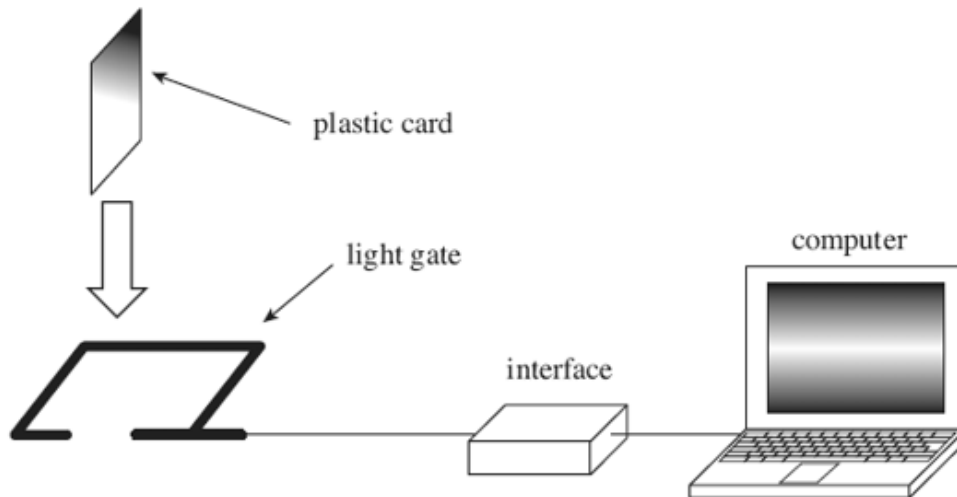


**Q1.** A student measures the acceleration due to gravity,  $g$ , using the apparatus shown in the figure below. A plastic card of known length is released from rest at a height of 0.50m above a light gate. A computer calculates the velocity of the card at this point, using the time for the card to pass through the light gate.



(a) The computer calculated a value of  $3.10\text{ms}^{-1}$  for the velocity of the card as it travelled through the light gate. Calculate a value for the acceleration due to gravity,  $g$ , from these data.

answer = .....  $\text{ms}^{-2}$

(2)

(b) The student doubles the mass of the card and finds a value for  $g$  that is similar to the original value. Use the relationship between *weight*, *mass* and  $g$  to explain this result.

.....

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.....

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(1)

- (c) State and explain **one** reason why the card would give more reliable results than a table tennis ball for this experiment.

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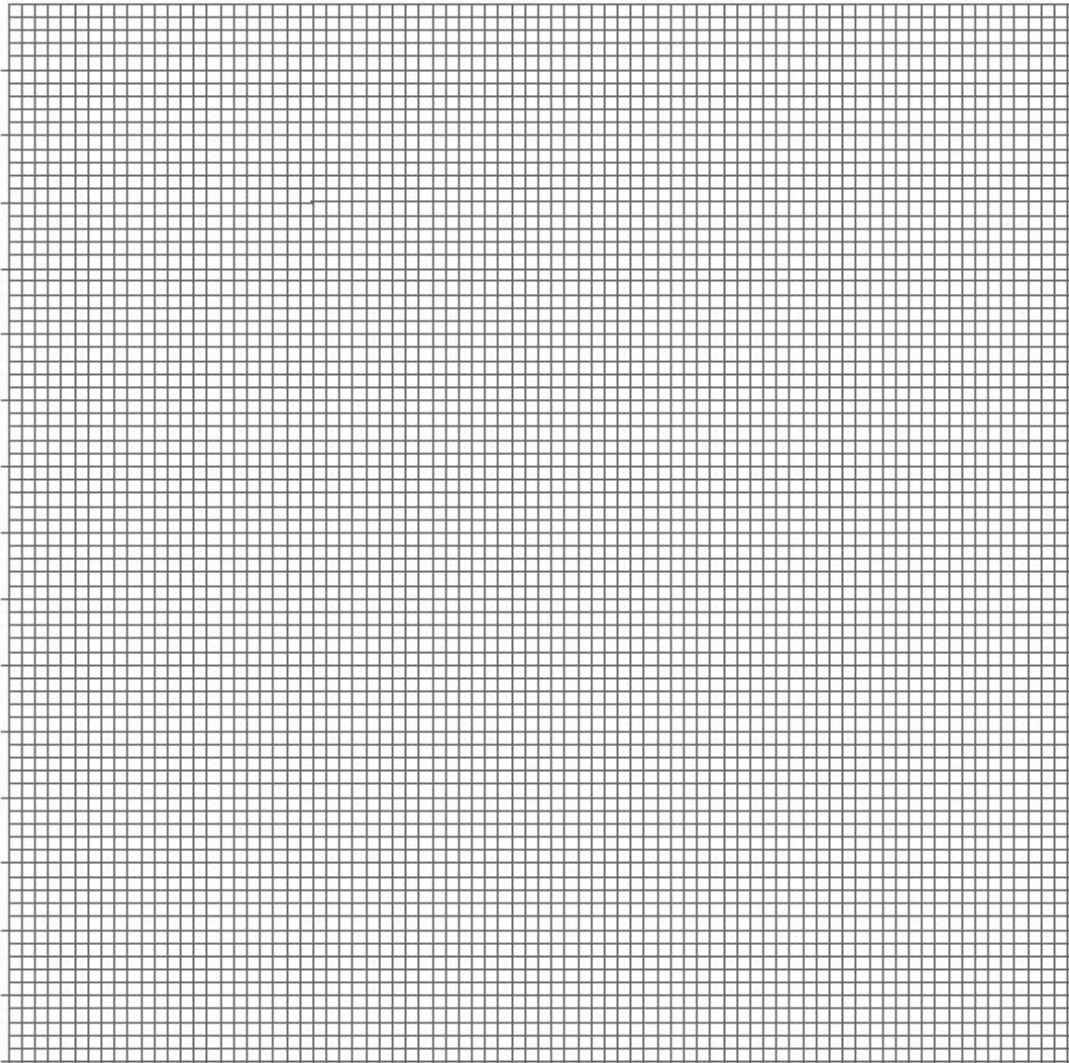
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**(2)**  
**(Total 5 marks)**

**Q2.** A car is travelling on a level road at a speed of  $15.0 \text{ m s}^{-1}$  towards a set of traffic lights when the lights turn red. The driver applies the brakes  $0.5 \text{ s}$  after seeing the lights turn red and stops the car at the traffic lights. The table below shows how the speed of the car changes from when the traffic lights turn red.

time/s	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5
speed/ $\text{m s}^{-1}$	15.0	15.0	12.5	10.0	7.5	5.0	2.5	0.0

(a) Draw a graph of speed on the y-axis against time on the x-axis on the grid provided.



(5)

(b) (i) State and explain what feature of the graph shows that the car's deceleration was uniform.

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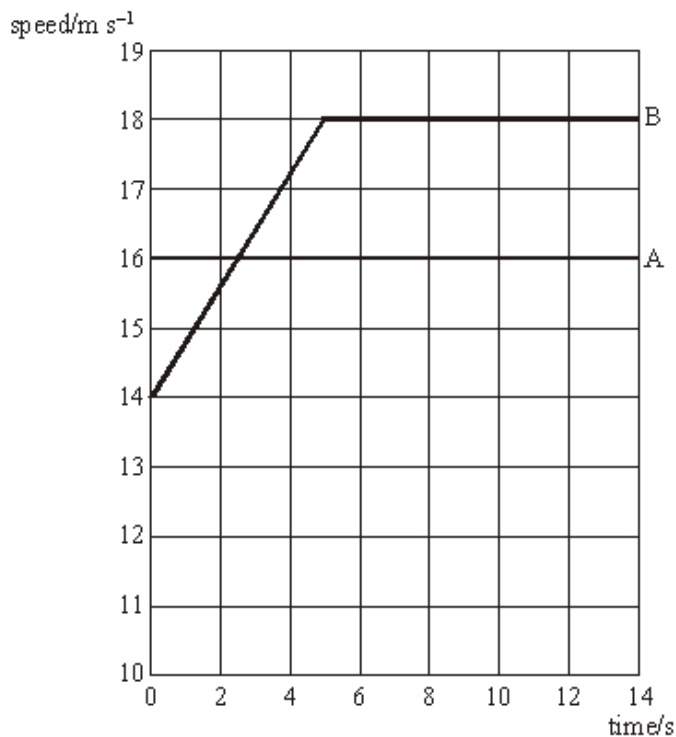
(2)

- (ii) Use your graph to calculate the distance the car travelled after the lights turned red to when it stopped.

Answer ..... m

(4)  
(Total 11 marks)

**Q3.** The graph represents the motion of two cars, A and B, as they move along a straight, horizontal road.



(a) Describe the motion of each car as shown on the graph.

(i) car A: .....

.....

(ii) car B: .....

.....

(3)

(b) Calculate the distance travelled by each car during the first 5.0 s.

(i) car A: .....

.....  
.....

(ii) car B: .....

.....  
.....

(4)

(c) At time  $t = 0$ , the two cars are level. Explain why car A is at its maximum distance ahead of B at  $t = 2.5$  s

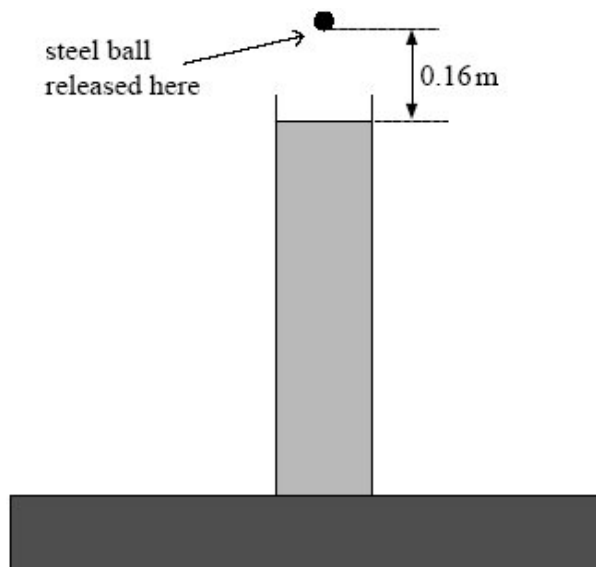
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(3)

(Total 10 marks)

**Q4.** A steel ball is released from rest above a cylinder of liquid, as shown in **Figure 1**. The ball descends vertically in the air then in the liquid until it reaches the bottom of the cylinder.

**Figure 1**



- (a) The vertical distance from the bottom of the ball at the point where it is released to the liquid surface is 0.16 m.
- (i) Calculate the time taken,  $t_0$ , by the ball to fall to the liquid surface from the point where it is released. Give your answer to an appropriate number of significant figures.

answer..... s

(3)

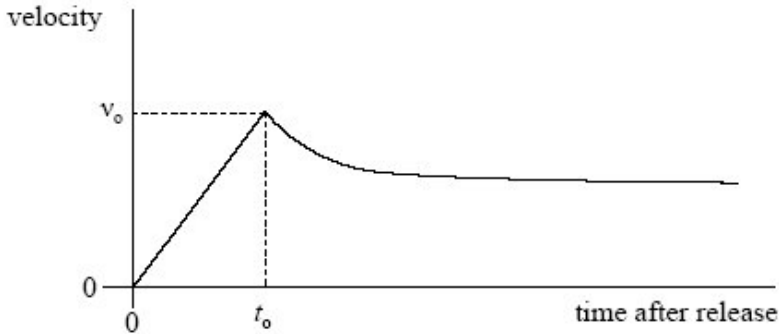
- (ii) Calculate the velocity,  $v_0$ , of the ball on reaching the liquid.

answer .....  $\text{m s}^{-1}$

(2)

(b) **Figure 2** below shows how the velocity of the ball changed after it was released.

**Figure 2**



Describe and explain how the acceleration of the ball changed after it entered the liquid until it reached the bottom of the cylinder.

The quality of your written answer will be assessed in this question.

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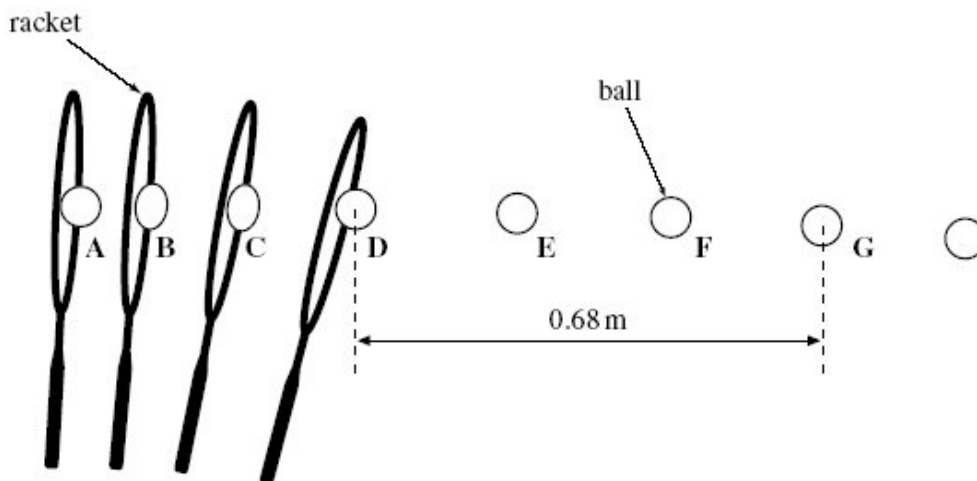
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(6)  
(Total 11 marks)

- Q5.** 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  $45 \text{ m s}^{-1}$ .

(3)

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

answer = .....  $\text{m s}^{-2}$

(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)**

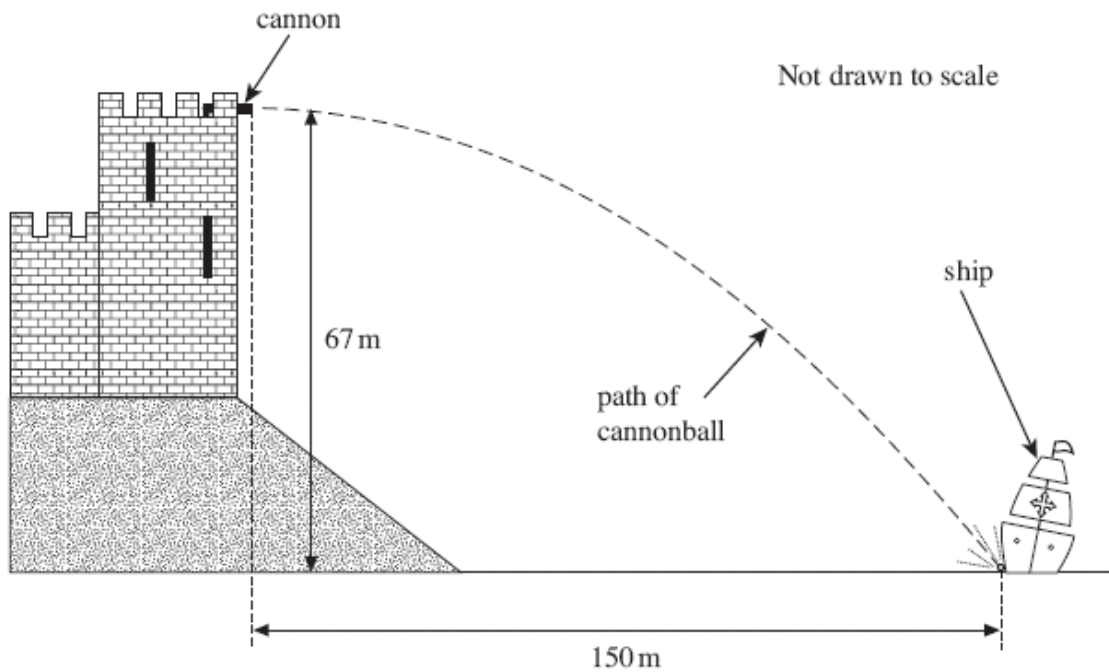
(iii) Explain why, in practice, the ball will not travel this far before hitting the ground.

.....  
.....  
.....

**(2)**

**(Total 11 marks)**

- Q6.** In a castle, overlooking a river, a cannon was once employed to fire at enemy ships. One ship was hit by a cannonball at a horizontal distance of 150 m from the cannon as shown in the figure below. The height of the cannon above the river was 67 m and the cannonball was fired horizontally.



- (a) (i) Show that the time taken for the cannonball to reach the water surface after being fired from the cannon was 3.7 s. Assume the air resistance was negligible.

(2)

- (ii) Calculate the velocity at which the cannonball was fired. Give your answer to an appropriate number of significant figures.

answer = ..... m s<sup>-1</sup>

(2)

- (iii) Calculate the vertical component of velocity just before the cannonball hit the ship.

answer = ..... m s<sup>-1</sup>

(2)

- (iv) By calculation or scale drawing, find the magnitude and direction of the velocity of the cannonball just before it hit the ship.

velocity = ..... m s<sup>-1</sup>

direction = .....

(4)

- (b) (i) Calculate the loss in gravitational potential energy of the cannonball.  
mass of the cannonball = 22 kg

answer = ..... J

(1)

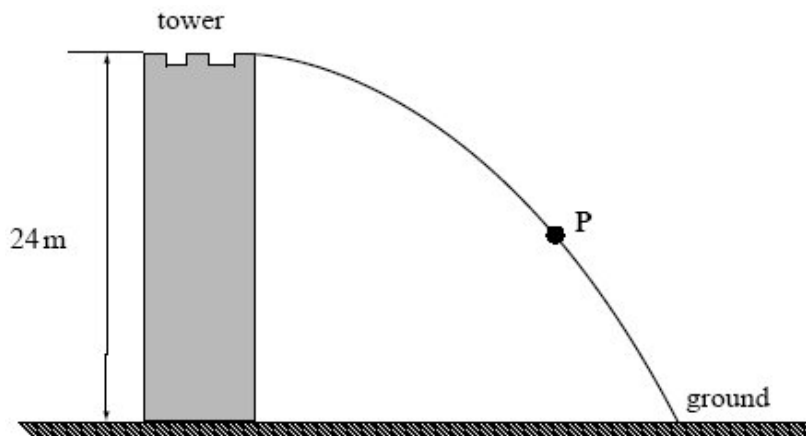
- (ii) Describe the energy changes that take place from the moment the cannonball leaves the cannon until just before it hits the water. Include the effects of air resistance.

.....  
.....  
.....  
.....

(2)

**(Total 13 marks)**

**Q7.** 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)

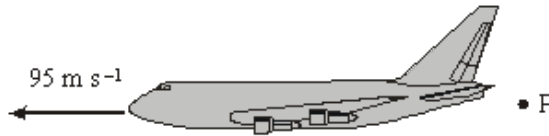
- (ii) The ball hits the ground 27 m from the base of the tower. Calculate the speed at which the ball is thrown.

Answer .....  $\text{m s}^{-1}$

(2)

**(Total 6 marks)**

- Q8.** The aeroplane shown in the diagram below is travelling horizontally at  $95 \text{ m s}^{-1}$ . 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  $32 \text{ m s}^{-1}$ . 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.

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

.....

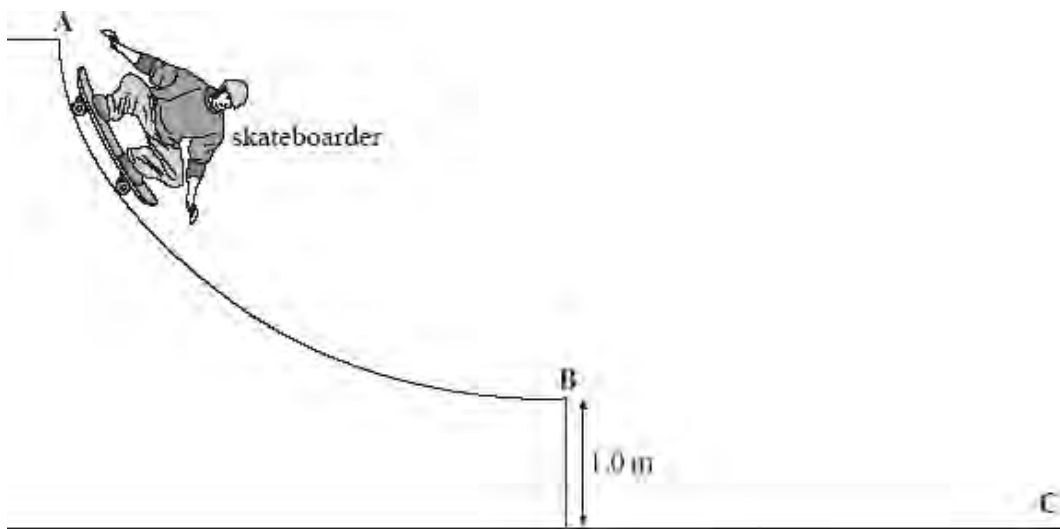
.....

- (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)

**Q9.** 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**,

.....  
.....  
.....

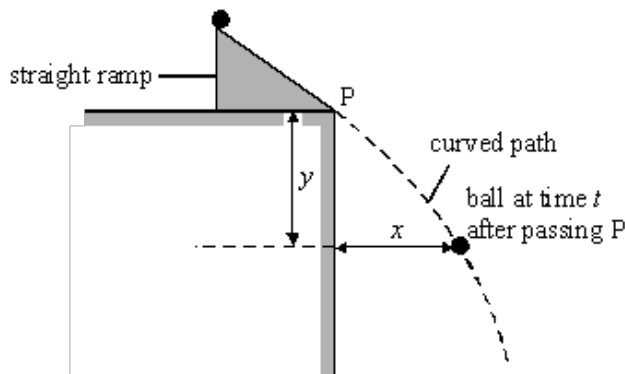
(iii) the magnitude of the resultant velocity immediately before impact at **C**.

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(5)

(Total 12 marks)

**Q10.** While investigating projectile motion, a student used stroboscopic photography to determine the position of a steel ball at regular intervals as it fell under gravity. With the stroboscope flashing 20 times per second, the ball was released from rest at the top of an inclined track, and left the foot of the track at P, as shown in the diagram below.



For each of the images on the photograph, the student calculated the horizontal distance,  $x$ , and the vertical distance,  $y$ , covered by the ball at time  $t$  after passing P. Both distances were measured from point P. He recorded his results for the distances  $x$  and  $y$  in the table.

image	$x/cm$	$y/cm$	$t/s$	$(y/t)/cm\ s^{-1}$
1	11.6	9.3	0.05	
2	22.0	21.0	0.10	
3	32.4	35.0	0.15	
4	44.2	51.8	0.20	
5	54.8	71.0	0.25	
6	66.0	92.2	0.30	

(a) Using two sets of measurements from the table, calculate the horizontal component of velocity of the ball. Give a reason for your choice of measurements.

.....  
 .....  
 .....

(2)

(b) The student worked out that the variables  $y$  and  $t$  in the experiment could be represented by

$$\frac{y}{t} = u + kt$$

where  $u$  and  $k$  are constants.

(i) Complete the table above.



(ii) Use the data in the table to plot a suitable graph to confirm the equation.

*(Allow one sheet of graph paper)*

(iii) Use your graph to find the values of  $u$  and  $k$ .

.....  
.....  
.....  
.....  
.....

**(9)**

(c) State the physical significance of

$u$  .....

.....

$k$  .....

.....

**(2)**

(d) Calculate the magnitude of the velocity of the ball at point P.

.....

.....

.....

.....

**(2)**  
**(Total 15 marks)**

**M1.** (a) correct substitution in  $(v^2 = u^2 + 2as)$

or correct rearrangement  $g = \frac{v^2}{2s}$  or  $\frac{3.10^2}{2 \times 0.50}$  ✓

= 9.6 (9.61 m s<sup>-1</sup>) ✓

2

(b)  $g = W/m$  or  $W = mg$  ( $ma$ ) and weight is proportional to mass/doubling the mass doubles the weight/masses cancel/the factor of two cancels (so  $g$  remains the same) ✓

1

(c) ball's acceleration will decrease/be less than card's or card's acceleration will be unaffected/nearly constant ✓

air resistance affects cards less or card is more streamlined  
or card does less work against air resistance ✓

*alternative timing/(velocity/speed/acceleration) uncertain/  
(inaccurate /imprecise/less reliable) ✓*

*indication that full width of ball may not pass through gate/difficulty  
in determining 'length' of ball passing through gate ✓*

2

[5]

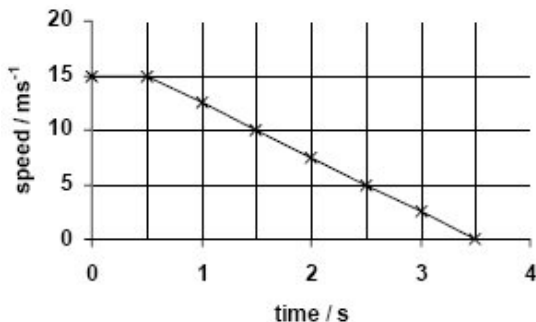
**M2.** (a) axes labelled correctly with correct units shown (1)

suitable scales (1)

6 points plotted correctly (1)

all points plotted correctly (1)

both sections of line drawn correctly (1)



5

(b) (i) the gradient (of the slope section) represents the deceleration/  
calculates 5 m s<sup>-2</sup> (1)

(deceleration is uniform because) the gradient is constant/  
line is straight (1)

(ii) distance travelled = area under line (0 to 3.5 s or 0.5 to 3.5 s) **(1)**

$$= 15.0 \times 0.5 = 7.5 \text{ m in first 0.5 s } \mathbf{(1)}$$

$$= 0.5 \times 15.0 \times 3.0 \text{ or } s = \frac{1}{2}(u + v)t, \text{ etc} = 22.5 \text{ m}$$

(from 0.5s to 3.5s) **(1)**

$$= \frac{1}{2}(0.5 + 3.5) \times 15 \text{ gets all three method marks}$$

(total distance travelled = 7.5 + 22.5) = 30m **(1)**

6

[11]

**M3.** (a) (i) car A: travels at constant speed **(1)**

(ii) car B: accelerates for first 5 secs (or up to  $18 \text{ m s}^{-1}$ ) **(1)**  
then travels at constant speed **(1)**

3

(b) (i) car A: distance =  $5.0 \times 16$  **(1)**  
= 80 m **(1)**

(ii) car B: (distance = area under graph)  
distance =  $[5.0 \times \frac{1}{2} (18 + 14)]$  **(1)**  
= 80 m **(1)**

4

(c) car B is initially slower than car A (for first 2.5 s) **(1)**  
distance apart therefore increases **(1)**  
cars have same speed at 2.5 s **(1)**  
**after 2.5 s**, car B travels faster than car A (or separation decreases) **(1)**

max 3

[10]

**M4.** (a) (i) ( $u = 0, s = 0.16 \text{ m}, a = 9.8(1) \text{ m s}^{-2}$ )  
(rearranging  $s = ut + \frac{1}{2} at^2$  with  $u = 0$  gives)

$$t = \frac{2s}{a} \text{ or } v^2 = u^2 + 2gs \text{ or } 0.16 = \frac{1}{2} \times 9.81 t^2$$

$$\text{or } t_0 = \sqrt{\frac{(2 \times 0.16)}{9.8(1)}} \mathbf{(1) = 0.1804 \text{ or } 0.1806 \text{ or } 0.181 \text{ etc } (1)}$$

(s) **2 sf only (1)**

(ii) ( $v_0 = u + at_0 =$ )  $0 + 9.81 \times 0.18$  ecf (a) (i) or  $v^2 = 2 \times 9.81 \times 0.16$  **(1)**  
= 1.8 or 1.77 ( $\text{m s}^{-1}$ ) **(1)**

5

- (b) the mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication

QWC	descriptor	mark range
good-excellent	The candidate provides a correct description of the motion of the ball including its <b>deceleration in the fluid decreasing and becoming zero</b> (or attaining constant velocity). They should give a comprehensive and coherent explanation which includes nearly all the necessary principles in a logical order. In their explanation, the candidate should refer to the forces including their <b>directions</b> acting on the ball, why the <b>resistive force decreases</b> and why the acceleration becomes zero.	<b>5-6</b>
modest-adequate	The description should refer to the ball decelerating in the fluid until it becomes zero or attains <b>constant velocity</b> . Their explanation should be fairly coherent although it may not be comprehensive and may focus only on the forces acting when the ball attains constant velocity - <b>balanced forces</b> - or on the reason for the initial deceleration.	<b>3-4</b>
poor-limited	The candidate knows that the ball <b>decelerates</b> (acceleration with direction) or is acted on by an <b>upward</b> force (as well as the force of gravity). Their explanation of why the ball attains constant velocity may be absent.  May be sketchy and lacks key considerations. They may not appreciate that the two forces are equal and opposite when the ball is moving at constant velocity.	<b>1-2</b>
incorrect, inappropriate or no response	No answer at all or answer refers to unrelated, incorrect or inappropriate physics.	<b>0</b>

**The explanation expected in a competent answer should include a coherent selection of the following physics ideas.**

The ball decelerates/slows down in the fluid **(1)** if acceleration is used the direction must be specified

- because a force due to fluid friction/resistance/viscosity acts (upwards) on the ball **(1)**
- (and) the force due to the fluid is greater than the weight of the ball **(1)**
- resistive force is upwards **(1)**
- resistive force decreases **(1)**

The deceleration decreases (to zero) **(1)**

- because the force due to fluid friction/resistance/viscosity decreases as the ball's speed decreases **(1)**
- until it is equal (and opposite) to the weight of the ball **(1)** (or the resultant force is zero)
- gradient of graph gives the acceleration and the ball moves at constant/terminal velocity/ $a = 0$  **(1)**

[11]

**M5.** (a) (i)  $v = \frac{s}{t}$  **(1)**

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

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

3

(ii)  $\left( a = \frac{\Delta v}{\Delta t} = \frac{45.3}{0.015} \right) = 3000$  (m s<sup>-2</sup>) (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]**

**M6.** (a) (i)  $t = \sqrt{\frac{2s}{g}}$  (evidence for correct rearrangement or substitution) **(1)**

$= \sqrt{\frac{2 \times 67}{9.81}}$  (correct substitution leading to answer) **(1)**

(= **3.7** (3.696) (s))

2

(ii)  $(v = \frac{s}{t} = \frac{150}{3.696}) = 41$  (m s<sup>-1</sup>) **(1)** 2sf **(1)**

2

(iii)  $(v = (u + )gt = )9.81 \times 3.696$  **(1)** = **36** **(1)** (m s<sup>-1</sup>)

2

(iv)  $v = \sqrt{40.586^2 + 36.257^2}$  (or correct scale drawing) **(1)**

= **54** (m s<sup>-1</sup>) **(1)**

ecf from (ii) (iii) [for scale drawing allow range 53 → 56]

$\tan \theta = \frac{36.257}{40.586}$  **(1)** or correct alternative

(angle from horizontal =) **42** (°) or correct alternative angle  
**and clear indication of direction (1)**

[for scale drawing allow range 40 → 44 **(1)**  
for scale drawing: quality of construction **(1)**]

4

(b) (i)  $(= mgh = 22 \times 9.81 \times 67) = 14000 \text{ (14460) (J) (1)}$

1

(ii) (G)PE  $\rightarrow$  KE **(1)**

(KE to) internal/thermal/'heat' (energy) **(1)**

2

[13]

**M7.** (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  $t = \sqrt{\frac{2y}{g}} = \sqrt{\frac{2 \times 24}{9.8(1)}} \text{ (1) } = 2.2(1) \text{ s (1)}$

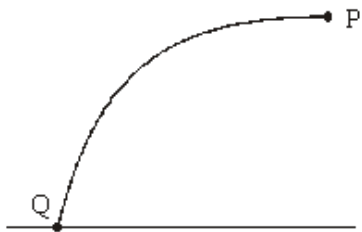
(ii)  $v (= s/t) = 27/2.2(1) \text{ (1) } = 12(.2 \text{ m s}^{-1}) \text{ or } 12(.3) \text{ (1) (ecf from (b)(i))}$

(answer only gets both marks)

4

[6]

**M8.** (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)**

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

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

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

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

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

(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]

- M9.** (a) potential energy to kinetic energy **(1)**  
 mention of thermal energy and friction **(1)**

2

(b) (use of  $\frac{1}{2} mv^2 = mgh$  gives)  $\frac{1}{2} v_h^2 = 9.81 \times 1.5$  **(1)**

$$v_h = 5.4(2) \text{ ms}^{-1} \text{ (1)}$$

(assumption) energy converted to thermal energy is negligible **(1)**

3

- (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)**

2



- (d) (i) distance ( $= 0.42 \times 5.4$ ) = 2.3m **(1)**  
(2.27m)  
(allow C.E. for value of  $v_h$  from (b))
- (ii)  $v_v = 9.8 \times 0.42$  **(1)**  
 $= 4.1$ (l)  $\text{m s}^{-1}$  **(1)**
- (iii)  $v^2 = 4.1^2 + 5.4^2$  **(1)**  
 $v = 6.8 \text{ m s}^{-1}$  **(1)**  
(6.78  $\text{m s}^{-1}$ )  
(allow C.E. for value of  $v_h$  from (b))

5

**[12]**

- M10.** (a) suitable calculation using a pair of values of  $x$  and corresponding  $t$  to give an average of  $2.2 \text{ m s}^{-1}$  ( $\pm 0.05 \text{ m s}^{-1}$ ) **(1)**  
valid reason given **(1)**  
(e.g. larger values are more reliable/accurate  
or use of differences eliminates zero errors)

2

- (b) (i) column D ( $y/t$  ( $\text{cm s}^{-1}$ ))  
186  
210  
233  
259  
284  
307  
  
all values correct to 3 s.f. **(1)**
- (ii) graph: chosen graph gives a straight line (e.g.  $y/t$  against  $t$ ) **(1)**  
axes labelled correctly **(1)**  
suitable scale chosen **(1)**  
minimum of four points correctly plotted **(1)**  
best straight line **(1)**
- (iii)  $u$  ( $y$  intercept)  $162 \text{ cm}^{-1}$  ( $\pm 4 \text{ cm}^{-1}$ ) **(1)**  
gradient =  $495 \text{ (cm s}^{-2}\text{)}$  ( $\pm 25 \text{ cm s}^{-2}$ ) **(1)**  
 $k = \text{gradient}$  ( $= 495 \text{ cm s}^{-2}$ ) **(1)**

9

(c) (i)  $u$  : initial vertical component of velocity **(1)**

(ii)  $k$  : =  $\frac{1}{2} g$  **(1)**

2

(d)  $v^2 = u^2 + 2.2^2$  **(1)**

gives  $v = (1.6^2 + 2.2^2)^{1/2} = 2.7 \text{ m s}^{-1} (\pm 0.1 \text{ m s}^{-1})$  **(1)**

2

**[15]**

