of the man and the wingsuit is 85 kg. The man takes a time of 2.8 minutes to glide from point A to point B.

(i) With reference to the motion of the man, state and explain whether he is in equilibrium.

....

....

....

....[2]

(ii) Show that the difference in height *h* between points A and B is 3200 m.

Q25 **(a)** State Newton's second law of motion.

....

....[1]

(b) A car of mass 850 kg tows a trailer in a straight line along a horizontal road, as shown in Fig. 2.1.

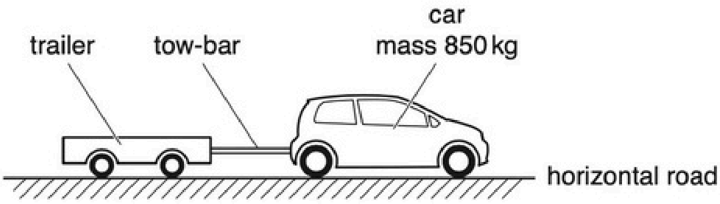


Fig. 2.1

The car and the trailer are connected by a horizontal tow-bar.

The variation with time *t* of the velocity *v* of the car for a part of its journey is shown in Fig. 2.2.

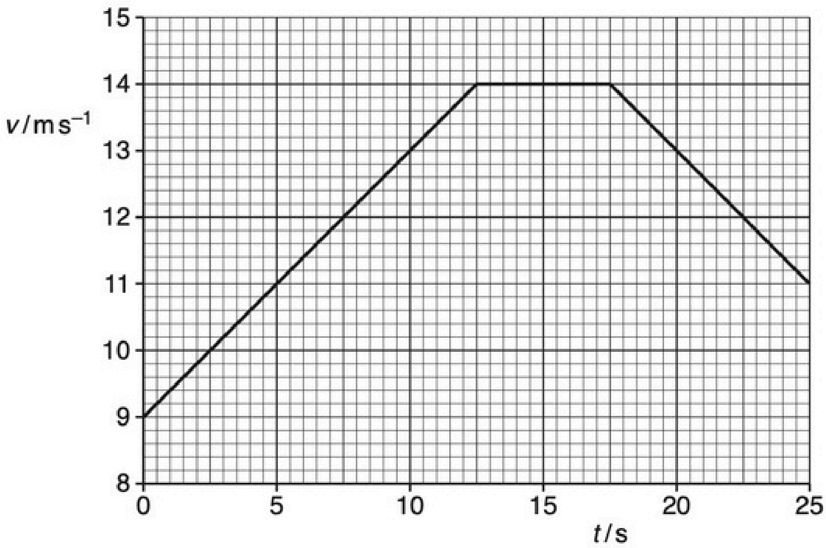


Fig. 2.2

(i) Calculate the distance travelled by the car from time $t = 0$ to $t = 10$ s.

distance = ... m [2]

(ii) At time $t = 10$ s, the resistive force acting on the car due to air resistance and friction is 510 N. The tension in the tow-bar is 440 N.

For the car at time $t = 10$ s:

1. use Fig. 2.2 to calculate the acceleration

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

Q1 a)	change in displacement / time (taken)	B1
2(b)(i)	horizontal velocity = 22 × cos 40°	C1
	time taken = 36 / (22 × cos 40°) = 2.1 s	A1
2(b)(ii)	*u* = 22 × sin 40° = 14 m s^{-1}	A1
2(b)(iii)	*s* = *ut* + ½ *at*^{2} = (14 × 2.1) + (½ × −9.81 × 2.1^2)	C1
	= 7.8 (m)	C1
	(therefore) height of wall = 7.8 + 1.2 = 9.0 m	A1

Q2 a)(i)	39 m s^{-1}	A1
2(a)(ii)	tangent line to curve drawn on Fig. 2.1	C1
	a = gradient of tangent line = Δ*v* / Δ*t* e.g. = (44 – 26) / (18 – 0) 0.9 ⩽ *a* ⩽ 1.1 m s^{-2}	A1
2(b)	(Σ)*F* = 68 × 9.81 – 1800 (= –1133 N)	C1
	a = (Σ)*F* / *m* = – 1133 / 68 = (–)17 m s^{-2}	A1
	upwards	B1
2c(i)	drag force decreases (as speed decreases)	B1
	(as speed decreases) resultant force decreases so (magnitude of) acceleration decreases (to zero)	B1

Q3 (a)	distance (from the point) in a straight line in a given direction	B1
2(b)(i)	distance = speed × time = 6.0 × 0.71 = 4.3 m	A1
2(b)(ii)	*s* = *ut* + ½ *at*^{2} = ½ × 9.81 × 0.71^2	C1
	= 2.5 m	A1
2(b)(iii)	tan θ = 2.5 / 4.3 **or** hypotenuse = √(4.3^2 + 2.5^2) (= 4.97 m) cos θ = 4.3 / 4.97 **or** sin θ = 2.5 / 4.97	C1
	θ = 30°	A1
2(b)(iv)	displacement = √(4.3^2 + 2.5^2)	C1
	= 4.9 m or 5.0 m	A1
	or	
	displacement = 2.5 / sin 30° **or** displacement = 4.3 / cos 30°	(C1)
	= 5.0 m	(A1)

Q4)	rate of change of velocity	B1
2(b)	$\frac{1}{2} m(\Delta)v^2 = mg(\Delta)h$	C1
	$v^2 = 5.9^2 + 2 \times 9.81 \times 7.8$ $v^2 = 188$	C1
	$v = 14\ \text{m s}^{-1}$	A1
	or by resolving components Vertically: $v^2 = u^2 + 2as$ $v^2 = (5.9\sin 60)^2 + 2 \times -9.81 \times (1.2-9.0)$ $v_v = 13.4$	(C1)
	horizontally: $v_h = 5.9\cos 60$ $v_h = 2.95$	(C1)
	resultant velocity $= \sqrt{(13.4^2 + 2.95^2)}$ $= 14\ \text{m s}^{-1}$	(A1)

Q5)	only electric current **and** time underlined	B1
1(b)	initial speed / velocity is zero	B1
	(non-zero magnitude of) acceleration is constant / uniform (and in a straight line)	B1
1(c)(i)	• magnitude of acceleration at t = 8.0 s is less than that at t = 14.0 s	B1
	• direction of acceleration at t = 8.0 s is opposite to that at t = 14.0 s	B1
1(c)(ii)	a = gradient **or** $a = (v-u)/t$ **or** $a = \Delta v/(\Delta)t$	C1
	a = e.g. (20 + 10) / 12 **or** (0 + 10) / 4 **or** (20 – 0) / (12 – 4) $a = 2.5\ \text{m s}^{-2}$	A1
1(c)(iii)	displacement $= [\frac{1}{2} \times (12-4) \times 20] - [\frac{1}{2} \times 4 \times 10]$ **or** displacement $= (-10 \times 12) + (\frac{1}{2} \times 2.5 \times 12^2)$ **or** displacement $= (20 \times 12) - (\frac{1}{2} \times 2.5 \times 12^2)$ **or** displacement $= \frac{1}{2} \times (20-10) \times 12$	C1
	displacement = 60 m	A1

Q6 (i)	(time / t =) 9(.0) / 9.5 = 0.95 (s)	A1
2(a)(ii)	$(u_V) = 9.5 \tan 38°$ **or** $9.5 / \tan 52°$ **or** $9.5 = u \cos 38°$ **and** $u_V = u \sin 38°$ **or** $9.5 = u \cos 38°$ **and** $u_V = (u^2 - 9.5^2)^{\frac{1}{2}}$	C1
	$u_V = 7.4\ \text{m s}^{-1}$	A1
2(a)(iii)	$s = ut + \frac{1}{2}at^2$ $(h =)\ 7.4 \times 0.95 - \frac{1}{2} \times 9.81 \times 0.95^2$	C1
	$h = 2.6\ \text{m}$	A1

Q7)	$t = \sqrt{(2s/g)}$ $= \sqrt{[(2 \times 36)/9.81]}$	C1
	= 2.7 s	A1
1(b)	• reaction time between hearing the splash and stopping the stop-watch • the sound (of the splash) takes time to reach the student **or** the stone hits the water at a different time to the sound being heard **or** the sound (of the splash) has to travel to the student • the student might not let go of the stone from ground level • the student might not let go of the stone and start the stop-watch at the same time • stop-watch may not be properly calibrated / has a zero error • (local value of) g is not (exactly) 9.81 (m s^{-2}) • stone given initial velocity / initial velocity not zero • stone does not fall (exactly) vertically / in a straight line *Any three points, 1 mark each*	B3
1(c)	precise: results are close together / have little scatter	B1
	not accurate: the values are not close to / 50% different / (very) different from the true value	B1

Q8

1(a)	only ampere and kelvin underlined	B1
1(b)	initial speed / velocity is zero	B1
	(non-zero magnitude of) acceleration is constant / uniform (and in a straight line)	B1
1(c)(i)	$a = 2.75^2 / (2 \times 3.89)$ $= 0.97\ \text{m s}^{-2}$	A1
1(c)(ii)	percentage uncertainty = $(2 \times 0.8) + 0.5$	C1
	= 2.1%	A1
1(c)(iii)	absolute uncertainty = $(2.1 / 100) \times 0.97$ $= 0.02\ \text{m s}^{-2}$	A1

Q9

Question	Answer	Marks
2(a)(i)	$t = 1.8 / 4.9$ $= 0.37$ s	A1
2(a)(ii)	$v = u + at$ $= 9.81 \times 0.37$	C1
	$= 3.6\ \text{m s}^{-1}$	A1
2(a)(iii)	$v^2 = 3.6^2 + 4.9^2$	C1
	$v = 6.1\ \text{m s}^{-1}$	A1
	$\theta = \tan^{-1}(3.6 / 4.9)$ $= 36°$	A1
2(b)(i)	$\rho = m / V$	C1
	$V = \frac{4}{3}\pi r^3$	C1
	$\rho = 0.017 / [\frac{4}{3}\pi \times (0.016 / 2)^3]$ $= 7900\ \text{kg m}^{-3}$	A1
2(b)(ii)	$(E =) \frac{1}{2}mv^2$	C1
	$(E =) \frac{1}{2} \times 0.017 \times 4.9^2 = 0.20$ (J)	A1

Question	Answer	Marks
2(b)(iii)	$k = F / x$ **or** k = gradient	C1
	e.g. $k = 6.4 / 10 \times 10^{-2}$ $= 64\ \text{N m}^{-1}$ (*allow 63–65 N m⁻¹*)	A1
2(b)(iv)	$E = \frac{1}{2}kx^2$ **or** $E = \frac{1}{2}Fx$ **and** $F = kx$	C1
	$x_0 = [(2 \times 0.20) / 64]^{0.5}$ $= 0.079$ m or 0.080 m	A1
2(c)(i)	same elastic potential energy / same (initial) kinetic energy and (polystyrene ball has) smaller mass (so greater speed) **or** same (average) force and (polystyrene ball has) smaller mass, (so greater average acceleration so greater speed)	B1
2(c)(ii)	(for the polystyrene ball there is) less (average vertical) acceleration / smaller (average vertical component of) <u>resultant</u> force (so takes longer time to reach ground)	B1

Q10

Question	Answer	Marks
(a)	$v^2 = u^2 + 2as$ $s = 5.6^2 / (2 \times 9.81)$	C1
	(max height =) $3.1 + 5.6^2 / (2 \times 9.81) = 4.7$ (m)	A1
3(b)	$s = ut + \frac{1}{2}at^2$ $4.7 = \frac{1}{2} \times 9.81 \times t^2$	C1
	$t = 0.98$ s	A1
3(c)	line drawn from a non-zero speed at $t = 0$ to a greater speed at $t = T$	B1
	a single sloping straight line drawn from $t = 0$ to $t = T$	B1
	line starts with a positive non-zero value of v and ends with a negative non-zero value of v	B1
3(d)	acceleration (of the ball)	B1
3(e)(i)	(magnitudes of accelerations are) equal / same	B1
3(e)(ii)	(speeds are) equal / same	B1

11 Question	Answer	Marks
1(a)	change in displacement / time (taken)	B1
1(b)(i)	(displacement =) area under graph	C1
	(at t = 4.0 s) v = (–) 2.4	C1
	height = ½ × 2.5 × 4.0 – ½ × 1.5 × 2.4 = 3.2 m	A1
1(b)(ii)	change in momentum = 7.5 (–4.0 – 2.4)	C1
	= (–) 48 N s	A1
1(b)(iii)	$W = \Delta p / (\Delta)t$ **or** $\Delta mv / (\Delta)t$	C1
	= 48 / 4.0 = 12 N	A1
	or	
	$W = ma$ **or** mg **or** $m(v - u) / t$	(C1)
	= 7.5 × 1.6 **or** 7.5 × (4 + 2.4) / 4.0 = 12 N	(A1)
1(c)	speed/velocity decreases so viscous force decreases	B1
	viscous force decreases (and weight constant) so resultant force decreases	B1

12 Question	Answer	Marks
(a)	force (on droplet of water) in horizontal direction is zero.	B1
(b)	(time taken =) 3.5 / 6.6 = 0.53 (s)	A1
(c)	$s = ut + ½at^2$ s = ½ × 9.81 × 0.53^2	C1
	h = 1.4 m	A1

Question	Answer	Marks
(d)	displacement is straight-line distance (from P to Q) so less (than distance along path) or displacement is the shortest distance (from P to Q).	B1
(e)	$(\text{displacement})^2 = 3.5^2 + 1.4^2$	C1
	displacement = 3.8 m	A1

13	(a)	acceleration: vector work: scalar power: scalar *Three correct scores 2 marks. Two correct scores 1 mark.*
	b)(i)	$a = (v - u) / t$ or a = gradient or $a = \Delta v / (\Delta)t$ e.g. $a = (1.40 \quad 0.70) / 4.0$
		$= 0.18$ m s^{-2}
	b)(ii)	distance $= 0.5 \times (0.70 + 1.40) \times 4.0$ or $(0.70 \times 4.0) + (0.5 \times 0.70 \times 4.0)$
		$= 4.2$ m

14	(a)	$v^2 = u^2 + 2as$ $u^2 = 8.7^2 - (2 \times 9.81 \times 1.5)$ $u = 6.8$ m s^{-1}

15	(a)	$s = \frac{1}{2}at^2$
		$57 = \frac{1}{2} \times 9.81 \times t^2$ **and** $t = 3.4$ (s)
	(b)	horizontal distance $= 41 \times 3.4$ $= 140$ m
	(c)	$(\text{displacement})^2 = 57^2 + 140^2$
		displacement $= (57^2 + 140^2)^{0.5}$ $= 150$ m
	(d)	straight line from the origin with positive gradient

16	(*a*)(i)	decelerates **or** speed/velocity decreases
	(*a*)(ii)	speed = (Δ)*d* / (Δ)*t* **or** gradient
		= e.g. (0.56 – 0.20) / 1.5 = 0.24 m s^{-1}
	4(*b*)	displacement is zero (so) average velocity is zero

17	(a)	constant gradient
	(b)	(displacement until 0.20 s =) ½ × 1.96 × 0.20 (= 0.196 m) **or** (displacement after 0.20 s =) ½ × 6.86 × 0.70 (= 2.401 m)
		height = 2.401 0.196
		= 2.2 m (*alternative methods are possible using equations of uniformly accelerated motion*)

18	6(a)	a body continues at (rest or) constant velocity unless acted upon by a resultant force
	(b)(i)	distance = [½ × (2.0 + 4.4) × 3.0] + [4.4 × 2.0]
		= 9.6 + 8.8 = 18 m
	(b)(ii)	*a* = (*v* – *u*) / *t* **or** gradient **or** Δ*v* / (Δ)*t*
		e.g. *a* = (4.4 2.0) / 3.0 = 0.80 m s^{-2}
	b)(iii)	**1.** force = 240 cos 28° **or** 240 sin 62° = 210 N
		2. resultant force = 89 × 0.80 (= 71.2 N)
		R = 210 – 71 = 140 N
	b)(iv)	*T* sin 45° = *mg*
		T = (89 × 9.81) / sin 45° = 1200 N

19	(a)(i)	area = $ut + ½(v – u)t$ **or** area = $vt – ½(v – u)t$ **or** area = $½(u + v)t$
	(a)(ii)	displacement
	(b)(i)	u = 15 sin 60° (= 13 m s^{-1})
		t = 15 sin 60° / 9.81
		= 1.3 s
	(b)(ii)	the force in the horizontal direction is zero
	(b)(iii)	(velocity =) 15 cos 60° = 7.5 (m s^{-1}) **or** (velocity =) 15 sin 30° = 7.5 (m s^{-1})

20	(a)	$v_X = (6.0^2 – 4.8^2)^{1/2}$ = 3.6 (m s^{-1}) **or** 6.0 sinθ = 4.8 (so θ = 53.1°) **and** v_x = 6.0 cos 53.1° = 3.6 (m s^{-1})
	(b)(i)	straight line from (0, 4.8) to (0.49, 0)
		straight line continues with same slope to (0.98, –4.8) (labelled Y)
	(b)(ii)	a horizontal line
		from (0, 3.6) to (0.98, 3.6) (labelled X)
	(c)	$s = ut + ½at^2$ = (4.8 × 0.49) + (½ × –9.81 × 0.49^2) **or** $s = ½(u + v)t$ **or** area under graph = ½ × (4.8 + 0) × 0.49 **or** $s = vt – ½at^2$ = ½ × 9.81 × 0.49^2 **or** $v^2 = u^2 + 2as$ s = 4.8^2 / (2 × 9.81)
		s = 1.2 m

21	(a)	time = 12s
	(b)	distance (up slope) = ½ × 12 × 18 (= 108)
		distance (down slope) = ½ × 12 × 6 (= 36)
		displacement from A = 108 – 36 = 72m
	(c)	$v = u + at$ **or** a = gradient **or** $a = \Delta v / (\Delta)t$
		a = 6 / 12 = 0.50 (m s ^{2}) *(other points from the line may be used)*
		or
		$v^2 = u^2 + 2as$ **and** $u = 0$ **or** $v^2 = 2as$
		$a = 6.0^2 / (2 \times 36)$ = 0.50 (m s ^{2})
		or
		$s = ut + ½at^2$ **and** $u = 0$ **or** $s = ½at^2$
		$a = 2 \times 36 / 12^2$ = 0.50 (m s ^{2})
		or
		$s = vt – ½at^2$
		$a = 2 \times (6 \times 12 – 36)/12^2$ = 0.50 (m s ^{2})
	(d)(i)	$F = 70 \times 0.50$ (= 35)
		frictional force = 80 – 35 = 45N
	(d)(ii)	sin θ = 80/(70 × 9.81)
		θ = 6.7°

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(a) change in velocity / time (taken) **or** rate of change of velocity B1

(b) (i) $v_X = (24/1.5) = 16\,(\text{m s}^{-1})$ A1

(ii) $\tan 28° = v_Y / v_X$ *or* $v_X = v\cos 28°$ *and* $v_Y = v\sin 28°$ C1
$v_Y = 16\tan 28°$ *or* $v_Y = 16 \times (\sin 28° / \cos 28°)$ so $v_Y = 8.5\,(\text{m s}^{-1})$ A1

(iii) $v = u + at$ C1
$t = (0 - 8.5)/(-9.81)$
$= 0.87$ (s) A1

(iv) straight line from positive v_Y at $t = 0$ to negative v_Y at $t = 1.5$ s M1
line starts at (0, 8.5) and crosses t-axis at (0.87, 0) and does not go beyond $t = 1.5$ s. A1

(c) (i) $(v^2 = u^2 + 2as)$ $0 = 8.5^2 + 2(-9.81)s$
or $(s = ut + ½at^2)$ $s = 8.5 \times 0.87 + ½ \times (-9.81) \times 0.87^2$
or $(s = vt - ½at^2)$ $s = 0 - ½ \times (-9.81) \times 0.87^2$
or ($s = ½(u + v)t$ or area under graph) $s = 0.5 \times 8.5 \times 0.87$ C1

$s = 3.7$ (m) A1

(ii) $\Delta E_P = mg\Delta h$ (*allow* $E = mgh$) C1
$m = 22 / (9.81 \times 3.7)$
$= 0.61$ (kg) A1

(d) acceleration (of freefall) is unchanged / not dependent on mass, and so no effect (on maximum height)
or *explanation in terms of energy:*
(initial) KE ∝ mass, (Δ)KE = (Δ)PE, (max) PE ∝ mass, and so
no effect (on maximum height) B1

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(a)	rate of change of displacement **or** change in displacement/time taken
(b)(i)	$s = ut + \frac{1}{2}at^2$
	$t = [(2 \times 1.25) / 9.81]^{1/2}$ (= 0.5048 s)
	or
	$v^2 = u^2 + 2as$ $v_{vert} = (2 \times 9.81 \times 1.25)^{1/2}$ (= 4.95)
	$t = [2s / (u + v)] = 2 \times 1.25 / 4.95$ (= 0.5048 s)
	$v = d / t = 1.5 / 0.50(48)$ = 3.0 (2.97) m s^{-1}
(b)(ii)	vertical velocity = at = 9.81×0.5048 (= 4.95) [using t = 0.50 gives 4.9]
	velocity = $[(v_h)^2 + (v\ )^2]^{1/2}$
	= $[(2.97)^2 + (4.95)^2]^{1/2}$ = 5.8 (5.79) [using t = 0.50 leads to 5.7]
	direction (= tan ^{1} 4.95/2.97) = 59°

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(a)(i)	distance in a specified direction (from a point)
(a)(ii)	change in velocity / time (taken)
(b)(i)	constant velocity so no resultant force
	no resultant force so in equilibrium
(b)(ii)	(difference in height =) $47 \times 2.8 \times 60 \times \sin 24° = 3200$ m

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(a)	(resultant) force proportional/equal to/is rate of change of momentum
(b)(i)	distance = area under graph **or** $s = ½ (u + v) t$ $= ½ \times (9 + 13) \times 10$ **or** $s = ut + ½at^2$ $= (9 \times 10) + (½ \times 0.40 \times 10^2)$ **or** $s = vt - ½at^2$ $= (13 \times 10) - (½ \times 0.40 \times 10^2)$ **or** $v^2 = u^2 + 2as$ $13^2 = 9^2 + (2 \times 0.40 \times s)$
	distance = 110 m
(b)(ii)	**1.** a = gradient **or** $a = (v - u) / t$ **or** $a = \Delta v / (\Delta)t$ e.g. $a = (14 - 9) / 12.5$ **or** $(13 - 9) / 10$
	$a = 0.40$ m s^{-2}