

1

A stone of mass 0.4 kg is projected horizontally at a speed of 6.0 m s^{-1} from the top of a wall, 5.0 m above the surrounding ground. When it arrives at the ground its speed is 10 m s^{-1} .

How much energy is lost by the stone in falling through the air?

- | | | |
|----------|------------------|-----------------------|
| A | 2.4 J | ☐ |
| B | 6.8 J | ☐ |
| C | 12.8 J | ☐ |
| D | 14.4 J | ☐ |

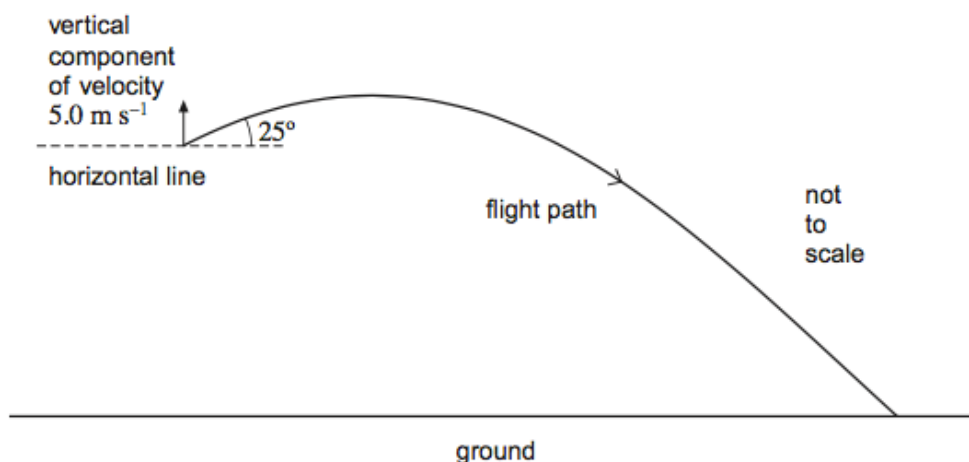
(Total 1 mark)

2

A projectile is launched some distance above the ground at an angle of 25° above the horizontal with a vertical component of velocity of 5.0 m s^{-1} . **Figure 1** shows the flight path of the projectile. The flight takes 1.3 s .

Ignore the effects of air resistance throughout this question.

Figure 1



- (a) (i) Show that the initial speed of the projectile is about 12 m s^{-1} .

(2)

- (ii) Calculate the horizontal component of velocity as the projectile hits the ground.

horizontal component of velocity = _____ m s^{-1}

(2)

- (b) (i) Calculate the maximum height above the starting point reached by the projectile.
Give your answer to an appropriate number of significant figures.

maximum height reached = _____ m

(2)

- (ii) Calculate the total horizontal distance travelled by the projectile from its starting point.

horizontal distance = _____ m

(1)

- (c) (i) Mark with an **A** on the flight path in **Figure 1** the position where the speed of the projectile is greatest.

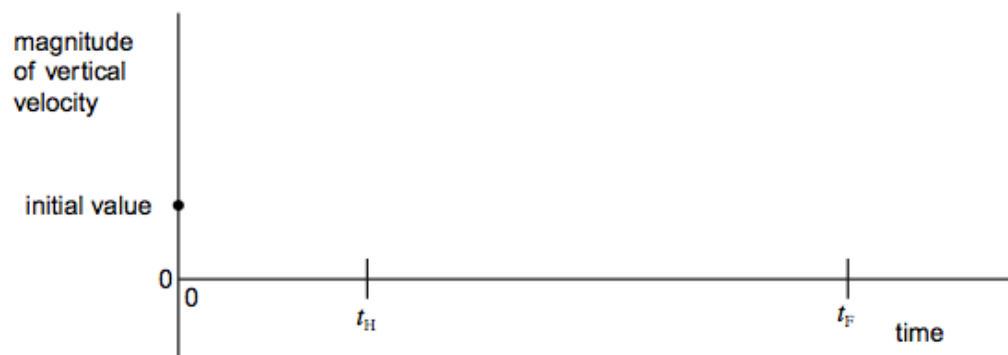
(1)

- (ii) Mark with a **B** on the flight path in **Figure 1** the position where the speed of the projectile is least.

(1)

- (iii) The projectile reaches its maximum height at time t_H and finishes its flight at time t_F .
Draw on **Figure 2** a graph to show how the **magnitude** of the vertical component of velocity of the projectile varies with time. Numerical values are **not** required.

Figure 2



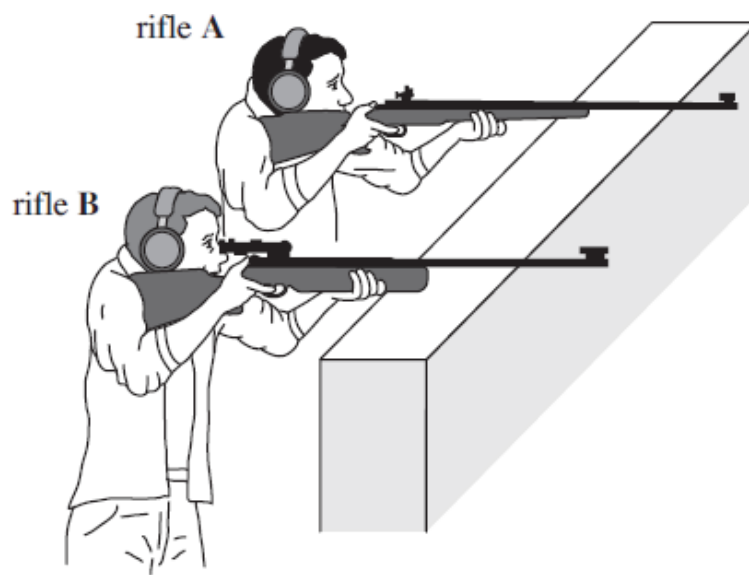
(2)

(Total 11 marks)

3

The diagram below shows two different rifles being fired horizontally from a height of 1.5 m above ground level.

Assume the air resistance experienced by the bullets is negligible.



- (a) When rifle **A** is fired, the bullet has a horizontal velocity of 430 m s^{-1} as it leaves the rifle. Assume the ground is level.

- (i) Calculate the time that the bullet is in the air before it hits the ground.

time _____ s

(2)

- (ii) Calculate the horizontal distance travelled by the bullet before it hits the ground.

horizontal distance _____ m

(1)

- (b) Rifle **B** is fired and the bullet emerges with a smaller horizontal velocity than the bullet from rifle **A**.

Explain why the horizontal distance travelled by bullet **B** will be less than bullet **A**.

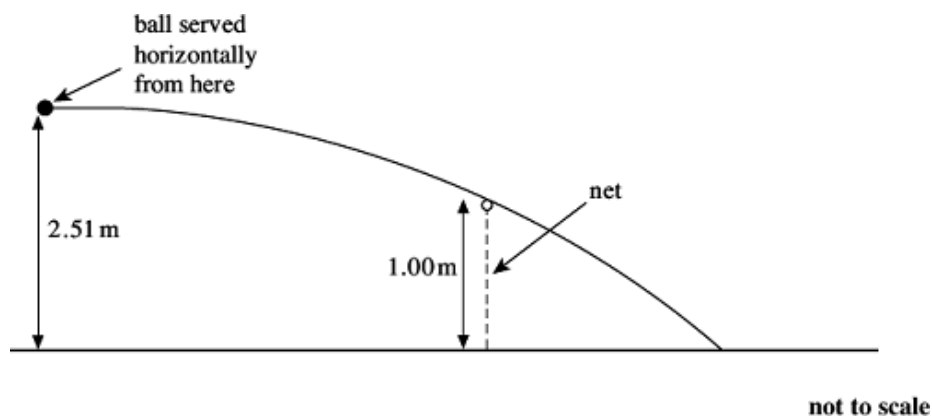
(3)

(Total 6 marks)

4

A tennis player serves a ball from a height of 2.51 m at 18.0 ms^{-1} in a horizontal direction. The ball just clears the net which is 1.00 m high. In this question assume that air resistance is negligible.

The figure below shows the ball and its resulting trajectory across the court.



- (a) Show that the ball takes approximately 0.6 s to reach the net after being served.

(3)

- (b) (i) Calculate the vertical component of the velocity of the ball as it passes over the net.

vertical component of velocity _____ ms^{-1}

(2)

- (ii) Calculate the overall velocity of the ball as it passes over the net.

magnitude of velocity _____ ms^{-1}

angle to horizontal _____ degree

(3)

(Total 8 marks)

5

The figure below shows the path that a tennis ball would follow in the absence of air resistance, after being hit horizontally at **A**.



- (a) Explain why the path of the ball is curved in this way.

(2)

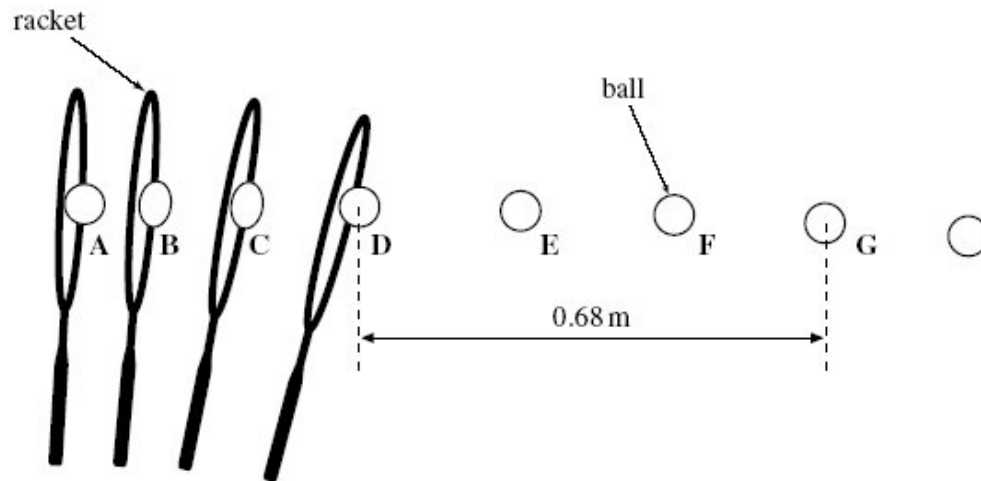
- (b) Draw onto the figure the path of a ball, hit in the same way at **A**, that is affected by air resistance.

(1)

(Total 3 marks)

6

A digital camera was used to obtain a sequence of images of a tennis ball being struck by a tennis racket. The camera was set to take an image every 5.0 ms. The successive positions of the racket and ball are shown in the diagram below.



- (a) The ball has a horizontal velocity of zero at **A** and reaches a constant horizontal velocity at **D** as it leaves the racket. The ball travels a horizontal distance of 0.68 m between **D** and **G**.

- (i) Show that the horizontal velocity of the ball between positions **D** and **G** in the diagram above is about 45 m s^{-1} .

(3)

- (ii) Calculate the horizontal acceleration of the ball between **A** and **D**.

answer = _____ m s^{-2}

(1)

(b) At **D**, the ball was projected horizontally from a height of 2.3 m above level ground.

(i) Show that the ball would fall to the ground in about 0.7 s.

(3)

(ii) Calculate the horizontal distance that the ball will travel after it leaves the racket before hitting the ground. Assume that only gravity acts on the ball as it falls.

answer = _____ m

(2)

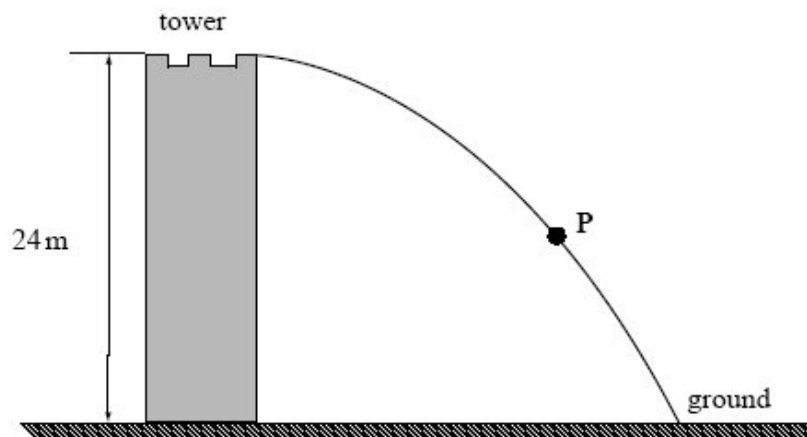
(iii) Explain why, in practice, the ball will not travel this far before hitting the ground.

(2)

(Total 11 marks)

7

The diagram below shows the path of a ball thrown horizontally from the top of a tower of height 24 m which is surrounded by level ground.



(a) Using two labelled arrows, show on the diagram above the direction of the velocity, v , and the acceleration, a , of the ball when it is at point **P**.

(2)

- (b) (i) Calculate the time taken from when the ball is thrown to when it first hits the ground. Assume air resistance is negligible.

Answer _____ s

(2)

- (ii) The ball hits the ground 27 m from the base of the tower. Calculate the speed at which the ball is thrown.

Answer _____ m s^{-1}

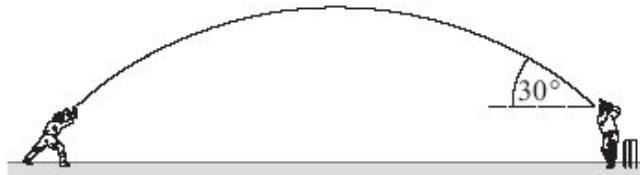
(2)

(Total 6 marks)

8

Figure 1 shows the flight of a cricket ball hit by a batsman at 30° to the horizontal at a speed of 22 m s^{-1} . The ball reached a fielder without bouncing and was caught at the same height as it was hit. The effect of air resistance on the cricket ball is negligible.

Figure 1



- (a) (i) Calculate the vertical speed of the ball at the instant it left the bat.

vertical speed _____ m s^{-1}

(1)

- (ii) Show that the ball was in the air for about 2.2 s.

(3)

- (iii) How far did the ball travel horizontally before it was caught?

distance _____ m

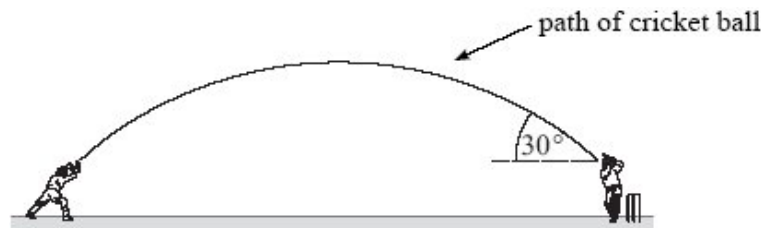
(1)

- (b) (i) A tennis ball is about the same size as a cricket ball but has a lower mass. By considering the energy changes that take place, explain why a tennis ball hit at the same speed and angle as the cricket ball would be unlikely to reach the fielder without bouncing.

(3)

- (ii) Draw on **Figure 2** the path you would expect a tennis ball to follow when hit at the same speed and angle as the cricket ball.

Figure 2

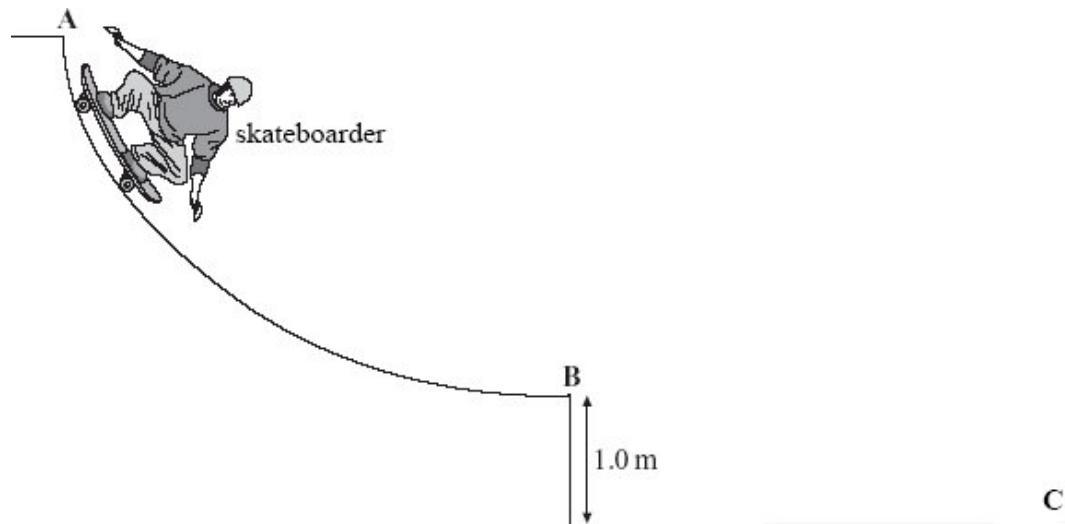


(2)

(Total 10 marks)

9

The figure below shows a skateboarder descending a ramp.



The skateboarder starts from rest at the top of the ramp at **A** and leaves the ramp at **B** horizontally with a velocity v .

- (a) State the energy changes that take place as the skateboarder moves from **A** to **B**.

(2)

- (b) In going from **A** to **B** the skateboarder's centre of gravity descends a vertical height of 1.5 m. Calculate the horizontal velocity, v , stating an assumption that you make.

(3)

- (c) Explain why the acceleration decreases as the skateboarder moves from **A** to **B**.

(2)

- (d) After leaving the ramp at **B** the skateboarder lands on the ground at **C** 0.42 s later.

Calculate for the skateboarder

- (i) the horizontal distance travelled between **B** and **C**,

- (ii) the vertical component of the velocity immediately before impact at **C**,

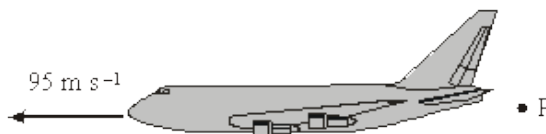
- (iii) the magnitude of the resultant velocity immediately before impact at **C**.

(5)

(Total 12 marks)

10

The aeroplane shown in the diagram below is travelling horizontally at 95 m s^{-1} . It has to drop a crate of emergency supplies. The air resistance acting on the crate may be neglected.



- (a) (i) The crate is released from the aircraft at point **P** and lands at point **Q**. Sketch the path followed by the crate between **P** and **Q** as seen from the ground.

- (ii) Explain why the horizontal component of the crate's velocity remains constant while it is moving through the air.

(3)

- (b) (i) To avoid damage to the crate, the maximum vertical component of the crate's velocity on landing should be 32 m s^{-1} . Show that the maximum height from which the crate can be dropped is approximately 52 m.

- (ii) Calculate the time taken for the crate to reach the ground if the crate is dropped from a height of 52 m.

- (iii) If **R** is a point on the ground directly below **P**, calculate the horizontal distance **QR**.

(6)

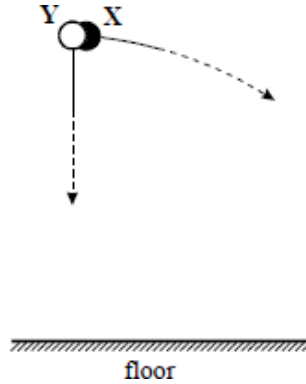
- (c) In practice air resistance is **not** negligible. State and explain the effect this has on the maximum height from which the crate can be dropped.

(2)

(Total 11 marks)

11

A ball **X** is projected horizontally from a certain point at the same time as a ball **Y** of the same diameter but twice the mass is released from rest and allowed to fall vertically from the same level. Air resistance is negligible. Which one of the following will occur?



- A Y will hit the floor just before X
- B X will hit the floor just before Y
- C X and Y will hit the floor at the same time
- D Y hits the floor while X is half way to the floor

(Total 1 mark)

12

- (a) **Figure 1** shows a skier descending the ramp of a ski jump. **Figure 2** shows a graph of the distance travelled along the ramp against time, from the time the descent starts until the skier leaves the end of the ramp.

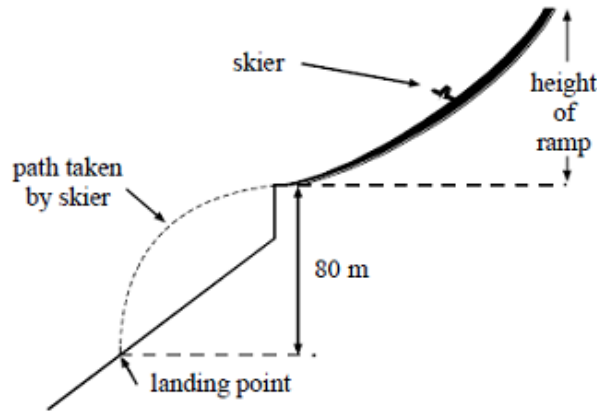


Figure 1

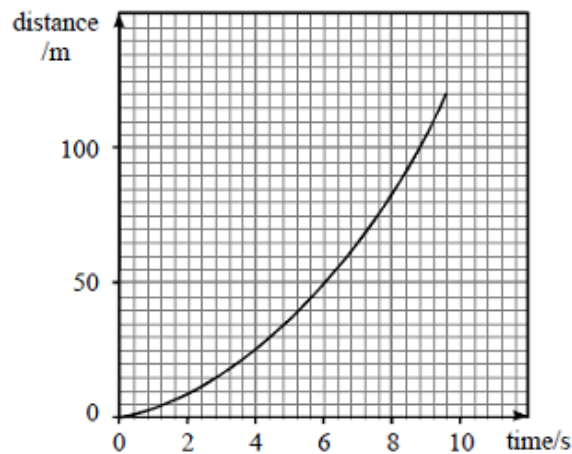


Figure 2

The skier of mass 80 kg (including equipment) skis down the ramp and leaves it horizontally. The skier gains 55% of the available gravitational potential energy as kinetic energy when descending the ramp.

acceleration of free fall, $g = 9.8 \text{ m s}^{-2}$

- (i) One energy transformation which occurs as the skier skis down the ramp is from gravitational potential energy to kinetic energy of the skier. State **two** other energy transformations that occur as the skier skis down the ramp.

(2)

- (ii) Use **Figure 2** to show that the speed at which the skier leaves the ramp is about 23 m s^{-1} . Show your reasoning clearly.

(2)

(iii) Determine the height of the ramp.

(3)

(b) **Figure 1** shows the path taken by the skier after leaving the ramp.
Assuming that there was no lift or drag due to the air during this jump, calculate:

(i) the time for which the skier was in flight;

(2)

(ii) the horizontal distance jumped by the skier before landing.

(2)

(c) On landing the skier has considerable vertical momentum that has to be reduced to zero. The surface on which the skier lands is hard-packed snow. To reduce the force experienced by the skier, the landing surface is angled at 40° to the horizontal.

Explain briefly how angling the landing surface reduces the vertical component of the force, experienced by the skier.

(3)

(Total 14 marks)

13

A student performs an experiment to find the acceleration due to gravity. The student measures the time t for a spherical object to fall freely through measured vertical distances s . The time is measured electronically. The results are shown in the table below.

s/m	t_1/s	t_2/s	t_3/s	mean time t_m/s	t_m^2/s^2
0.300	0.245	0.246	0.244	0.245	0.0600
0.400	0.285	0.286	0.286	0.286	0.0818
0.500	0.319	0.321	0.318	0.319	0.102
0.600	0.349	0.351	0.348	0.349	0.122
0.700	0.378	0.380	0.378	0.379	0.144
0.800	0.403	0.406	0.404		
0.900	0.428	0.428	0.430		

(a) Complete the table by entering the missing values for t_m and t_m^2

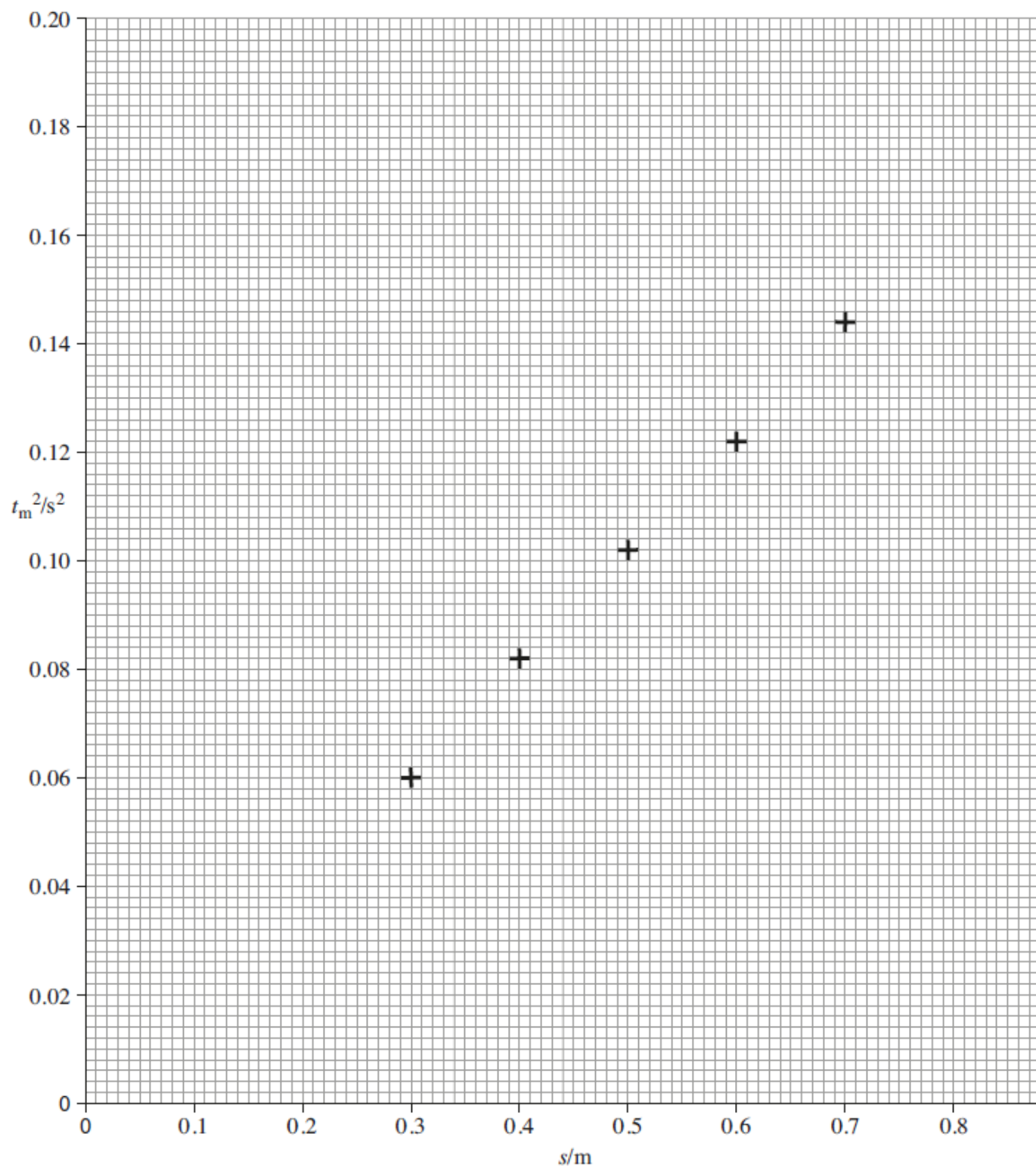
(1)

(b) Complete the graph below by plotting the remaining two points and draw a line of best fit.

(2)

(c) Determine the gradient of the graph.

(3)



- (d) Theory suggests that the equation for the line is $t^2 = \frac{2s}{g}$ where g is the acceleration due to gravity.

Calculate a value for g using the above equation and the gradient of your graph above.

(1)

- (e) Calculate the percentage difference between your value for g and the accepted value of 9.81 m s^{-2} .

(1)

- (f) Calculate the uncertainty in the smallest value of t_m .

(1)

- (g) Calculate the value of g which would be given from the smallest value of t_m and the corresponding value of s .

(3)

(h) The uncertainty in each value of s is ± 0.001 m.

Calculate the uncertainty in the value of g you calculated in part **(g)**.

You will need to use the uncertainty for t_m you calculated in part **(f)**.

(3)

- (i) A student wishes to investigate the effect of changing the mass of the spherical object on the acceleration of free fall.

Explain how you would modify the experiment seen at the start of this question.

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

(3)

(Total 18 marks)

14

A body falls freely, with negligible air resistance. What quantity of the body is its rate of change of momentum?

- | | | |
|----------|----------------|-----------------------|
| A | mass | ☐ |
| B | power | ☐ |
| C | kinetic energy | ☐ |
| D | weight | ☐ |

(Total 1 mark)

Mark schemes

1

B

[1]

2

- (a) (i) (using $\sin 25^\circ = V_V/V$
 $V = V_V / \sin 25^\circ$)

$$= 5.0 / \sin 25^\circ \checkmark$$

$$11.8 \text{ (m s}^{-1}\text{)} \checkmark$$

(working and answer is required)

Look out for $\cos 65^\circ = \sin 25^\circ$ in first mark.

Also calculating the horizontal component using $\cos 25^\circ$ followed by Pythagoras is a valid approach.

Working backwards is not acceptable.

2

- (ii) (using $\tan 25^\circ = V_V/V_H$)

$$V_H = V_V / \tan 25^\circ \checkmark$$

$$= 5 / \tan 25^\circ = 11 \text{ (m s}^{-1}\text{)} \checkmark \text{ (10.7 m s}^{-1}\text{)}$$

Or (using $\cos 25^\circ = V_H / V$)

$$V_H = V \cos 25^\circ \checkmark = 11.8 \cos 25^\circ = 11 \text{ (m s}^{-1}\text{)} \checkmark \text{ (10.7 m s}^{-1}\text{)}$$

Or (using $V_H^2 + V_V^2 = V^2$)

$$V_H^2 + 5^2 = 11.8^2 \checkmark \text{ (Or } 12^2\text{)}$$

$$V_H = 11 \text{ (m s}^{-1}\text{)} \checkmark \text{ (10.7 m s}^{-1}\text{)}$$

Note $1/\cos 65^\circ = \sin 25^\circ$

and $\tan 25^\circ = 1/\tan 65^\circ$

Rounding means answers between 10.7 and 11 m s⁻¹ are acceptable

2

- (b) (i) (using $v^2 = u^2 + 2as$ with up being positive)

$$0 = 5.0^2 + 2 \times -9.81 \times s$$

$$s = 1.3 \text{ (m)} \checkmark \text{ (1.27} \rightarrow \text{1.28 m)}$$

or (loss of KE = gain of PE)

$$\frac{1}{2} m v^2 = m g h$$

$$\frac{1}{2} 5.0^2 = 9.81 \times h$$

$$h = 1.3 \text{ (m)} \checkmark \text{ (1.27} \rightarrow \text{1.28 m)}$$

quoted to 2 sig figs $\checkmark$

for the sig fig mark the answer line takes priority. If a choice of sig figs given and not in answer line – no sig fig mark

Sig fig mark stands alone provided some working is shown

2

- (ii) (using $s = (u + v)t/2$) or horizontal distance = speed $\times$ time)

$$s = 11 \times 1.3 = 14 \text{ (m)} \checkmark \text{ (using 10.7 gives the same answer)}$$

allow CE $s = (a_{ii}) \times 1.3$ but working must be seen

1

- (c) (i) **A** marked at the point of landing or immediately before $\checkmark$

*The **A** or its marked position must not be further to the left than the 'c' in the word 'scale'*

1

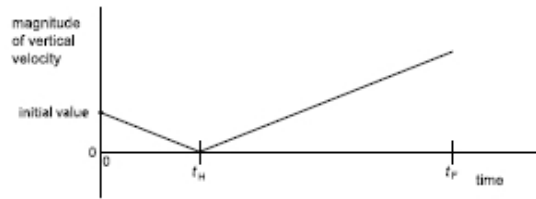
- (ii) **B** marked at the maximum height of the path ✓

*The **B** must lie vertically between the 'r' and 'a' in the word 'resistance' above figure 2.*

1

- (d) straight line from point given down to point t_H on the axis ✓

straight line starting where first line stops (t_H) but with opposite gradient to the first line ✓



(A measure of accuracy for the second mark) The second line must end (t_H) between the height of the vertical axis and half this height. Obviously straight lines drawn by hand are acceptable.

2

[11]

3

- (a) (i)

$$(s = \frac{1}{2}gt^2)$$

Allow $g=10$ (0.5477)

$$1.5 = \frac{1}{2}9.81t^2 \quad \text{OR} \quad t = \sqrt{\frac{2s}{g}} \quad \text{OR} \quad t = \sqrt{\frac{2 \times 1.5}{9.81}} \quad \checkmark$$

$$(= 0.553) = 0.55 \text{ (s) } \checkmark$$

0.6 gets 2 marks only if working shown. 0.6 on its own gets 1 mark.

2

- (ii) $(s = vt = 430 \times 0.553 = 237.8 =) 240 \text{ (m) } \checkmark$
ecf a(i)

1

- (b) their vertical motion is independent of their horizontal motion

OR downward / vertical acceleration is the same for both

OR acceleration due to gravity is the same for both

OR vertical speed / velocity is the same for both ✓

Allow 'time is constant'

Don't allow 'similar'

(bullets A and B will be in the air) for the same time ✓

(Horizontal acceleration is zero and thus horizontal) distance is proportional to horizontal speed **OR** $s = ut$ where u is the horizontal velocity ✓

'velocity smaller so distance smaller' is not sufficient

3

[6]

4	(a) $\Delta h = 2.51 - 1.00 = 1.51 \text{ (m) / (s} \Rightarrow \text{) } 1.51 \text{ m seen}$	M1		[8]
	use of appropriate kinematics formula correctly makes t subject	M1	3	
	time = 0.555 (s) / 0.56 (s) (allow 0.55 (s))	A1		
	(b) (i) use of appropriate kinematics equation to find vertical v	C1		
	$v = 5.4 \text{ (ms}^{-1}\text{) (accept 5.4 to 5.9)}$	A1	2	
	(ii) any use of Pythagoras where $v_h = 18$ or use of appropriate trig ratio where $v_h = 18$ and angle is to horizontal	C1		
	velocity = 18.8 / 18.9 / 19 (ms ⁻¹)	A1		
	angle = 16.8 to 18.1 (°)	A1	3	
5	(a) constant horizontal (component of) velocity/no horizontal force or acceleration	B1		[8]
	accelerates vertically/increasing vertical (component) of velocity	B1	2	
	(b) appropriate curve starting at same place with shorter trajectory	B1	1	[3]

6

(a) (i) $v = \frac{s}{t}$ (1)

$t = 0.015$ (s) or 15 (ms) (1)

$0.68/0.015$ (1) (= 45)

3

(ii) $\left(a = \frac{\Delta v}{\Delta t} = \frac{45.3}{0.015} \right) = 3000 \text{ (m s}^{-2}\text{) (3022) (1)}$

1

(b) (i) $s = (ut) = \frac{1}{2}gt^2$ or $t = \sqrt{\frac{2s}{g}}$ (1)

correct substitution seen = $\sqrt{\frac{2 \times 2.3}{9.81}}$ (1)

0.68 to 0.69 correct answer to more than one dp seen (1)

3

(ii) $(s = vt) = 45(.3) \times 0.685$ or 0.7 (1)

= 30.6 to 32 (1) (m)

2

(iii) mention of air resistance or drag (1)

causing **horizontal** deceleration or 'slowing down' (1)

2

[11]

7

(a) velocity vector tangential to path and drawn from the ball, arrow in correct direction (1)

acceleration vector vertically downwards, arrow drawn and in line with ball (1)

2

(b) (i) $s = \frac{1}{2}gt^2$ gives $t = \sqrt{\frac{2y}{g}} = \sqrt{\frac{2 \times 24}{9.8(1)}}$ (1) = 2.2(1) s (1)

(ii) $v (= s/t) = 27/2.2(1)$ (1) = 12(.2 m s⁻¹) or 12(.3) (1) (ecf from (b)(i))

(answer only gets both marks)

4

[6]

8

- (a) (i) vertical speed = $22 \sin 30 = 11 \text{ m s}^{-1}$ **(1)**

C1

- (ii) use of $v = u + at$ or substitution **(1)**

B1

or any correct alternative using equations of motion
working leading to 1.12 s **(1)**

B1

working showing that it is doubled for up and down **(1)**

B1

- (iii) 41.9 – 43m **(1)**

B1

5

- (b) (i) **max 3 from**

tennis ball doesn't travel as far because:

tennis ball has lower KE when hit **(1)**

B1

tennis ball has a rougher surface so more friction/air
resistance) **(1)**

B1

(although)rate of energy loss to air (initially) is
the same **(1)**

B1

tennis ball loses KE quicker **(1)**

B1

- (ii) sketch showing significantly lower height and range **(1)**

M1

acceptable flight path initially same (for short
distance then always below cricket ball path° **(1)**

A1

5

[10]

9

- (a) potential energy to kinetic energy **(1)**
mention of thermal energy and friction **(1)**
- (b) (use of $\frac{1}{2}mv^2 = mgh$ gives) $\frac{1}{2}v_h^2 = 9.81 \times 1.5$ **(1)**
 $v_h = 5.4(2)\text{ms}^{-1}$ **(1)**
(assumption) energy converted to thermal energy is negligible **(1)**
- (c) component of weight down the slope causes acceleration **(1)**
this component decreases as skateboard moves further down the slope **(1)** air resistance/friction increases (with speed) **(1)**
- (d) (i) distance $(= 0.42 \times 5.4) = 2.3\text{m}$ **(1)**
(2.27m)
(allow C.E. for value of v_h from (b))
- (ii) $v_v = 9.8 \times 0.42$ **(1)**
 $= 4.1(1) \text{ m s}^{-1}$ **(1)**
- (iii) $v^2 = 4.1^2 + 5.4^2$ **(1)**
 $v = 6.8 \text{ m s}^{-1}$ **(1)**
(6.78 m s^{-1})
(allow C.E. for value of v_h from (b))

2

3

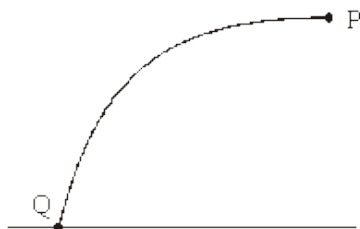
2

5

[12]

10

- (a) (i)



(1)

- (ii) no **horizontal** force acting **(1)**
(hence) no (horizontal) acceleration **(1)**
[or correct application of Newton's First law]

3

(b) (i) (use of $v^2 = u^2 + 2as$ gives) $32^2 = (0) + 2 \times 9.81 \times s$ **(1)**

$$s = \frac{1024}{19.62} \text{ **(1)** } (= 52.2 \text{ m})$$

(ii) (use of $s = \frac{1}{2} at^2$ gives) $52 = \frac{1}{2} 9.81 \times t^2$ **(1)**

$$t = \sqrt{\left(\frac{104}{9.81}\right)} = 3.3 \text{ s **(1)** } (3.26 \text{ s})$$

[or use of $v = u + at$ gives $32 = (0) + 9.81 \times t$ **(1)**

$$t = \frac{32}{9.81} = 3.3 \text{ s **(1)** } (3.26 \text{ s})]$$

(iii) (use of $x = vt$ gives) $x (= QR) = 95 \times 3.26$ **(1)**
 $= 310 \text{ m **(1)** }$

(use of $t = 3.3$ gives $x = 313.5 \text{ m}$)
 (allow C.E. for value of t from (ii)

6

- (c) maximum height is greater **(1)**
 because vertical acceleration is less **(1)**
 [or longer to accelerate]

2

[11]

11

C

[1]

12

- (a) (i) (kinetic) energy of air / snow (pushing it out of the way)
 (**not** internal energy)

B1

melting / internal energy of snow / ice
or internal energy of air / skis (condone heat)

award 1 mark only for "heat and sound"
 award zero marks for sound alone even if explained

B1

(2)

- (ii) clear attempt to draw tangent to graph at end of run

B1

correct co-ordinates and manipulation for tangent
 or use of 2 points on curve $\geq t = 7\text{s}$

(no unit penalty) (no significant figure penalty)

B1

(2)

(iii) potential energy loss = $100 / 55 \times \text{KE}$

B1

$$\text{final KE} = 0.5 \times m \times 23^2$$

or

equates any KE to mgh

C1

height = 49 m allow e.c.f. from (ii)

A1

(3)

(b) (i) $s = \frac{1}{2}at^2$ or $s = ut + \frac{1}{2}at^2$ or correct numerical equivalent

C1

4.0 s or 4.04 s

A1

(2)

(ii) $s = vt$ or numerical equivalent

C1

92 m – 93 m

allow e.c.f. from (a)(ii) and (b)(i)

A1

(2)

(c) force is lower because $F = \frac{\Delta(mv)}{t}$

B1

skier has vertical momentum after landing

B1

change in momentum is reduced

B1

or

$$F = \frac{\Delta(mv)}{t}$$

B1

skier takes longer time to reduce (vertical) momentum

B1

compare with time when surface is flat

B1

or

$$F = \frac{\text{work done}}{s}$$

B1

skier moves though longer distance (vertically) to come to rest

B1

compare with distance to come to rest when surface is flat

B1

or

$$F = ma$$

B1

time to come to rest (vertically) is increased

B1

acceleration is reduced

allow 1 mark for idea that “(vertical) component of normal reaction is reduced”

B1

(3)

[14]

13

- (a) Both t_m values correct: 0.404, 0.429

AND

Both t_m^2 values correct: 0.163, 0.184 ✓

Exact values required for the mark.

1

- (b) Both plotted points to nearest mm ✓

Best line of fit to points ✓

The line should be a straight line with approximately an equal number of points on either side of the line.

2

- (c) Large triangle drawn (at least 8 cm × 8 cm) ✓

Correct values read from graph ✓

Gradient value in range 0.190 to 0.222 ✓

Allow 2 or 3 sf for gradient

3

- (d) $g = 9.71 \text{ (ms}^{-2}\text{)}$ or correct value from gradient value in (c) ✓.

(The answer must be in the range 9.0 to 10.5 (ms⁻²)).

Allow 2 or 3 sf.

Unit not required

1

(e) $\% \text{ difference} = \frac{(9.81 - 9.71)}{9.81} \times 100 = 1.02$

OR correct computation using value from (d) ✓

If the candidate's value is exactly 9.81, then a statement that there is no (or zero) percentage difference is acceptable.

No sf penalty.

NB. Allow an answer from a calculation with either the candidate's value or the accepted value as the denominator in the equation.

1

- (f) 0.001 s ✓ (half the spread)
(Must have unit).

1

- (g) $g = 2s/t_m^2$ ✓
 $= 2 \times 0.300/0.245^2$ ✓
 $= 10.0$ (or 10.00) ms^{-2} ✓

Unit required and 3 or 4sf for the last mark.

3

- (h) % uncertainty in $s = 0.33$ **and**
 % uncertainty in $t_m = 0.41$ ✓

Allow ecf from part (f).

% uncertainty in g
 $= 0.33 + (2 \times 0.41) = 1.15$ ✓

Allow ecf at each stage of calculation.

Uncertainty in g
 $= 10.0 \times 1.15/100 = 0.12 \text{ m s}^{-2}$ or 0.1 m s^{-2} ✓

Allow ecf from part (g).

(allow 1 or 2 sf only)
 (Must have unit for 3rd mark).

3

- (i) (a) Use spherical objects of different mass **and** determine mass with balance ✓

Annotate the script with the appropriate letter at the point where the mark has been achieved.

(b) Would need **same diameter** spherical objects for fair comparison (same air resistance etc) ✓

(c) Time spherical object falling through same height **and** compare times

Alternative for (c):

i.e. repeat whole of experiment, plot extracted values of g against mass. Horizontal line expected, concluding acceleration same for different masses.

3

[18]