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EDEXCEL A LEVEL PHYSICS: QUESTIONS BY TOPIC

Mechanics (2)

A Level Physics Topic 2

139 questions · 760 marks · Mark schemes included

AS & A Level content · Pearson Edexcel 8PH0 / 9PH0 papers, 2016–2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.
Click any row below to jump straight to that sub-topic or question.
On every question page, click ANSWER in the top-right corner to jump to its mark scheme.
Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

	QUESTION		SOURCE	MARKS	PAGE
2.1	**DISTANCE, VELOCITY AND ACCELERATION-TIME GRAPHS**			14 Qs · 40 marks	**6**
1.	**Q1**		AS Paper 1 June 2016	1	**7**
2.	**Q2**		AS Paper 1 June 2017	1	**8**
3.	**Q3**		AS Paper 1 June 2019	1	**9**
4.	**Q4**		AS Paper 1 October 2020	1	**10**
5.	**Q3**		A Level Paper 1 November 2021	1	**11**
6.	**Q10**		A Level Paper 1 June 2023	1	**12**
7.	**Q3**	*also Topic 4*	AS Paper 1 June 2023	1	**13**
8.	**Q8**		AS Paper 1 June 2024	1	**14**
9.	**Q5**		AS Paper 1 June 2025	1	**15**
10.	**Q10**		AS Paper 1 June 2022	3	**16**
11.	**Q11**		A Level Paper 1 June 2017	6	**17**
12.	**Q11**		AS Paper 1 November 2021	6	**18**
13.	**Q2**	*also Topic 1*	A Level Paper 3 October 2020	8	**20**
14.	**Q10**		AS Paper 1 June 2023	8	**21**
2.2	**EQUATIONS OF UNIFORMLY ACCELERATED MOTION (SUVAT)**			8 Qs · 58 marks	**24**
15.	**Q8**		AS Paper 1 June 2023	1	**25**
16.	**Q6**		AS Paper 1 June 2025	1	**26**
17.	**Q12**		A Level Paper 2 June 2022	3	**27**
18.	**Q11**		AS Paper 1 June 2017	7	**28**
19.	**Q14**	*also Topic 6*	A Level Paper 1 June 2018	7	**30**
20.	**Q17**	*also Topic 3*	A Level Paper 1 June 2017	11	**32**
21.	**Q10**	*also Topic 7*	A Level Paper 3 June 2018	13	**35**
22.	**Q14**		AS Paper 1 June 2018	15	**37**
2.3	**SCALARS, VECTORS AND RESOLVING VECTORS**			16 Qs · 35 marks	**40**
23.	**Q7**		AS Paper 1 June 2016	1	**41**
24.	**Q1**		AS Paper 1 June 2017	1	**42**
25.	**Q8**		AS Paper 1 June 2018	1	**43**
26.	**Q5**		AS Paper 1 June 2019	1	**44**
27.	**Q1**		A Level Paper 1 October 2020	1	**45**
28.	**Q3**		AS Paper 1 October 2020	1	**46**
29.	**Q5**		AS Paper 1 October 2020	1	**47**
30.	**Q6**		AS Paper 1 November 2021	1	**48**

	QUESTION		SOURCE	MARKS	PAGE
31.	**Q7**		A Level Paper 1 June 2022	1	**49**
32.	**Q3**		AS Paper 1 June 2022	1	**50**
33.	**Q2**		AS Paper 1 June 2023	1	**51**
34.	**Q1**		AS Paper 1 June 2024	1	**52**
35.	**Q2**		A Level Paper 1 June 2025	1	**53**
36.	**Q12**		AS Paper 1 June 2022	6	**54**
37.	**Q10**		AS Paper 1 June 2018	7	**56**
38.	**Q17**		AS Paper 1 June 2024	9	**58**
2.4	**PROJECTILE MOTION**			16 Qs · 107 marks	**60**
39.	**Q6**		AS Paper 1 June 2016	1	**61**
40.	**Q6**		AS Paper 1 June 2017	1	**62**
41.	**Q2**		AS Paper 1 June 2018	1	**63**
42.	**Q3**		A Level Paper 1 June 2022	1	**64**
43.	**Q10**		A Level Paper 1 June 2024	1	**65**
44.	**Q6**		AS Paper 1 June 2024	1	**66**
45.	**Q10**		A Level Paper 1 June 2025	1	**67**
46.	**Q12**		A Level Paper 1 June 2017	8	**68**
47.	**Q11**		AS Paper 1 June 2018	8	**70**
48.	**Q12**		AS Paper 1 June 2019	11	**72**
49.	**Q13**		AS Paper 1 June 2022	11	**74**
50.	**Q17**		A Level Paper 1 June 2023	11	**77**
51.	**Q13**		AS Paper 1 June 2025	11	**79**
52.	**Q16**		AS Paper 1 October 2020	12	**81**
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54.	**Q14**		AS Paper 1 November 2021	14	**87**
2.5	**FORCES, FREE-BODY DIAGRAMS AND NEWTON'S LAWS**			20 Qs · 75 marks	**89**
55.	**Q5**	*also Topic 1*	AS Paper 1 June 2016	1	**90**
56.	**Q3**		A Level Paper 1 June 2018	1	**91**
57.	**Q3**		A Level Paper 1 June 2019	1	**92**
58.	**Q1**	*also Topic 4*	A Level Paper 2 June 2022	1	**93**
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60.	**Q7**		AS Paper 1 June 2022	1	**95**
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63.	**Q9**		A Level Paper 1 June 2024	1	**98**
64.	**Q3**		AS Paper 1 June 2024	1	**99**
65.	**Q9**		A Level Paper 1 June 2025	1	**100**
66.	**Q1**	*also Topic 4*	AS Paper 1 June 2025	1	**101**
67.	**Q11**		AS Paper 1 June 2024	4	**102**
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2.6	**CORE PRACTICAL 1: DETERMINING G BY FREE FALL**			2 Qs · 16 marks	**115**
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2.7	**MOMENTUM AND CONSERVATION OF MOMENTUM**			14 Qs · 108 marks	**120**
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78.	**Q7**	*also Topic 6*	A Level Paper 1 June 2023	1	**122**
79.	**Q2**		AS Paper 1 June 2024	1	**123**
80.	**Q8**		AS Paper 1 June 2025	1	**124**
81.	**Q12**		AS Paper 1 June 2018	7	**125**
82.	**Q7**	*also Topic 6*	A Level Paper 3 June 2022	8	**127**
83.	**Q13**		AS Paper 1 November 2021	9	**129**
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85.	**Q15**		AS Paper 1 June 2023	10	**133**
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87.	**Q8**	*also Topic 6*	A Level Paper 3 June 2024	11	**137**
88.	**Q14**	*also Topic 6*	A Level Paper 1 June 2019	12	**139**
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90.	**Q16**		AS Paper 1 June 2017	14	**143**
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97.	**Q11**		A Level Paper 1 June 2024	5	**153**
98.	**Q10**		AS Paper 1 October 2020	6	**155**
99.	**Q13**		AS Paper 1 June 2023	7	**157**
100.	**Q13**		AS Paper 1 June 2017	8	**159**
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102.	**Q13**		A Level Paper 1 June 2018	9	**163**
103.	**Q14**		A Level Paper 1 June 2023	9	**165**
104.	**Q3**	*also Topic 1*	A Level Paper 3 June 2025	9	**167**
105.	**Q11**		AS Paper 1 June 2016	10	**169**

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108.	**Q17**	*also Topic 1*	AS Paper 1 June 2022	14	**177**
2.9	**WORK, ENERGY AND POWER**			31 Qs · 199 marks	**181**
109.	**Q4**		A Level Paper 1 June 2017	1	**182**
110.	**Q6**		AS Paper 1 June 2018	1	**183**
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112.	**Q8**		AS Paper 1 June 2019	1	**185**
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114.	**Q3**		AS Paper 1 November 2021	1	**187**
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116.	**Q8**		AS Paper 1 November 2021	1	**189**
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118.	**Q6**		A Level Paper 1 June 2023	1	**191**
119.	**Q6**	*also Topic 3*	AS Paper 1 June 2023	1	**192**
120.	**Q3**		A Level Paper 1 June 2024	1	**193**
121.	**Q9**	*also Topic 3*	AS Paper 1 June 2016	3	**194**
122.	**Q10**		AS Paper 1 June 2025	5	**195**
123.	**Q11**		A Level Paper 1 June 2022	6	**197**
124.	**Q10**		AS Paper 1 June 2024	6	**198**
125.	**Q12**		AS Paper 1 June 2017	8	**199**
126.	**Q15**	*also Topic 4*	AS Paper 2 June 2019	8	**201**
127.	**Q9**		AS Paper 1 October 2020	8	**204**
128.	**Q11**	*also Topic 6*	A Level Paper 1 June 2019	9	**205**
129.	**Q12**	*also Topic 1*	A Level Paper 3 June 2019	9	**207**
130.	**Q17**	*also Topic 4*	AS Paper 2 November 2021	10	**209**
131.	**Q16**		AS Paper 2 June 2022	10	**211**
132.	**Q17**		AS Paper 2 June 2017	11	**214**
133.	**Q15**	*also Topic 3*	AS Paper 1 June 2022	11	**217**
134.	**Q13**	*also Topic 3*	AS Paper 1 October 2020	12	**220**
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139.	**Q18**	*also Topic 7*	A Level Paper 1 June 2024	16	**235**

QUESTIONS

139 questions · 760 marks · 9 sub-topics

SUB-TOPIC 2.1

DISTANCE, VELOCITY AND ACCELERATION-TIME GRAPHS

Sub-topic 2.1 · 14 questions · 40 marks · lowest tariff first

1 The winner of a 400 m race must have the greatest

- ☒ **A** acceleration.
- ☒ **B** average speed.
- ☒ **C** instantaneous speed.
- ☒ **D** maximum speed.

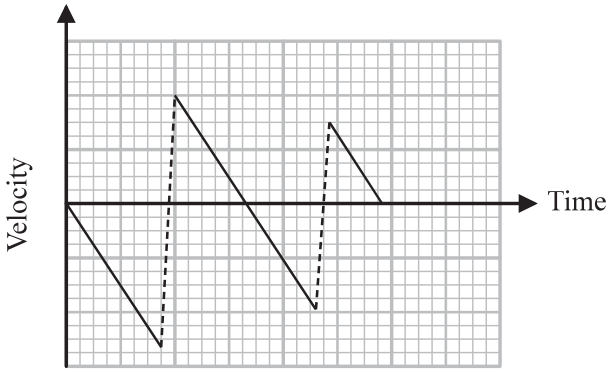
(Total for Question 1 = 1 mark)

2 Which of the following can be used to determine the magnitude of velocity?

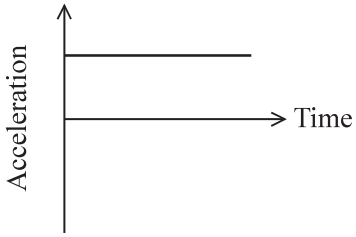
- ☒ **A** area under an acceleration-time graph
- ☒ **B** area under a velocity-time graph
- ☒ **C** gradient of an acceleration-time graph
- ☒ **D** gradient of a velocity-time graph

(Total for Question 2 = 1 mark)

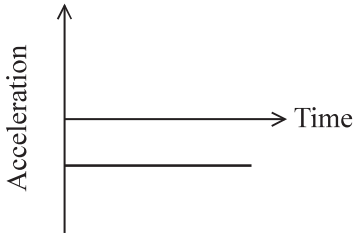
3 A ball is dropped vertically onto a horizontal surface and bounces twice before being caught. The graph shows how the velocity of the ball varies with time for the motion of the ball.



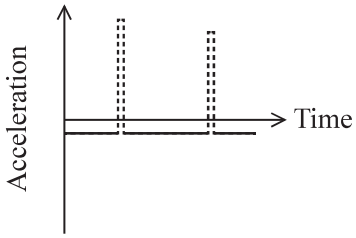
Which of the following is the acceleration-time graph for the motion of the ball?



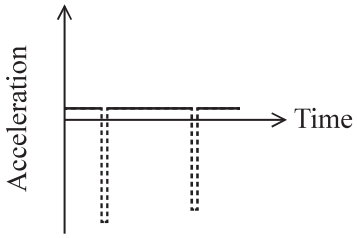
☒ **A**



☒ **B**



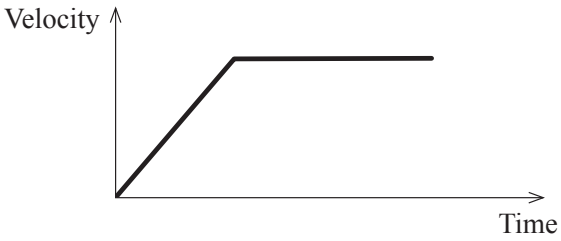
☒ **C**



☒ **D**

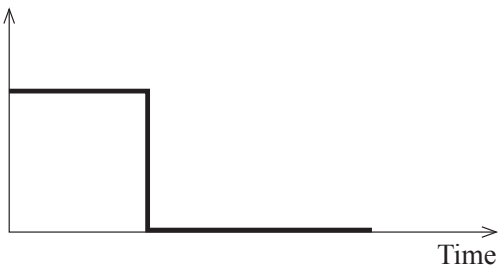
(Total for Question 3 = 1 mark)

4 The graph shows how the velocity varies with time for an object.

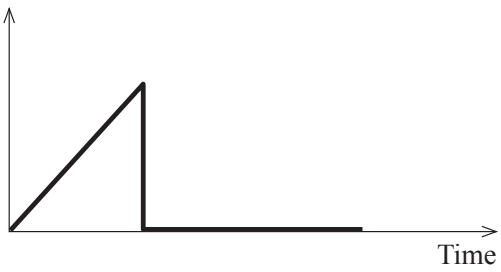


Which of the following graphs shows how the displacement varies with time for this object?

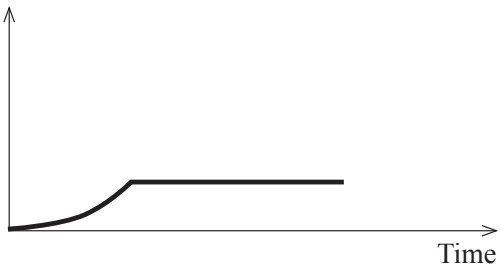
☒ **A**



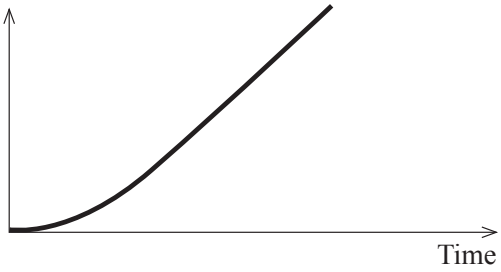
☒ **B**



☒ **C**



☒ **D**

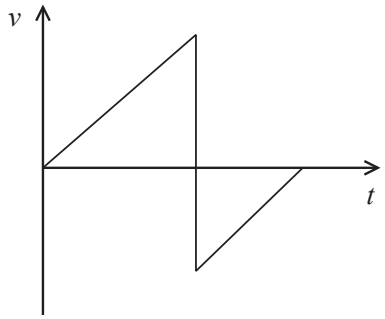


(Total for Question 4 = 1 mark)

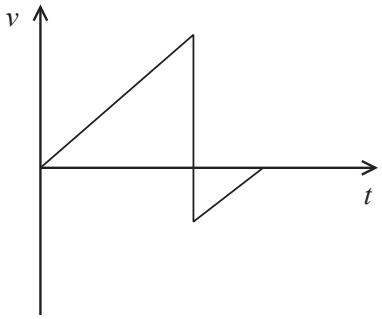
3 A ball was dropped from rest, from a height above the ground. The ball bounced back up to about half its initial height.

Which graph shows how the velocity v of the ball varied with time t?

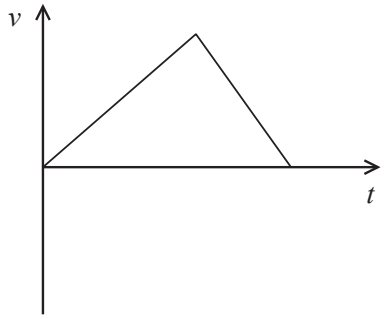
A



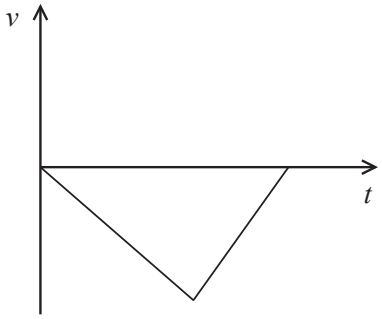
B



C



D



☒ **A**

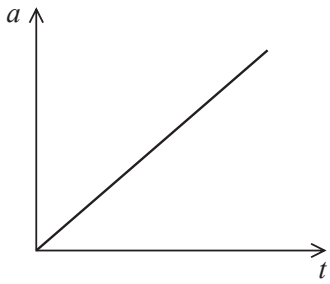
☒ **B**

☒ **C**

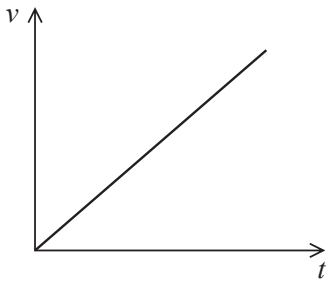
☒ **D**

(Total for Question 3 = 1 mark)

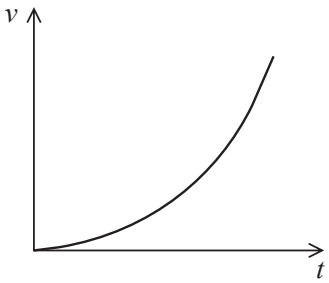
10 An object moves from rest. The graph shows how the acceleration a varies with time t.



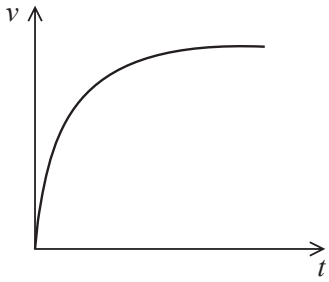
Which of the following graphs best shows how the velocity v of the object varies with t over the same time interval?



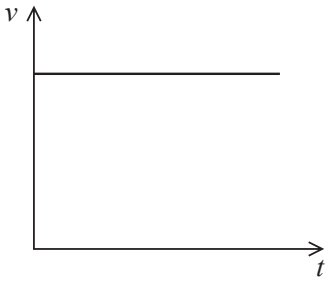
☒ **A**



☒ **B**



☒ **C**

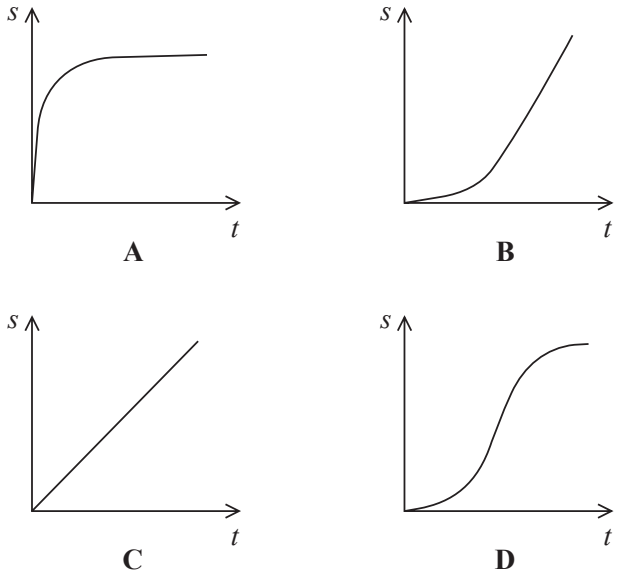


☒ **D**

(Total for Question 10 = 1 mark)

3 A ball falls from rest through glycerine and reaches terminal velocity.

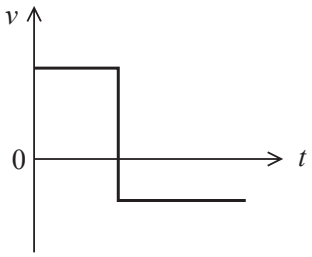
Which of the following graphs shows how displacement s varies with time t for the ball?



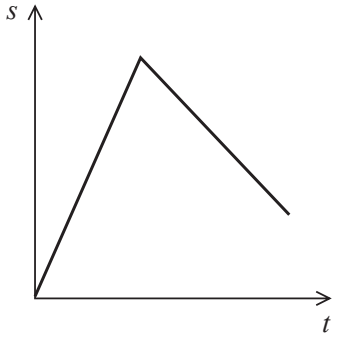
- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 3 = 1 mark)

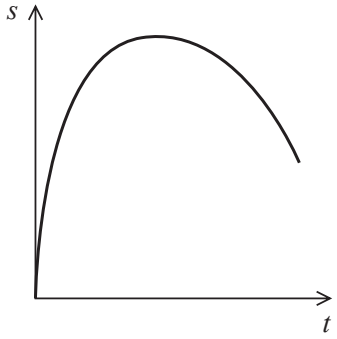
8 A simplified velocity-time graph for the flight of a drone is shown.



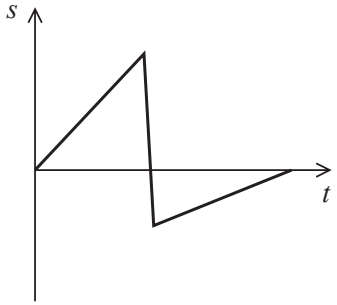
Which of the following is a displacement-time graph for the same flight?



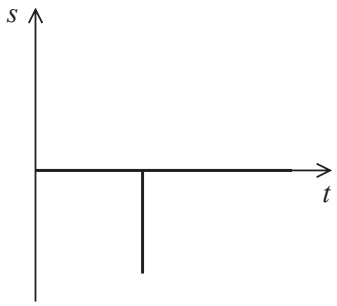
A



B



C



D

☒ **A**

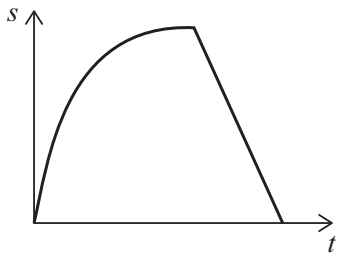
☒ **B**

☒ **C**

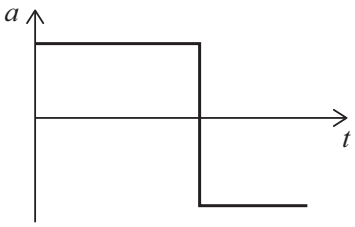
☒ **D**

(Total for Question 8 = 1 mark)

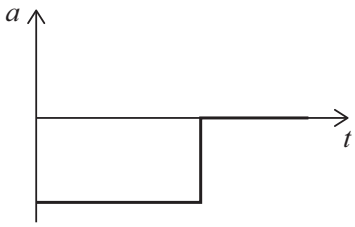
5 The graph shows how the displacement s varies with time t for an object.



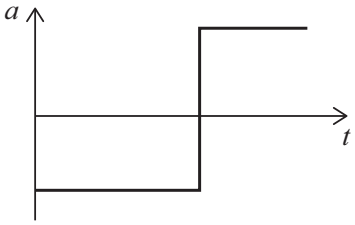
Which of the following graphs shows how acceleration a varies with time t for the object?



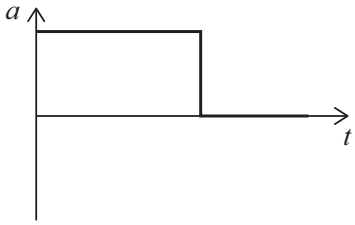
A



B



C

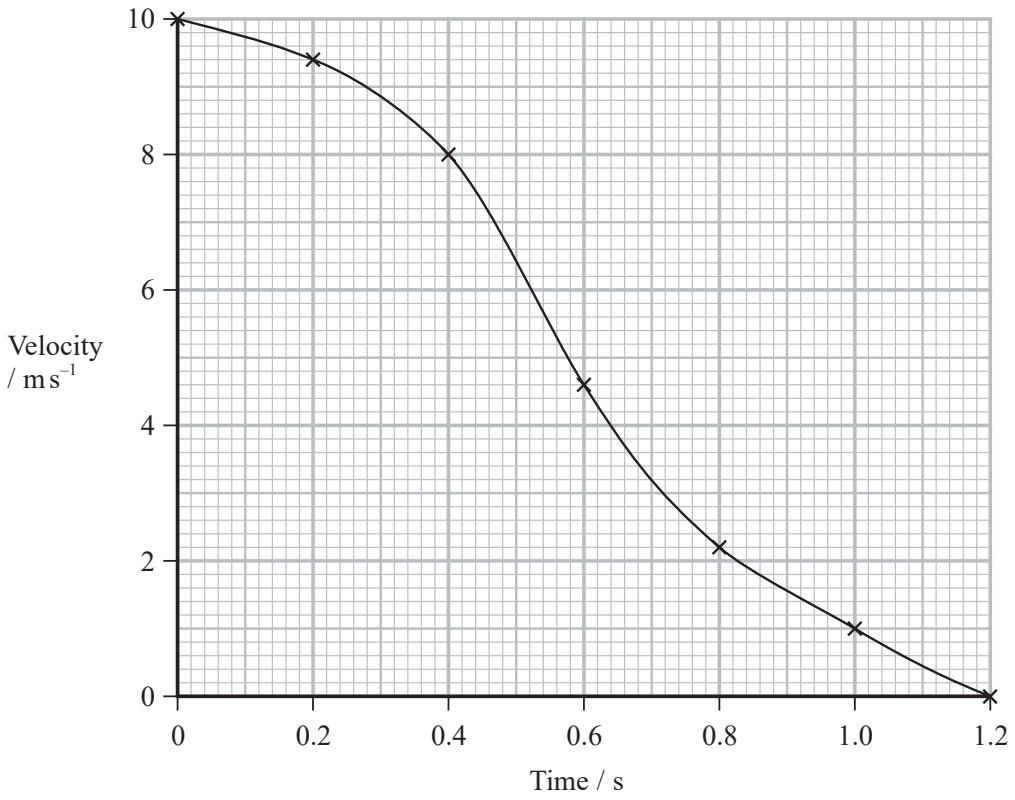


D

- ☐ **A**
- ☐ **B**
- ☐ **C**
- ☐ **D**

(Total for Question 5 = 1 mark)

10 A sprinter crossed the finish line of a race and then decelerated to rest. The graph shows how the velocity of the sprinter varied with time once the sprinter had crossed the finish line.



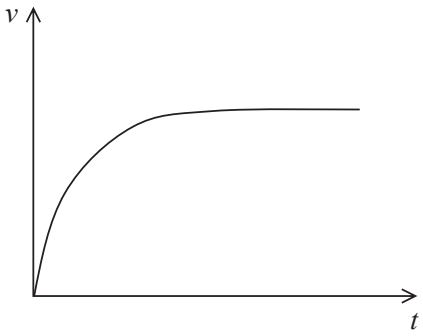
Determine the distance travelled by the sprinter whilst decelerating to rest.

Distance = ... m

(Total for Question 10 = 3 marks)

11 A sports class is studying cycling. They produce a video of a cyclist on a horizontal lawn. The cyclist starts from rest.
They produce a sketch graph of the velocity v of the cyclist against time t.





(a) Explain the shape of this graph and include a consideration of force as part of your answer.

(3)

(b) A student makes the following statement.

The work done by the cyclist is converted into the kinetic energy of the cyclist and bicycle.

Criticise this statement.

(3)

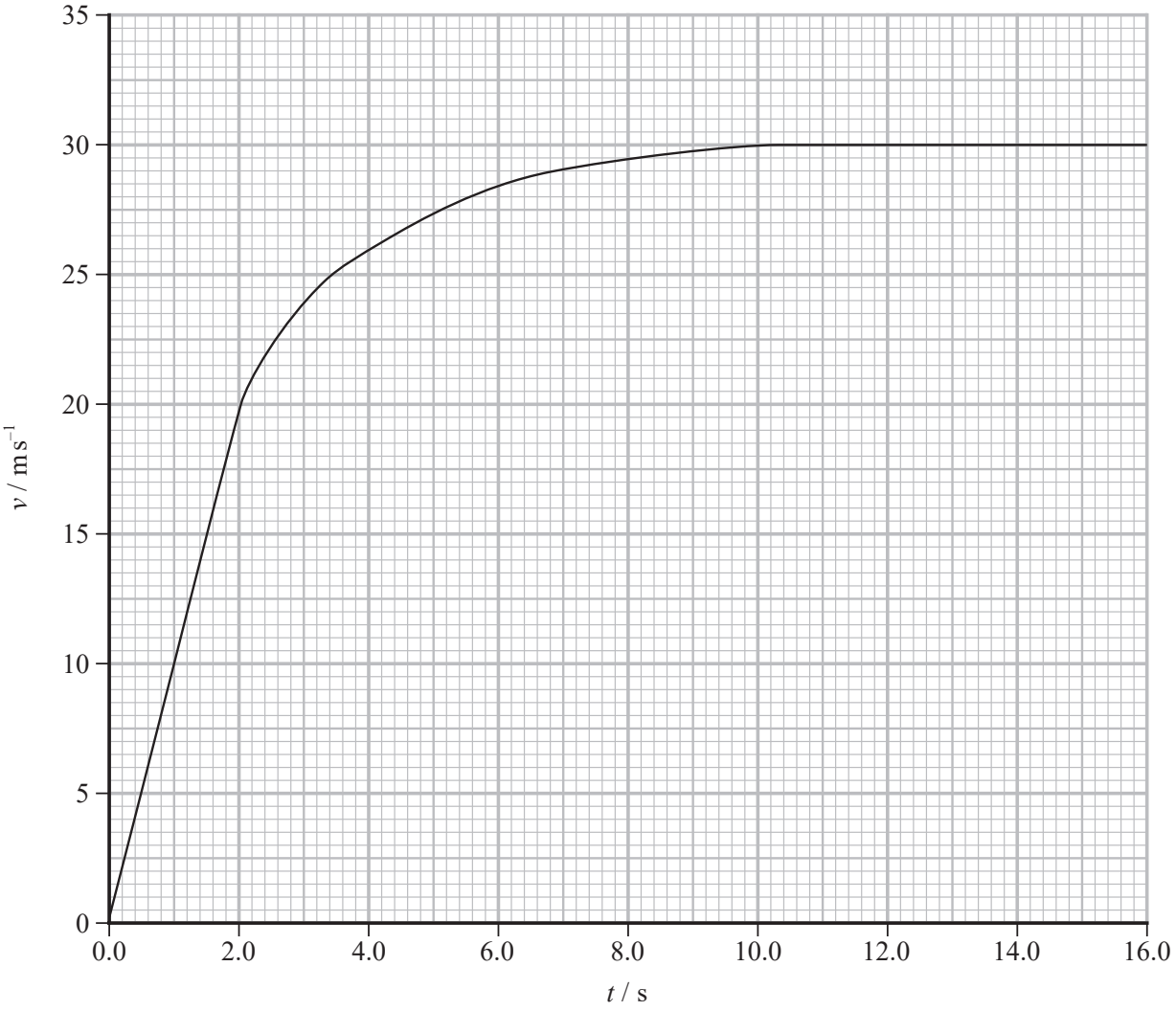
(Total for Question 11 = 6 marks)

11 A skydiver made a skydive from a plane.



(Source: © Sky Antonio/Shutterstock)

The graph shows how the velocity v of the skydiver varied with time t, from the instant she left the plane to the instant just before the parachute opened.



(a) Determine the acceleration of the skydiver when $t = 4.0\,s$.

(3)

Acceleration of skydiver = ...

(b) Determine an approximate value for the displacement of the skydiver over the first 16.0 s of the skydive.

(3)

Displacement of skydiver = ...

(Total for Question 11 = 6 marks)

2 A student released a ping pong ball in front of a metre rule and used a phone camera to record the motion of the ball as it fell. The phone camera captures 60 images per second, which may be played back one image at a time.

(a) The ball was dropped from a height such that it reached its terminal velocity as it passed the metre rule.

(i) Explain how the terminal velocity of the ball could be determined using the phone camera recording.

(4)

(ii) Explain how a systematic error could affect the value obtained for the terminal velocity.

(2)

(b) This experiment could have been attempted using a stopwatch to measure the time as the ping pong ball fell.

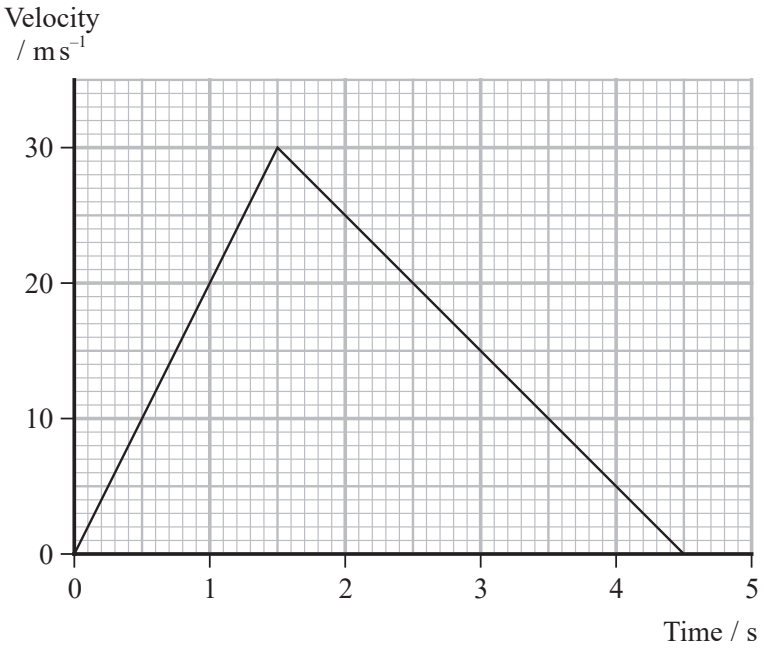
Explain an advantage of using a phone camera rather than a stopwatch.

(2)

(Total for Question 2 = 8 marks)

10 A model rocket accelerates vertically upwards then decelerates due to gravity until it reaches a maximum height.

(a) A velocity-time graph for the rocket until it reaches maximum height is shown.



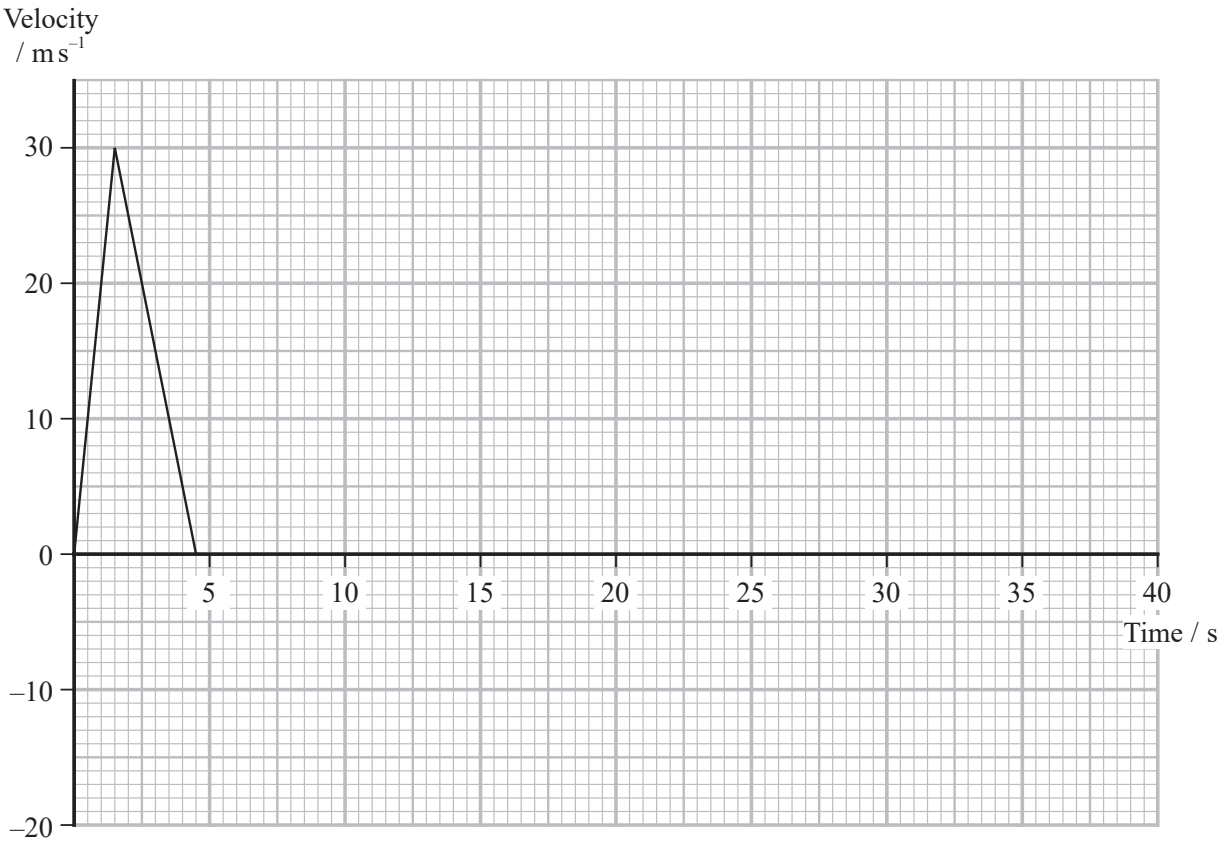
Show that the rocket reaches a maximum height of about 68 m.

(2)

(b) When the rocket reaches the maximum height of 68 m, a parachute opens. Almost instantly, the rocket reaches a terminal velocity of 2.0 m s^{-1}.

Complete the velocity-time graph below for the motion of the rocket until it reaches the ground.

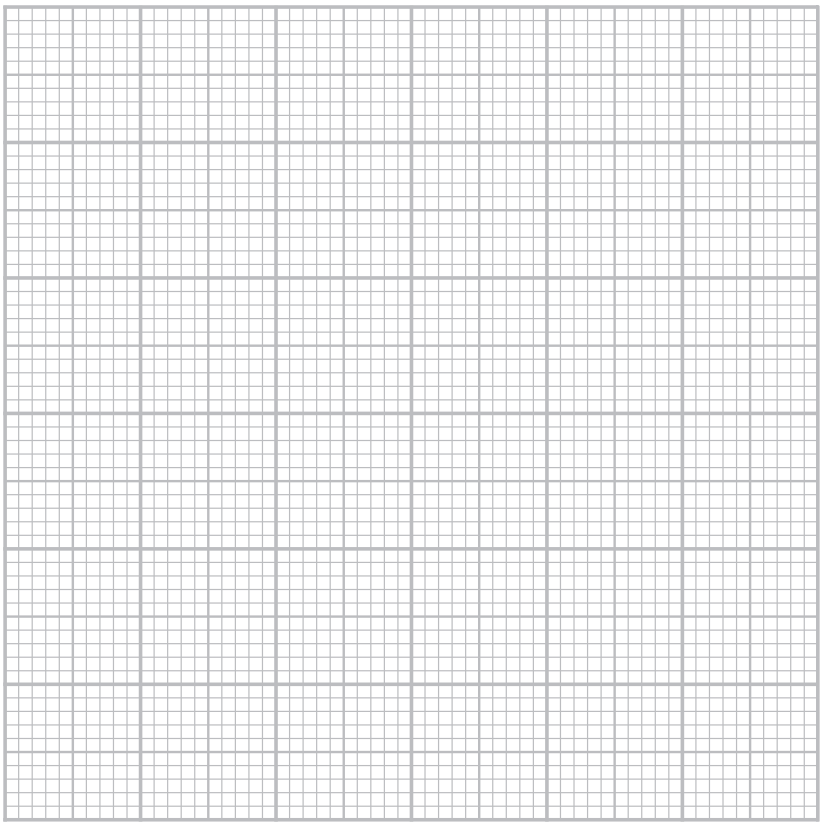
(2)



(c) The rocket is fired upwards a second time when the wind is blowing. The rocket falls with a vertical velocity of $2.0\,m\,s^{-1}$ and a horizontal velocity of $1.5\,m\,s^{-1}$.

Determine the velocity of the rocket by drawing a scaled vector diagram.

(4)



Magnitude of velocity = ... $m\,s^{-1}$

Angle to the horizontal of velocity = ... °

(Total for Question 10 = 8 marks)

SUB-TOPIC 2.2

EQUATIONS OF UNIFORMLY ACCELERATED MOTION (SUVAT)

Sub-topic 2.2 · 8 questions · 58 marks · lowest tariff first

8 A ball is thrown vertically upwards at a velocity of $6.0\,\text{m}\,\text{s}^{-1}$.

Which of the following gives the maximum height, in m, reached by the ball?

☒ **A** $\dfrac{6.0^2}{2 \times 9.81}$

☒ **B** $\dfrac{6.0^2}{2 \times (-9.81)}$

☒ **C** $\dfrac{6.0}{2 \times 9.81}$

☒ **D** $\dfrac{6.0}{2 \times (-9.81)}$

(Total for Question 8 = 1 mark)

6 A stone is dropped from rest down a well. The sound as the stone hits the water is heard 3.5 s after the stone is dropped.

Which of the following gives the distance, in m, travelled by the stone before it hits the water?

☒ **A** $\frac{9.81 \times 3.5^2}{2}$

☒ **B** 9.81×3.5

☒ **C** $2 \times 9.81 \times 3.5^2$

☒ **D** $\frac{3.5^2 - 0}{2 \times 9.81}$

(Total for Question 6 = 1 mark)

12 In February 2021 the spacecraft Perseverance Rover landed on Mars. When the spacecraft was 11.0 km above the surface of Mars, parachutes opened to slow the descent. The parachutes detached from the spacecraft when it was 2.1 km above the surface of Mars.

Calculate the change in gravitational potential energy of the spacecraft during the parachute section of its descent.

mass of spacecraft = 1030 kg
mass of Mars = 6.39×10^{23} kg
radius of Mars = 3390 km

Change in gravitational potential energy of the spacecraft = ...

(Total for Question 12 = 3 marks)

11 A motorist received a speeding penalty notice, from the police, for a short journey along 120 m of road.

(a) The car's specification states that the minimum time for the car to accelerate from 0 to 60 miles per hour is 9.5 seconds.

Show that the maximum value for the average acceleration of the car over 9.5 s is about 3 m s^{-2}.

1 mile = 1600 m

(2)

(b) The police recorded a maximum speed for the car of 20 m s^{-1}.

The motorist knows that the speed at the start and at the end of the 120 m journey was zero.

Assume that the car had:

- constant positive acceleration, equal to the value in part (a), for the first 60 m of the journey
- constant negative acceleration of the same magnitude for the final 60 m of the journey.

Determine whether the motorist should challenge the penalty notice.

(3)

(c) Explain why the assumptions about the acceleration in (b) may **not** be correct in practice.

(2)

.....

.....

.....

.....

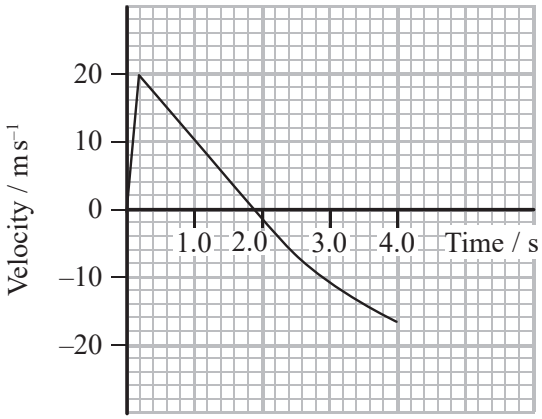
.....

(Total for Question 11 = 7 marks)

14 A physics class made a toy rocket. A drinks bottle was partially filled with water and inverted over a valve. An air pump delivered air to the bottle until the pressure forced the bottle from the valve and the water was ejected from the bottle at high speed.



A velocity-time graph for the bottle for the first 4 s after take-off is shown.



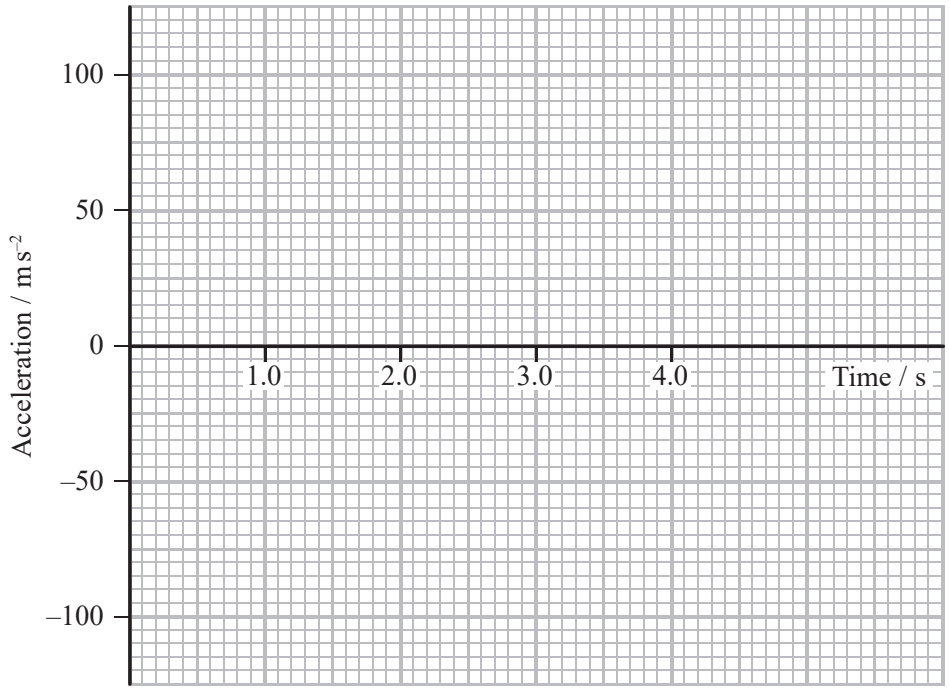
(a) Determine the height to which the rocket travelled.

(2)

Height = ...

(b) Sketch the corresponding acceleration-time graph on the axes below.

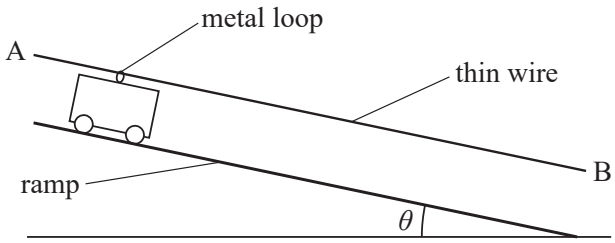
(5)



(Total for Question 14 = 7 marks)

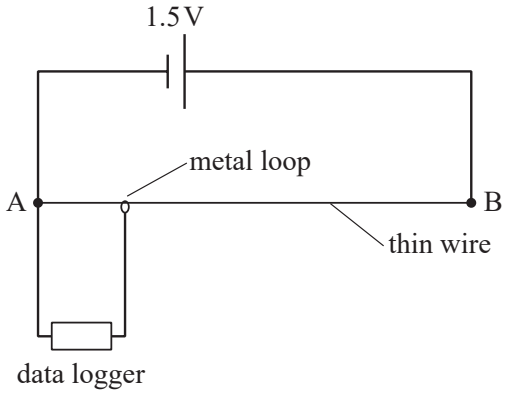
17 A student investigates the motion of a friction-free trolley down a ramp. On the top of the trolley there is a metal loop which makes contact with a length of thin resistance wire, AB, fixed above the ramp. The resistance wire has a uniform diameter.

The trolley accelerates down the ramp and the metal loop stays in contact with the wire along the full length of the ramp.



The student uses a protractor to measure the angle θ between the ramp and the horizontal and records a value of 4° with an uncertainty of ±1°.

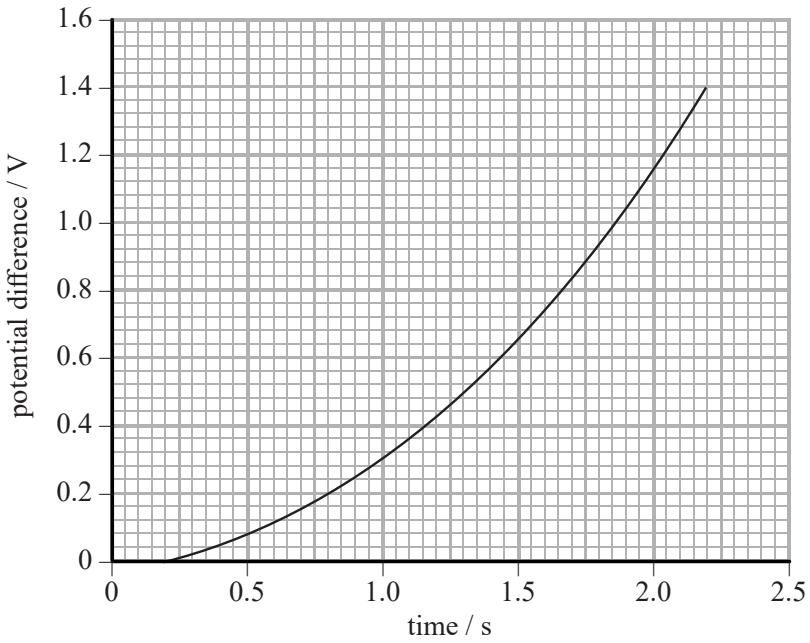
(a) The two ends of the wire are connected to a 1.5 V cell. A data logger, set to measure potential difference, is connected to the metal loop and to the negative terminal of the cell.



Explain how the potential difference recorded by the data logger will vary as the loop moves along the length of the wire AB.

(3)

(b) The graph shows the data obtained from the data logger.



Determine the velocity of the trolley at 1.5 s.

1.5 V represents a distance of 2.00 m.

(4)

Velocity = ...

(c) The student calculated the velocity of the trolley at 2.0 s to be 1.5 m s^{-1}.

By considering the acceleration of the trolley, determine whether the student's measurement of θ was within the uncertainty quoted.

(4)

(Total for Question 17 = 11 marks)

10 The Shanghai Maglev Train is the first commercially operated high-speed magnetic levitation train in the world, connecting the airport and central Shanghai.



(a) The total distance travelled is 29.9 km and the total journey time is 440 s. The train starts from rest and reaches a speed of 97 m s^{-1} in 120 s.

(i) Calculate the average acceleration of the train during the first 120 s.

(2)

Average acceleration of train = ...

(ii) Calculate the average speed of the train for the period following the 120 s acceleration.

(3)

Average speed of train = ...

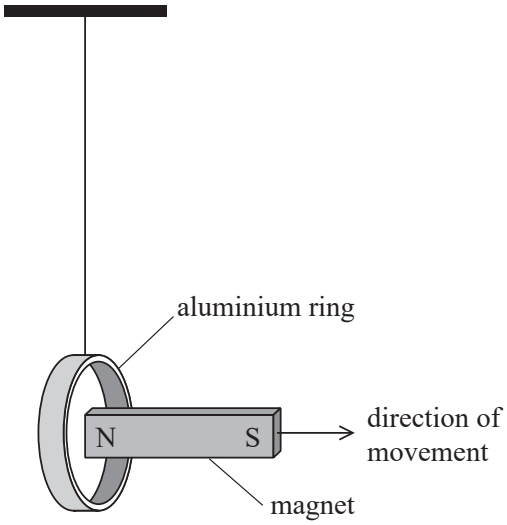
(b) Electromagnetic forces enable the train to levitate above a steel rail.

Explain why magnetic levitation is an advantage for a high-speed transport system.

(2)

*(c) A linear induction motor provides the force to accelerate the train forwards. A current flows in sequence through coils of wire mounted in the track. The train is dragged along as the magnetic field progresses along the coils of wire in the track. This is similar to moving a permanent magnetic field away from a conductor.

A teacher demonstrates this effect by quickly removing one end of a bar magnet from a suspended aluminum ring.



When the magnet is removed from the ring, the ring moves in the same direction as the magnet.

Explain, using the laws of electromagnetic induction, why the ring moves in the direction of the magnet.

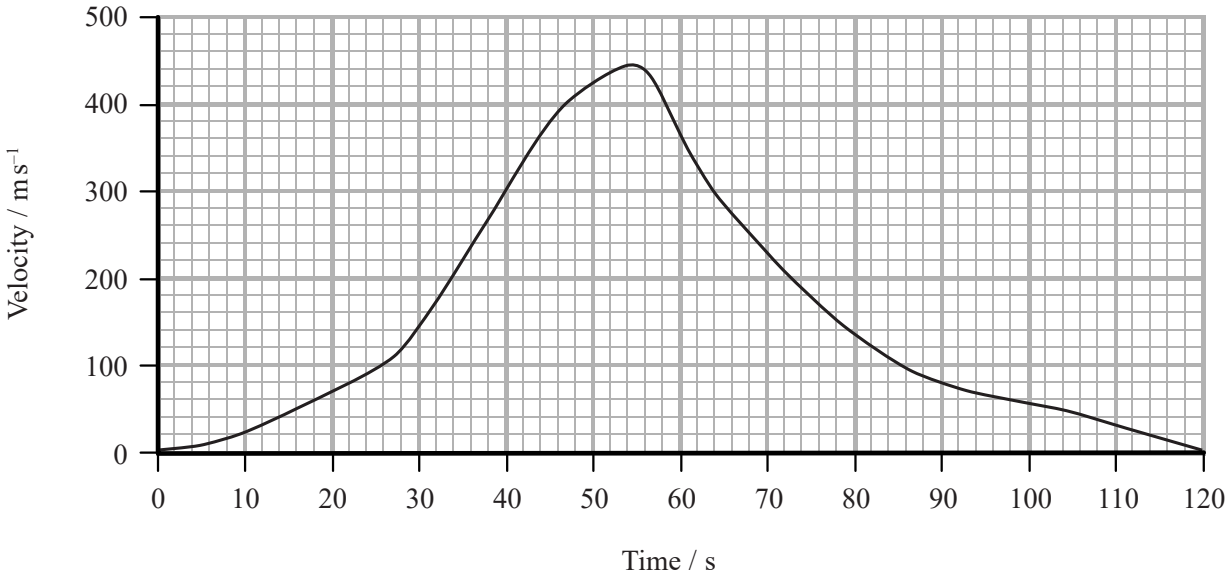
(6)

(Total for Question 10 = 13 marks)

14 The world land speed record of 341 m s^{-1} was set in October 1997. In an attempt to break this record, a new supersonic car has been developed called the Bloodhound.



The developers of the Bloodhound have used computer modelling to produce a velocity-time graph for the predicted motion of the car, on a straight track, during the record attempt.



(a) A track of length 23 km is available for the record attempt.

Determine whether this track is long enough.

(3)

(b) The car has two different engines: a jet engine providing a thrust of 89 kN and a rocket engine providing a thrust of 120 kN.

(i) The jet engine runs throughout the car's acceleration stage. The rocket engine runs for only part of that stage.

State the time at which the rocket engine is started during the car's predicted motion.

(1)

.....

(ii) Use the graph to determine the maximum positive acceleration of the car.

(2)

.....

.....

.....

.....

Maximum positive acceleration of the car = ...

(iii) Calculate a value for the frictional force acting on the car when the positive acceleration is a maximum.

(3)

mass of car including fuel at this time = 7790 kg

.....

.....

.....

.....

.....

.....

.....

Frictional force during maximum positive acceleration = ...

*(c) Discuss, with reference to the graph, the factors that would have been used to predict the motion of the car over the 120 s.

(6)

(Total for Question 14 = 15 marks)

SUB-TOPIC 2.3

SCALARS, VECTORS AND RESOLVING VECTORS

Sub-topic 2.3 · 16 questions · 35 marks · lowest tariff first

7 A pilot wishes to fly due east. A wind is blowing in a northerly direction.

The direction of north is as shown.



Which of the following correctly shows the direction the plane should point?



☒ **A** ☒ **B** ☒ **C** ☒ **D**

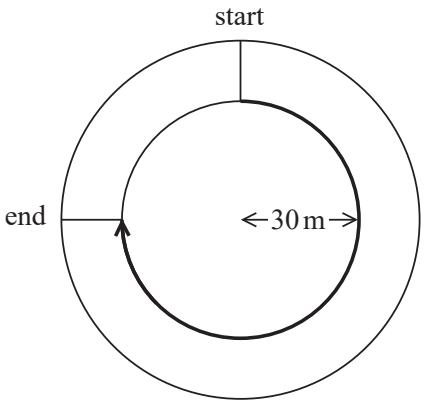
(Total for Question 7 = 1 mark)

1 Which of the following is **not** a vector quantity?

- ☒ **A** acceleration
- ☒ **B** distance
- ☒ **C** momentum
- ☒ **D** velocity

(Total for Question 1 = 1 mark)

8 An athlete runs a race around three quarters of a circular track of radius 30 m using the inside lane.



What is the magnitude of the displacement of the athlete at the end of the race?

☒ **A** 141 m

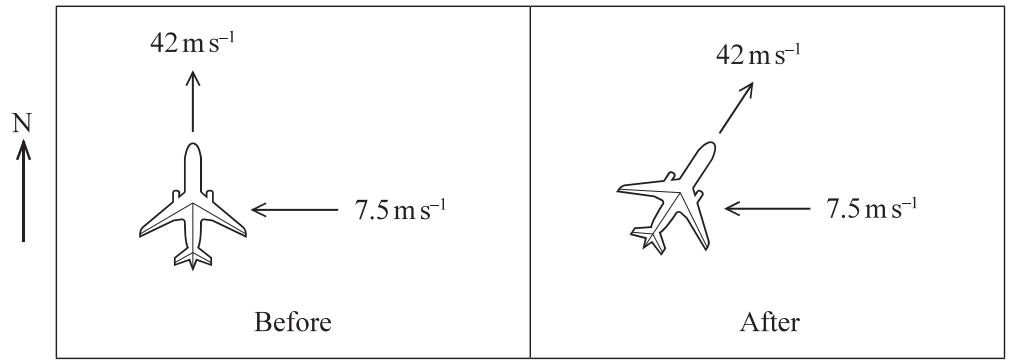
☒ **B** 47 m

☒ **C** 42 m

☒ **D** 30 m

(Total for Question 8 = 1 mark)

5 A plane is travelling north at $42\,m\,s^{-1}$. It enters a region with a wind blowing from the east at $7.5\,m\,s^{-1}$. To keep travelling north, the plane turns towards the east, without changing the thrust, as shown.



Which of the following could be used to calculate the angle through which the plane turns?

☒ **A** $\cos^{-1}\left(\frac{42}{7.5}\right)$

☒ **B** $\sin^{-1}\left(\frac{7.5}{42}\right)$

☒ **C** $\tan^{-1}\left(\frac{7.5}{42}\right)$

☒ **D** $\tan^{-1}\left(\frac{42}{7.5}\right)$

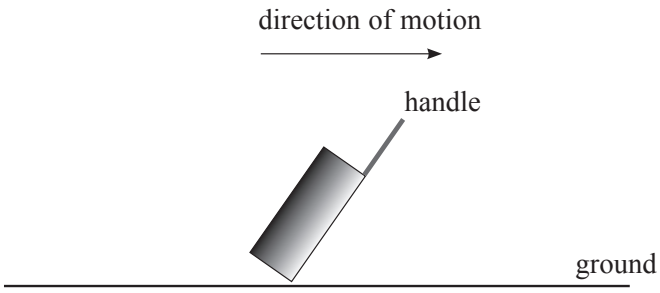
(Total for Question 5 = 1 mark)

1 Which of the following is an example of a scalar quantity?

- ☒ **A** displacement
- ☒ **B** energy
- ☒ **C** momentum
- ☒ **D** velocity

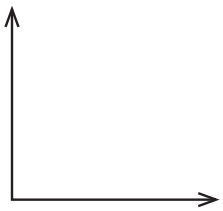
(Total for Question 1 = 1 mark)

3 A suitcase is being dragged along the ground by the handle in the direction shown.

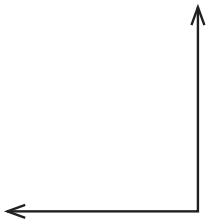


Which of the following shows the direction of the horizontal and vertical components of force acting on the ground due to the suitcase?

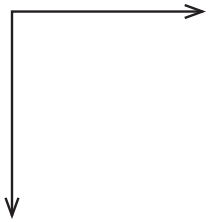
☒ **A**



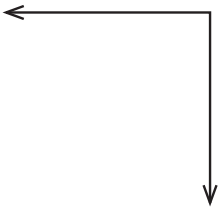
☒ **B**



☒ **C**



☒ **D**



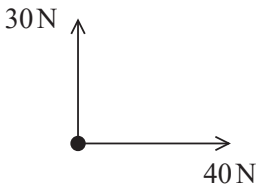
(Total for Question 3 = 1 mark)

5 Which of the following is a vector quantity?

- ☒ **A** kinetic energy
- ☒ **B** momentum
- ☒ **C** time
- ☒ **D** work done

(Total for Question 5 = 1 mark)

6 The diagram shows the two forces acting on a point mass.



The mass accelerates.

Which of the following gives the angle between the direction of the acceleration and the 40 N force?

☒ **A** $\cos^{-1}(30/40)$

☒ **B** $\sin^{-1}(40/50)$

☒ **C** $\tan^{-1}(30/40)$

☒ **D** $\tan^{-1}(40/50)$

(Total for Question 6 = 1 mark)

7 Which of the following quantities is a vector?

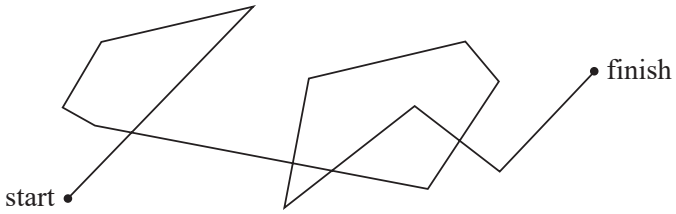
- ☒ **A** charge
- ☒ **B** mass
- ☒ **C** momentum
- ☒ **D** time

(Total for Question 7 = 1 mark)

3 The diagram shows the path of a pollen particle on the surface of water as it is hit by water molecules.

Scale

1 cm : 0.5 mm



Which of the following is the magnitude of the displacement of the pollen particle in mm?

- ☒ **A** 260
- ☒ **B** 80
- ☒ **C** 13
- ☒ **D** 4

(Total for Question 3 = 1 mark)

2 Which row of the table contains only scalar quantities?

☒	**A**	speed	displacement	current
☒	**B**	energy	mass	momentum
☒	**C**	power	time	work done
☒	**D**	acceleration	work done	temperature

(Total for Question 2 = 1 mark)

1 Which of the following quantities is a scalar quantity?

- ☒ **A** energy
- ☒ **B** moment of a force
- ☒ **C** momentum
- ☒ **D** velocity

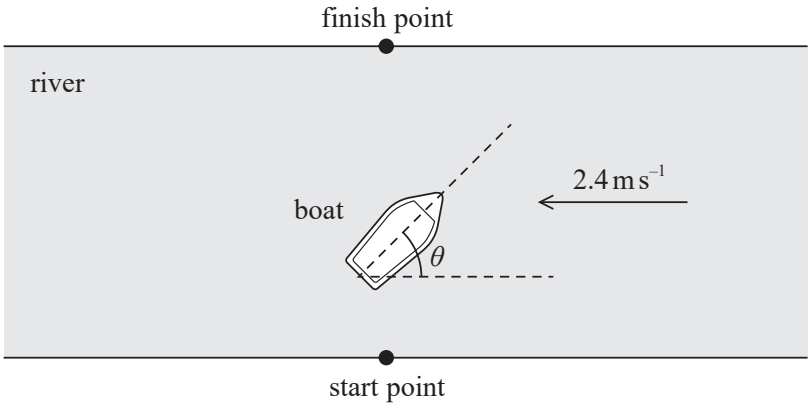
(Total for Question 1 = 1 mark)

2 Which of the following is a scalar quantity?

- ☒ **A** charge
- ☒ **B** displacement
- ☒ **C** electric field strength
- ☒ **D** force

(Total for Question 2 = 1 mark)

12 A boat crosses a river, to a point on the bank directly opposite the starting point as shown. The velocity of the water in the river is $2.4\,m\,s^{-1}$.



(a) The boat is steered at an angle θ to the velocity of the water in the river in order to travel in a straight line across to the finish point.

The speed of the boat relative to the water is $4.3\,m\,s^{-1}$.

Determine the value of θ by drawing a scaled vector diagram.

(3)

$\theta =$ .....

(b) The boat repeats the crossing, at the same speed, when the velocity of the water in the river is greater.

Explain how the time taken for the crossing will change.

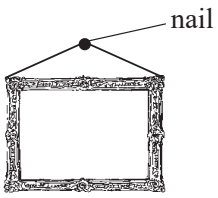
(3)

(Total for Question 12 = 6 marks)

10 A thin wire of negligible mass is used to hang a picture on a wall. The wire is hung over a nail and can be attached to the picture using arrangement 1 or arrangement 2, as shown.



arrangement 1



arrangement 2

(a) Deduce which wire arrangement should be used to keep the tension in the wire as small as possible.

(4)

(b) It was observed that if the wire was not hung with its midpoint over the nail, as in Diagram 1, the picture moved and then remained in the position shown in Diagram 2.



Diagram 1



Diagram 2

Use the idea of moments to explain why.

(3)

.....

.....

.....

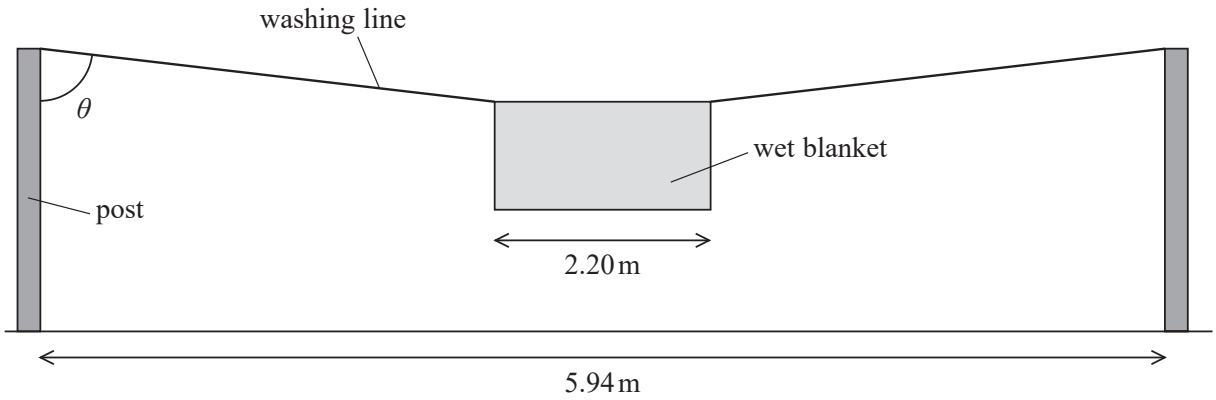
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(Total for Question 10 = 7 marks)

17 A washing line is attached to two posts which are a distance 5.94 m apart. A wet blanket of width 2.20 m is hung from the centre of the washing line. The washing line stretches to a length of 6.06 m and hangs at an angle θ, as shown.



(a) Calculate the tension in the washing line.

mass of wet blanket = 9.36 kg

(4)

Tension = ...

(b) Explain what happens to the height of the blanket from the ground as the blanket dries. Your answer should make reference to the Young modulus of the material of the line.

(5)

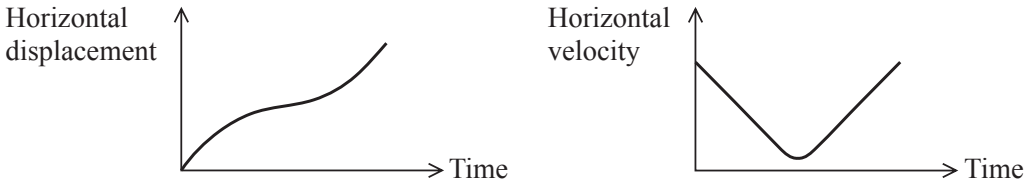
(Total for Question 17 = 9 marks)

SUB-TOPIC 2.4

PROJECTILE MOTION

Sub-topic 2.4 · 16 questions · 107 marks · lowest tariff first

6 The graphs shown represent the displacement-time and velocity-time graphs for the horizontal component of the motion of a ball.



Which of the following situations could produce this motion of the ball?

☒ **A** Rolling down one ramp and then rolling up a second ramp.

☒ **B** Rolling down a ramp then along the floor.

☒ **C** Rolling up one ramp and down a second ramp.

☒ **D** Rolling up a ramp and rolling back down the same ramp.

(Total for Question 6 = 1 mark)

6 A ball is kicked, giving it an initial velocity v at an angle of 35° to the vertical. The ball remains in the air for a time t.

Which of the following gives the distance travelled over the ground?

☒ **A** $vt\cos 35°$

☒ **B** $\frac{v\cos 35°}{t}$

☒ **C** $vt\sin 35°$

☒ **D** $\frac{v\sin 35°}{t}$

(Total for Question 6 = 1 mark)

2 Two balls, X and Y, are kicked across a football pitch.

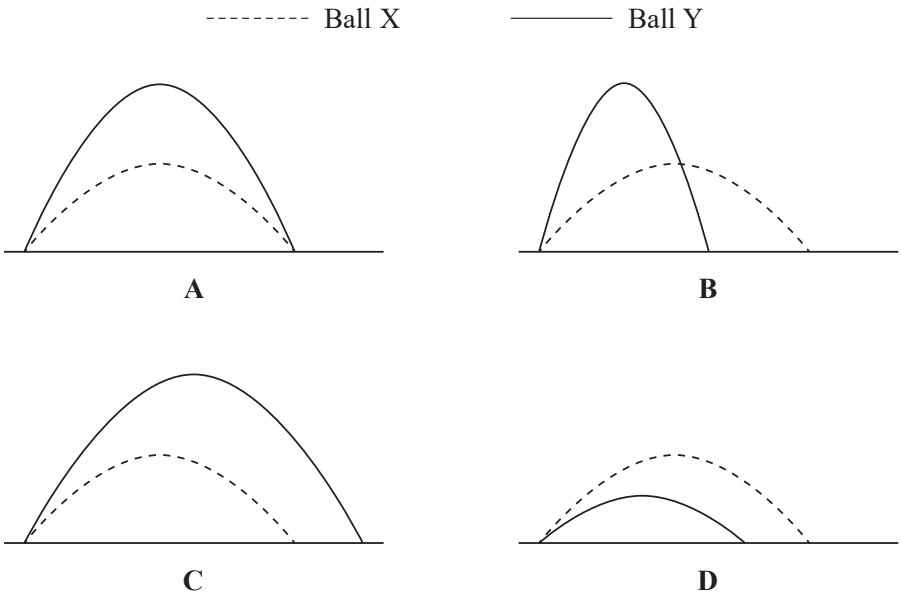
Ball X is kicked at an angle of θ to the horizontal, where θ is greater than 45°.

The trajectory for the motion of ball X is shown.



Ball Y is kicked with the same speed at an angle greater than θ to the horizontal.

Which diagram correctly shows the trajectory of ball Y?



☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 2 = 1 mark)

3 A ball is thrown with an initial horizontal component of velocity u and an initial vertical component of velocity v. The effects of air resistance are negligible.

Which of the following statements about the motion of the ball is **not** correct?

- ☒ **A** The magnitude of the acceleration in the vertical plane is g.
- ☒ **B** The horizontal component of velocity is constant.
- ☒ **C** The time taken for the ball to reach its maximum height is equal to $\frac{v}{g}$.
- ☒ **D** The maximum height of the ball depends on the values of u and v.

(Total for Question 3 = 1 mark)

10 An object was thrown so that it followed the path shown. Assume drag forces were negligible.



The object was thrown with an initial vertical component of velocity u. The time taken to reach maximum height is t.

Which of the following could **not** be used to determine the maximum vertical height s reached by the object?

☒ **A** $s = ut - \frac{1}{2}gt^2$

☒ **B** $s = ut$

☒ **C** $s = \frac{1}{2}ut$

☒ **D** $s = \frac{u^2}{2g}$

(Total for Question 10 = 1 mark)

6 A ball rolls along a table of height 0.83 m. The ball has a horizontal velocity of $1.72\,\text{m s}^{-1}$ as it falls off the edge of the table.

Which of the following is an expression for the speed of the ball, in m s^{-1}, as it hits the floor?

☒ **A** $\sqrt{(2 \times 9.81 \times 0.83)^2 + 1.72^2}$

☒ **B** $(2 \times 9.81 \times 0.83)^2 + 1.72^2$

☒ **C** $\sqrt{(2 \times 9.81 \times 0.83) + 1.72^2}$

☒ **D** $(2 \times 9.81 \times 0.83) + 1.72^2$

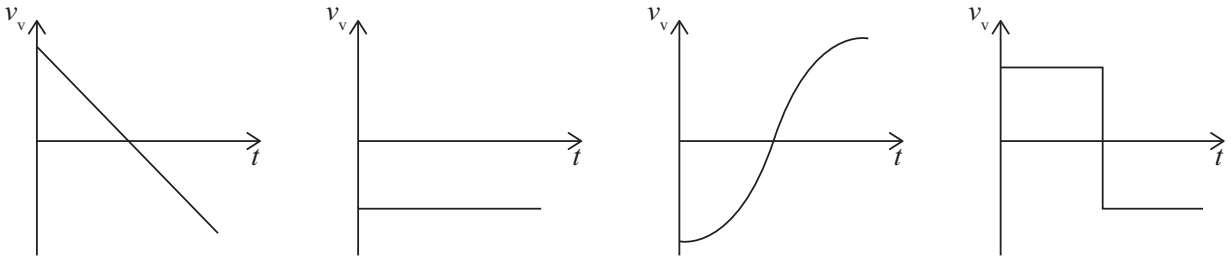
(Total for Question 6 = 1 mark)

Questions 9 and 10 refer to the information below.

A ball was thrown so that it followed the path shown. Assume drag forces were negligible.



10 Which of the following graphs shows how the vertical component of the velocity, v_v, varies with time t from when the ball is thrown to just before it hits the ground?



☒ **A**

☒ **B**

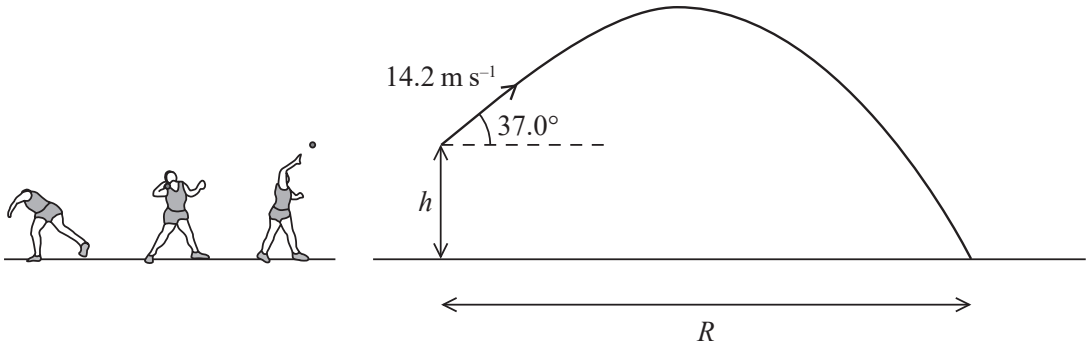
☒ **C**

☒ **D**

(Total for Question 10 = 1 mark)

12 The shot put is an Olympic field event. The distance for the women's world record shot put is in excess of twenty two metres.

The shot is a metal ball, which is thrown from a standing position so that it lands on the ground a horizontal distance R away from the thrower.



A shot is thrown from a height h above the ground with an initial velocity of 14.2 m s^{-1} at an angle of 37.0° to the horizontal. The time it takes for the shot to reach the ground is 1.98 s.

(a) Show that the vertical component of the initial velocity is about 8.6 m s^{-1}.

(2)

(b) Calculate the height h above the ground from which the shot was thrown.

(3)

h = ...

(c) Calculate the horizontal distance R for this throw.

(3)

.....

.....

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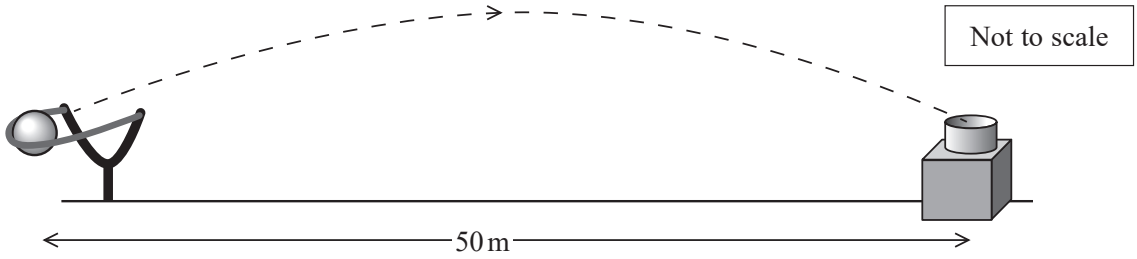
.....

$R =$ .....

(Total for Question 12 = 8 marks)

11 A fairground game requires the player to catapult a ball towards a target to score points.

The ball is required to reach a target a horizontal distance of 50 m away, at the same vertical height, as shown.



(a) The time taken for the ball to reach the target is 2.0 s.

Calculate the angle to the horizontal at which the ball is launched.

(4)

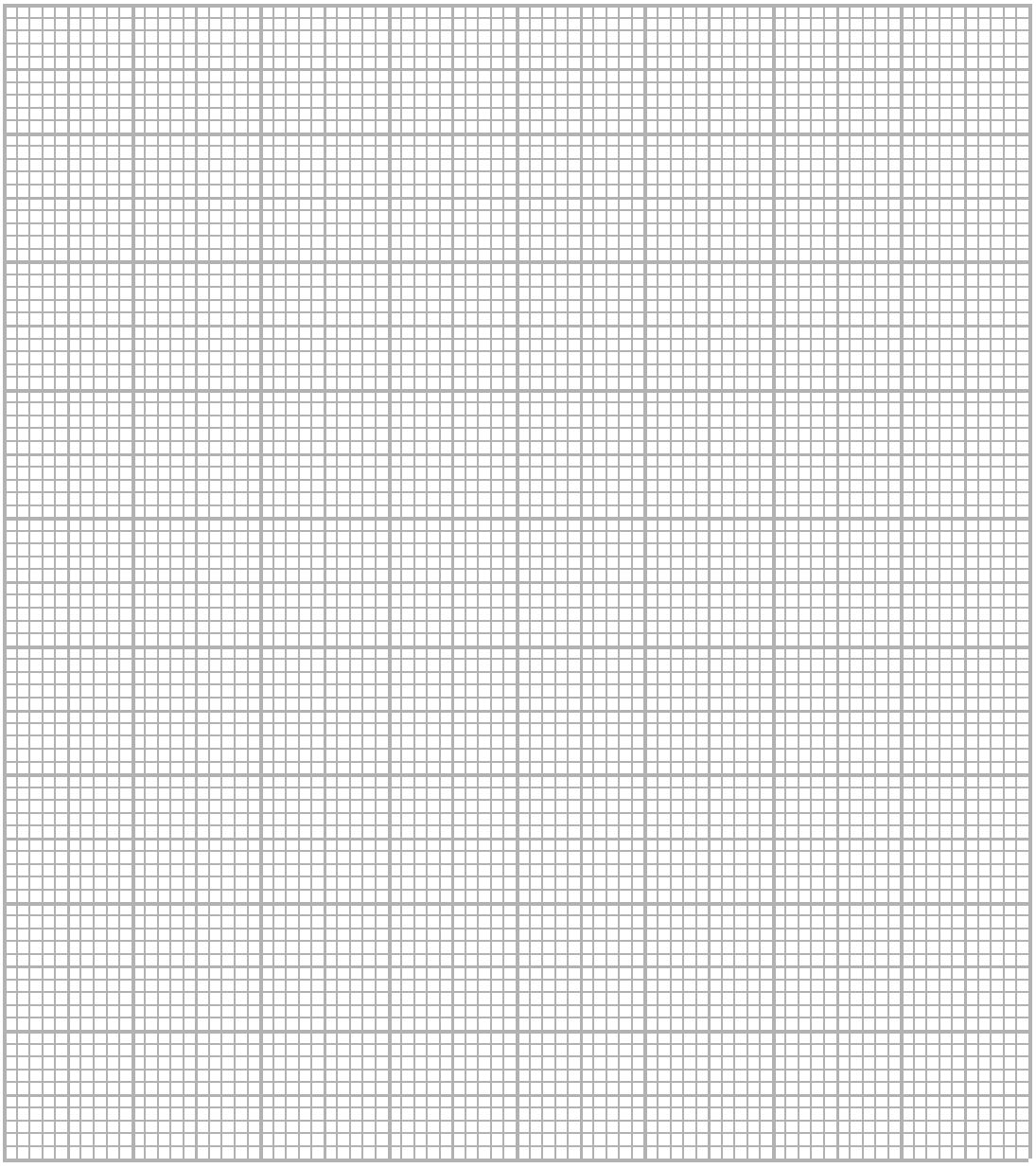
Angle to the horizontal = ...

(b) During another launch, the catapult exerts a force on the ball of 9.0 N at 40° to the horizontal at the time of release.

Draw a labelled vector diagram to determine the resultant force acting on the ball at the time of release.

(4)

weight of ball = 2.0 N

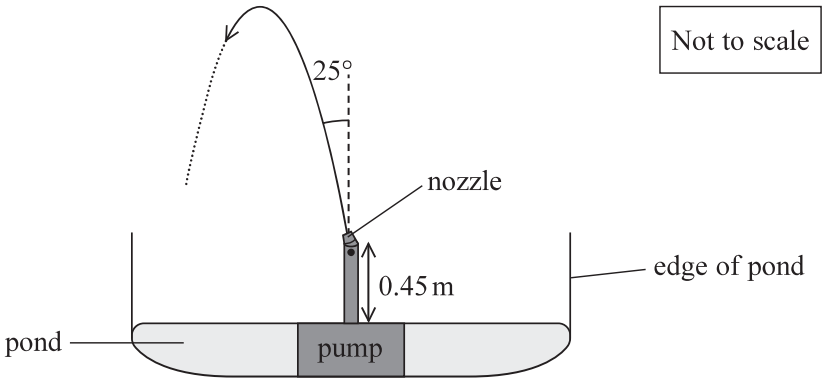


Magnitude of resultant force = ...

Angle of resultant force to the horizontal = ...

(Total for Question 11 = 8 marks)

12 A garden pond contains a water fountain. The fountain consists of a pump and nozzle and is used to create a jet of water which falls back into the pond as shown. The top of the edge of the pond is level with the nozzle.



The water is lifted through a height of 0.45 m before it leaves the nozzle at an angle of 25° to the vertical.

(a) The efficiency of the pump is 76%.

Show that the water leaves the nozzle at a speed of about 8 m s^{-1}.

mass of water leaving the pump each second = 3.5 kg s^{-1}
power of pump = 160 W

(5)

(b) Determine the minimum horizontal distance that the nozzle should be placed from the edge of the pond so that the water falls back into the pond. It can be assumed that air resistance is negligible.

(4)

Minimum horizontal distance = ...

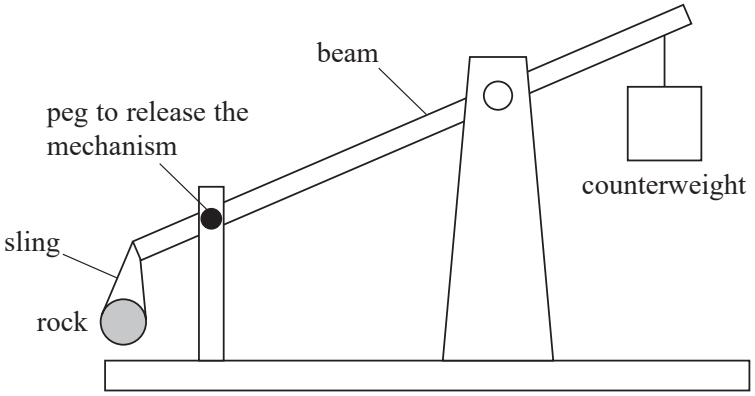
(c) The minimum horizontal distance calculated in (b) is an overestimate because air resistance was ignored.

Explain another reason for the distance calculated to be an overestimate.

(2)

(Total for Question 12 = 11 marks)

13 A trebuchet is a medieval catapult designed to project a rock over large distances. A simplified diagram of a trebuchet is shown.



The rock is held in a sling. When the peg is removed the counterweight falls and the rock is projected through the air.

(a) A student assumes that all the gravitational potential energy transferred from the counterweight is transferred to the kinetic energy of the rock.

Give two reasons why this is not correct.

(2)

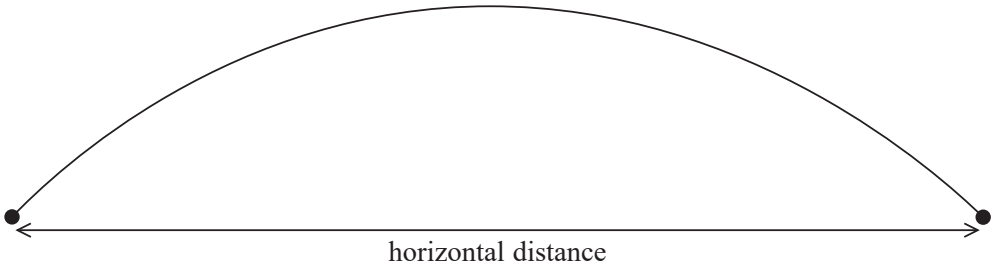
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(b) The rock was projected with a velocity of $41.5\,m\,s^{-1}$ at an angle of 30° to the horizontal. The diagram shows the flight of the rock after it has left the trebuchet.



The rock rises to a maximum height and then falls back to the same height as its release height.

Calculate the horizontal distance travelled by the rock in this time.

(4)

Horizontal distance = ...

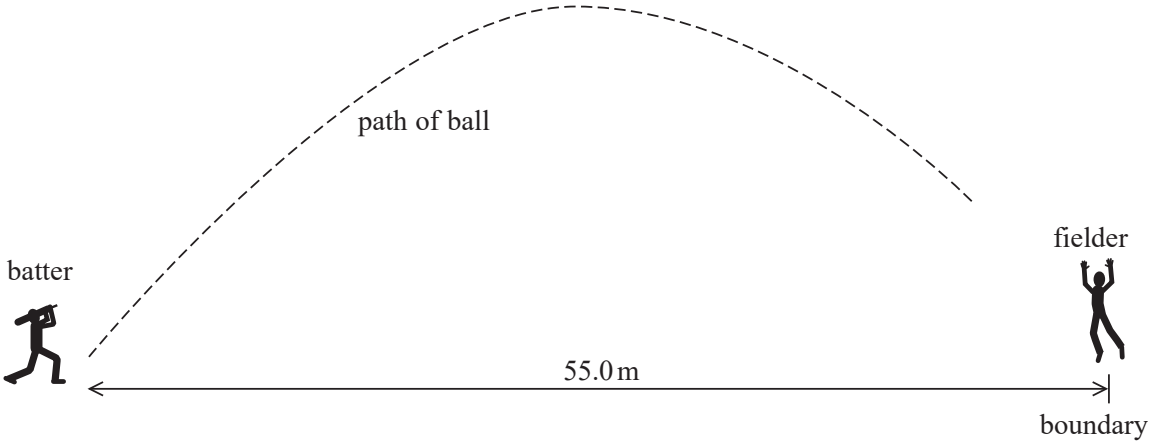
(c) The mass of the counterweight was reduced. The trebuchet was then used to project the rock again.

Explain why the horizontal distance travelled by the rock decreases.

(5)

(Total for Question 13 = 11 marks)

17 In cricket a fielder is often placed at the boundary edge as shown. If the fielder catches the ball, the batter is out.



The fielder is 55.0 m away from the batter. The fielder can catch the ball providing the ball is less than three metres above the height at which it was hit.

The ball is hit with a velocity of 23.8 m s^{-1} and at an angle of 50.0° to the horizontal.

(a) Deduce whether the fielder can catch the ball in this case.

(5)

(b) The ball was bowled. Just after the bat hit the ball, the ball had a velocity of $23.8\,m\,s^{-1}$ at an angle of 50° to the horizontal.

(i) Show that the magnitude of the momentum of the ball, after it was hit, was about 3.3 N s.

mass of cricket ball = 0.140 kg

(1)

.....

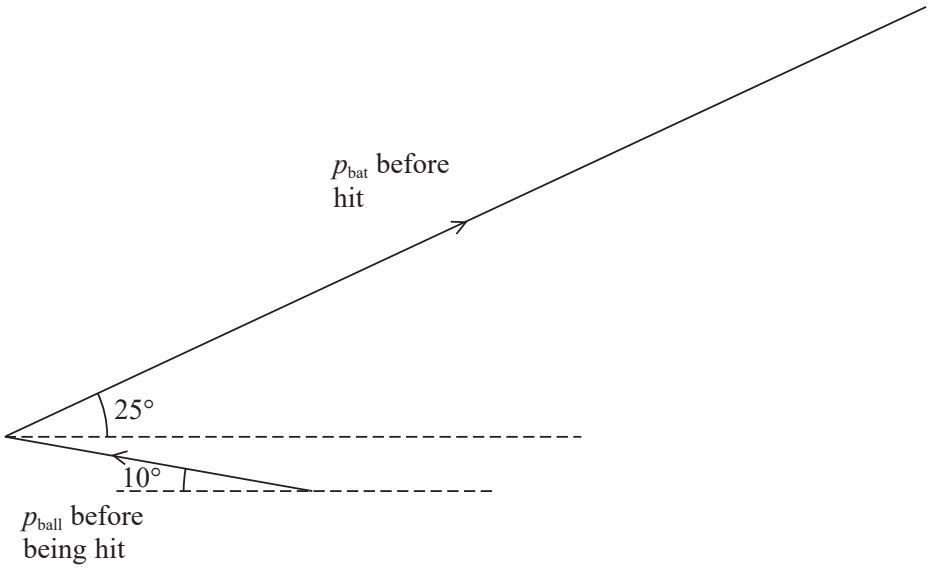
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(ii) The vector diagram below shows, accurately to scale, the momentum of the ball and the momentum of the bat before the hit.

Determine, by completing the vector diagram, the momentum of the bat after it hit the ball.

momentum of bat before hitting ball = 15.0 N s at 25° to the horizontal
momentum of ball before hitting bat = 4.6 N s at 10° to the horizontal

(5)



Momentum of bat after hitting ball = ...

at an angle of ..... to the horizontal

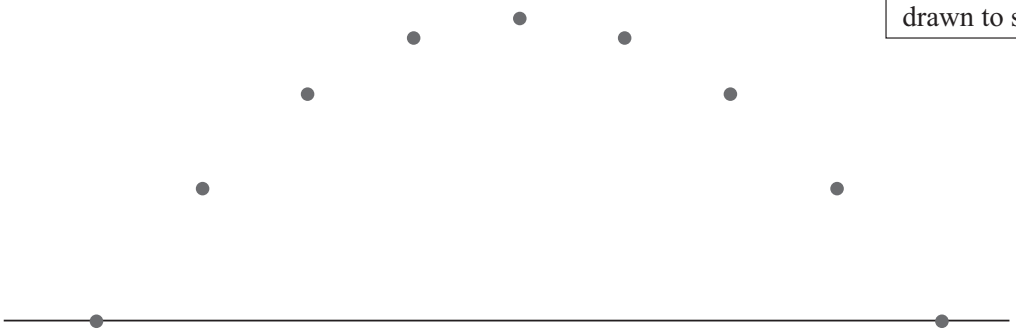
(Total for Question 17 = 11 marks)

13 A textbook has the following statement about the motion of a projectile with negligible air resistance acting on it.

'The only force acting on a projectile is the weight of the projectile. This affects the vertical motion of the projectile but not the horizontal motion.'

A ball was projected up from the ground at an angle. The position of the ball was plotted at equal time intervals, as shown.

Diagram is drawn to scale



*(a) Explain how the diagram gives evidence to support the statement in the textbook.

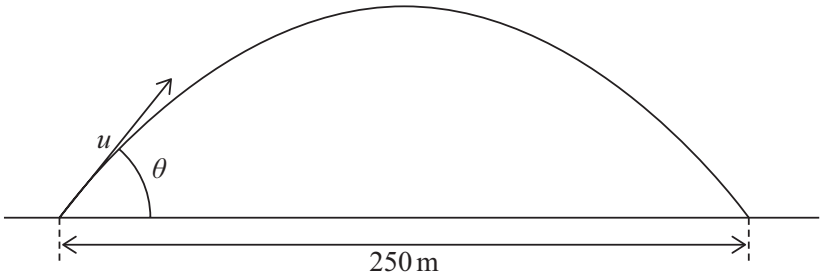
(6)

(b) The photograph shows a cannon which was used to fire cannonballs over long distances in the 15th century.



(Source: © Ton Bangkeaw/Shutterstock)

A cannonball was projected over a horizontal distance of 250 m, as shown below. The time of flight of the cannonball was 7.5 s.



Calculate the angle θ at which the cannonball was fired and the initial speed u of the cannonball.

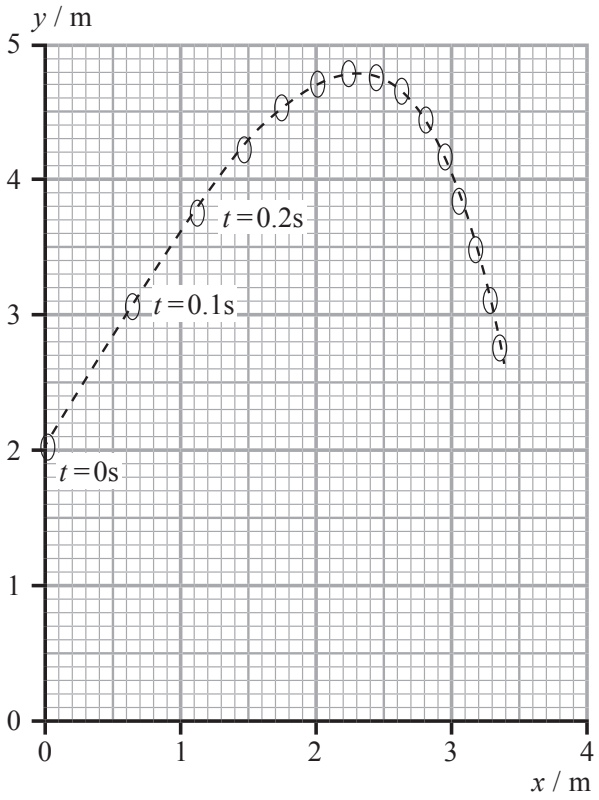
(5)

θ = ...

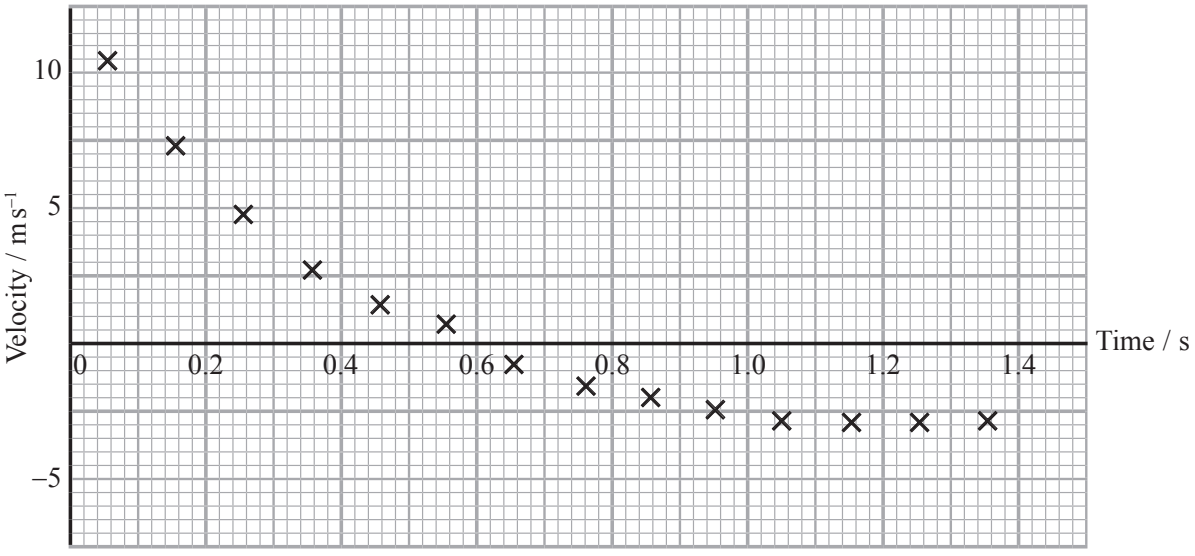
u = ...

(Total for Question 13 = 11 marks)

16 In a game of badminton, a shuttlecock is hit by a racket. The graph shows how the vertical displacement (y) and horizontal displacement (x) of the shuttlecock vary from the moment it leaves the racket. The positions are recorded every 0.10 s.



(a) The graph below shows how the velocity of the shuttlecock in the vertical direction varies with time.



(i) Explain how the velocities have been calculated from the successive vertical positions of the shuttlecock.

(2)

(ii) State why these velocities have been plotted at the mid-range of the time interval.

(1)

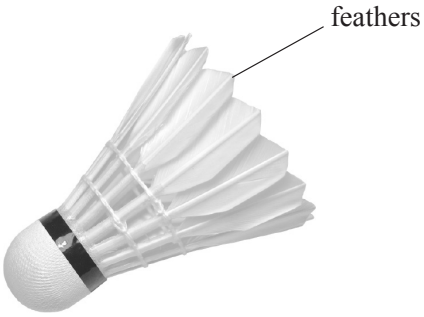
(iii) State, with a reason, two pieces of evidence from the graphs that show that the shuttlecock does **not** follow the motion of a projectile moving freely under gravity.

(3)

(iv) Show, using the velocity-time graph, that the maximum height gained by the shuttlecock is about 3 m.

(3)

(b) The photograph shows a shuttlecock.



© Pearson Asset Library

The shuttlecock always moves through the air with the 'feathers' trailing behind.

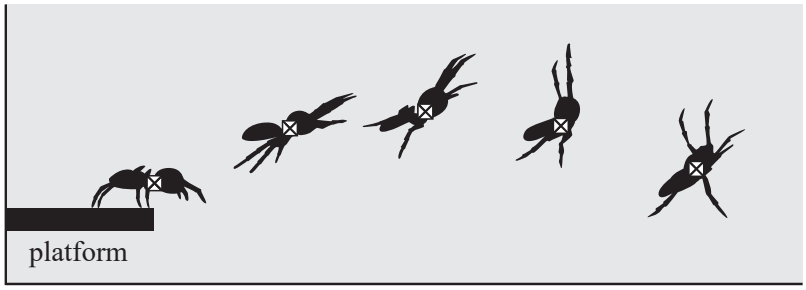
Explain how the feathers affect the motion of the shuttlecock along its path.

(3)

(Total for Question 16 = 12 marks)

16 Scientists have been studying a type of jumping spider that can jump up to six times its body length.

(a) The scientists photographed a spider at 0.02s intervals, during a jump. The picture is taken from the photograph and is shown actual size.



(i) Deduce whether the images show that the motion in the x-direction is independent of the motion in the y-direction. You should take measurements using the cross marking the centre of gravity of the spider.

(4)

(ii) Show that the initial velocity of the spider at the start of the jump is about $1\,m\,s^{-1}$.
You should take measurements using the cross marking the centre of gravity of the spider.

(5)

(iii) The spider achieves this jump by extending its two back legs by 3.0 mm.

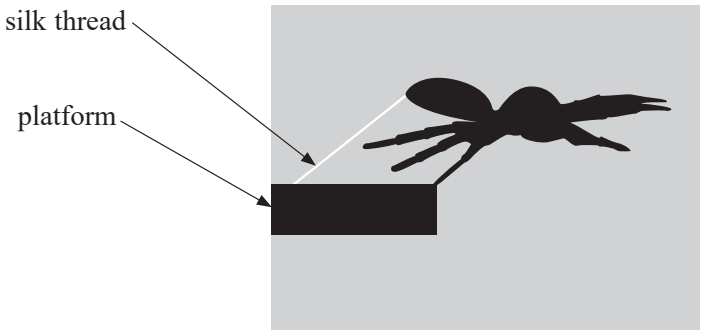
Calculate the average force the spider exerts in each leg to achieve the jump.

mass of spider = 150 mg

(3)

Average force = ...

(b) Just as the spider starts the jump, it fixes a silk thread to the platform. It is thought that the thread acts as a safety line in case the spider falls.



A student makes the comment:

'If the silk thread can withstand a tension equal to the weight of the spider then this safety system should work.'

Deduce whether this statement is correct.

(2)

.....

.....

.....

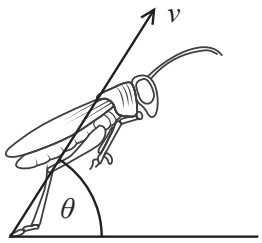
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(Total for Question 16 = 14 marks)

14 Grasshoppers can jump up to twenty times their length to escape predators. The magnitude of the launch velocity v does not vary significantly for a given grasshopper, so the length of the jump mostly depends on the launch angle θ.

The diagram shows a grasshopper at the instant it launches.



(Source: adapted from http://gclipart.com/grasshopper-clipart_28241/)

(a) The grasshopper jumps from rest on level ground. The launch velocity is $2.6\,m\,s^{-1}$ at an angle of 57° to the horizontal.

(i) Show that the vertical component of the launch velocity is about $2\,m\,s^{-1}$.

(1)

(ii) Assess whether the horizontal distance travelled by the grasshopper in the jump is about 20 times the grasshopper's length.

length of grasshopper = 5.0 cm

(5)

(b) Grasshoppers with longer legs accelerate to their launch velocity over a longer time.

Leg length has a negligible effect on both the mass of a grasshopper and the energy released in a jump.

Explain how leg length affects the force exerted on the ground during a jump.

(4)

(c) In a recent study it was discovered that grasshoppers, living in an environment with hunting spiders, increase their launch velocity on average by 20%. The jump length of these grasshoppers was more than doubled.

Assess whether a 20% increase in launch velocity alone is sufficient to double the jump length.

(4)

(Total for Question 14 = 14 marks)

SUB-TOPIC 2.5

FORCES, FREE-BODY DIAGRAMS AND NEWTON'S LAWS

Sub-topic 2.5 · 20 questions · 75 marks · lowest tariff first

5 Which of the following is the unit for tension expressed in SI base units?

- ☒ **A** N
- ☒ **B** N s
- ☒ **C** kg m s^{-1}
- ☒ **D** kg m s^{-2}

(Total for Question 5 = 1 mark)

3 An object is falling at terminal velocity.

Which of the following is **not** a valid conclusion from this statement?

☒ **A** The acceleration of the object is zero.

☒ **B** There is a resistive force acting on the object.

☒ **C** There is a resultant force acting on the object.

☒ **D** The object has weight.

(Total for Question 3 = 1 mark)

3 A space rocket lifts off vertically.



The rocket lifts off because

- ☒ **A** the exhaust gases exert a force on the ground.
- ☒ **B** the exhaust gases exert a force on the rocket.
- ☒ **C** the ground exerts a force on the rocket.
- ☒ **D** the rocket exerts a force on the ground.

(Total for Question 3 = 1 mark)

1 A skydiver steps out of an aeroplane and falls from rest, towards the ground. Her parachute opens a short time after she reaches terminal velocity.

Which of the following statements is correct for the vertical acceleration a of the skydiver until her parachute opens?

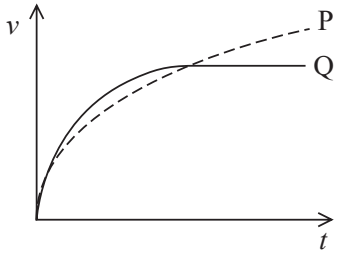
- ☒ **A** a decreases to zero
- ☒ **B** a increases to a maximum
- ☒ **C** a is constant and equal to g
- ☒ **D** a is constant but less than g

(Total for Question 1 = 1 mark)

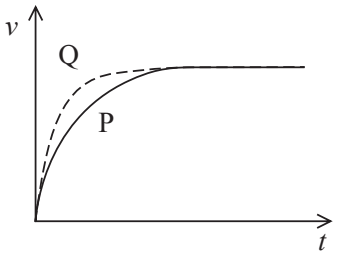
6 Two identical lorries, P and Q, carry different loads inside them so that the total mass of P is greater than the total mass of Q.

P and Q start from rest along the same road. The forward force from the engine of each lorry is the same.

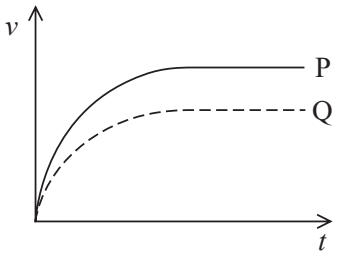
Which of the following graphs correctly shows how velocity v varies with time t for the two lorries?



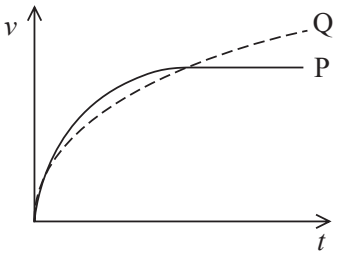
A



B



C



D

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 6 = 1 mark)

7 A cable is used to pull a mass of 2.5 kg vertically upwards with an acceleration of 4.3 $m\,s^{-2}$.

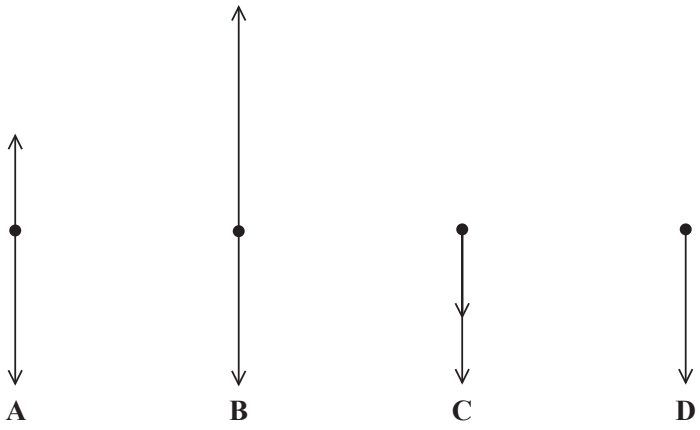
Which of the following expressions gives the tension in the cable in N?

- ☒ **A** 2.5×4.3
- ☒ **B** $(2.5 \times 4.3) - (2.5 \times 9.81)$
- ☒ **C** $(2.5 \times 4.3) + (2.5 \times 9.81)$
- ☒ **D** 2.5×9.81

(Total for Question 7 = 1 mark)

1 A student throws a ball vertically upwards.

Which of the following shows a free-body force diagram for the ball immediately after it leaves the student's hand?



- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 1 = 1 mark)

5 A car is travelling at a constant speed in a straight line along a horizontal road.

Which row of the table gives a Newton's third law pair of forces?

		Force 1	Force 2
☒	**A**	normal force of car on road	friction between wheels and road
☒	**B**	normal force of car on road	normal force of road on car
☒	**C**	weight of car	normal force of car on road
☒	**D**	weight of car	normal force of road on car

(Total for Question 5 = 1 mark)

9 A person of mass 70 kg is standing on the floor of a lift, as shown. The lift is accelerating downwards at $1.5\,\text{m}\,\text{s}^{-2}$.



Which of the following gives the normal reaction R, in N, acting on the person?

☒ **A** $R = 70 \times 9.81$

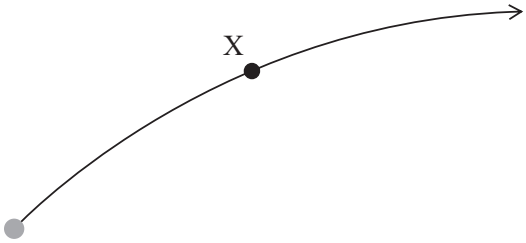
☒ **B** $R = 70 \times 1.5$

☒ **C** $R = (70 \times 9.81) + (70 \times 1.5)$

☒ **D** $R = (70 \times 9.81) - (70 \times 1.5)$

(Total for Question 9 = 1 mark)

3 A ball is thrown and follows the path shown.



Air resistance is negligible.

Which of the following is a free-body force diagram for the ball at position X?



A **B** **C** **D**

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

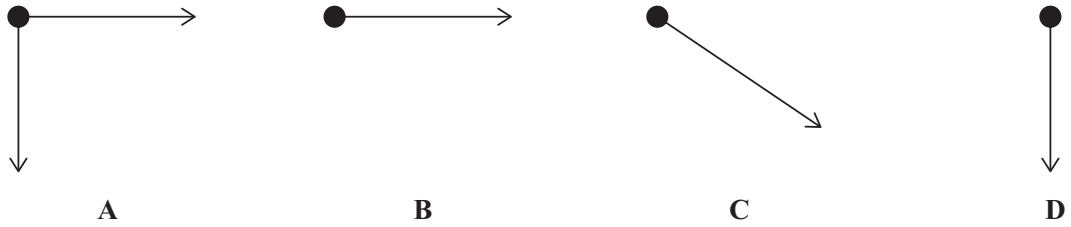
(Total for Question 3 = 1 mark)

Questions 9 and 10 refer to the information below.

A ball was thrown so that it followed the path shown. Assume drag forces were negligible.



9 Which of the following is a free-body force diagram for the ball at its maximum height?



- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 9 = 1 mark)

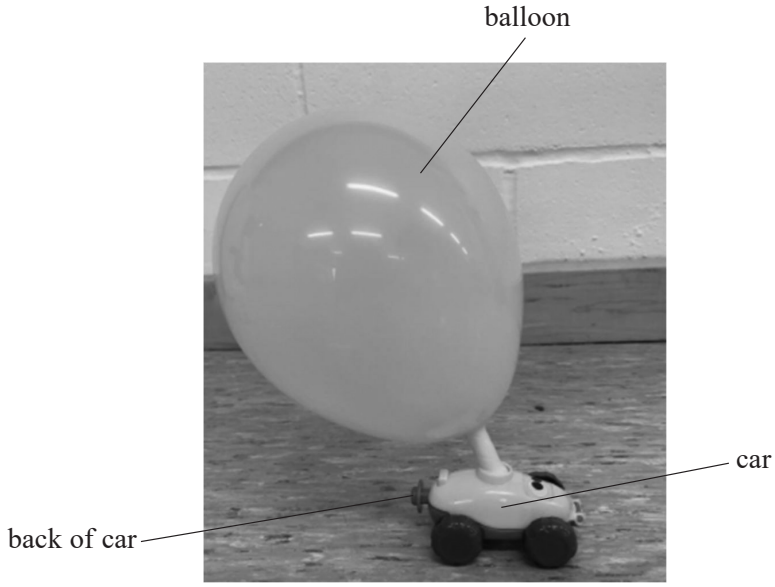
1 A ball bearing falls from rest through oil.

Which of the following statements is correct during the initial motion of the ball bearing?

- ☒ **A** The resultant force on the ball bearing decreases.
- ☒ **B** The resultant force on the ball bearing increases.
- ☒ **C** The resultant force on the ball bearing decreases then increases.
- ☒ **D** The resultant force on the ball bearing stays constant.

(Total for Question 1 = 1 mark)

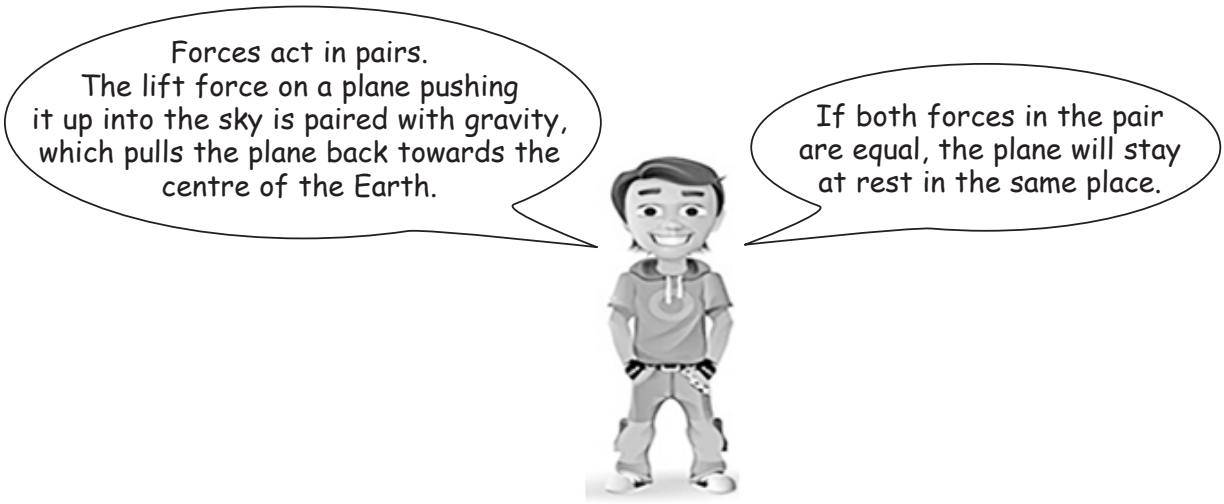
11 The picture shows a toy car. There is an inflated balloon attached to the car. As the balloon deflates, air is released from the back of the car and the car starts to move.



Explain, with reference to Newton's laws of motion, how the release of the air from the back of the car causes the car to start to move.

(Total for Question 11 = 4 marks)

***5** The following extract comes from a section on forces, on a website written for children.



Criticise this extract.

(6)

(Total for Question 5 = 6 marks)

***14** A student is travelling forwards at constant speed on a skateboard.

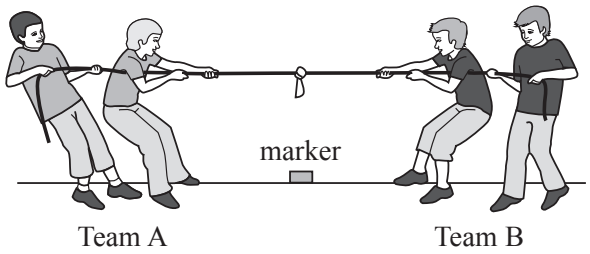
The student jumps forward off the skateboard.



Explain how Newton's laws of motion apply to the student and the skateboard as he jumps forward off the moving skateboard.

(Total for Question 14 = 6 marks)

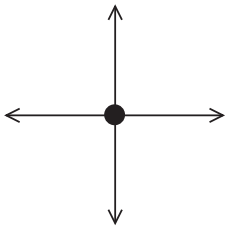
10 In a game of tug-of-war two teams of children pull on opposite ends of a rope. The team that pulls the other team over a marker wins the game.



(a) Initially Team A and Team B are stationary.

Add labels to the free-body force diagram for the child at the end of the rope for Team A at this instant.

(3)



*(b) Team B wins by pulling Team A over the marker.

By considering the forces on the children and on the rope explain, in terms of Newton's laws, the process by which Team A loses the game.

(6)

(Total for Question 10 = 9 marks)

13 Road trains are used in Australia to transport freight across large, flat areas of the country. They consist of a minimum of three trailers connected to a cab unit to pull them along.



(a) The braking distance of a road train travelling at 15 m s^{-1} is 70 m.

Assuming that the same braking force is applied at all speeds, show that the braking distance of a road train when travelling at 25 m s^{-1} is about 190 m.

(3)

(b) A car accelerates uniformly at 3.7 m s^{-2} as it passes a stationary road train.

The initial speed of the car is 30 m s^{-1} and it reaches the speed limit of 130 km h^{-1} as it passes the front of the cab.

Calculate the length of the road train.

(3)

Length of the road train = ...

(c) One region of Australia decided to trial the removal of the speed limit on some roads.

The following statements were made in an online forum discussing this issue.

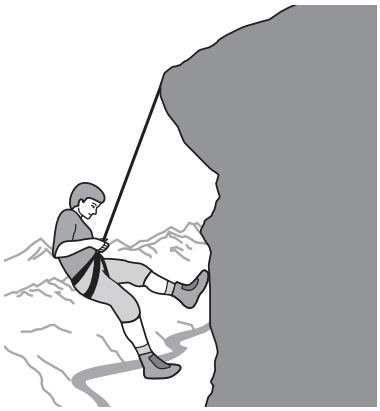
> Comment
>
> *"If a car was going faster, it would have better fuel economy. A lot of modern cars have engines that are more efficent at 200 km h^{-1} than at 100 km h^{-1}."*
>
> Reply
>
> *"You confuse efficiency with fuel consumption. You cannot get better fuel economy at higher speeds."*

Justify the statement in the reply.

(3)

(Total for Question 13 = 9 marks)

16 The diagram shows a rock climber of mass 55 kg. She is hanging on a rope with one foot in contact with a rock face. She uses this foot to push herself horizontally away from the rock face. The rope is inclined at 20° to the vertical.



(a) Complete the free-body force diagram below to represent the forces acting on the climber.

(3)

(b) (i) Show that the tension in the rope is about 600 N.

(3)

(ii) The rope extends by 2.5 cm when used as shown.

Calculate the energy stored within the rope.

(2)

.....

.....

.....

.....

Energy stored = ...

(iii) State one assumption made in this calculation.

(1)

.....

.....

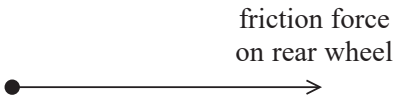
(Total for Question 16 = 9 marks)

12 The photograph shows a cyclist cycling at a constant velocity on horizontal ground.



(a) Complete the free-body force diagram to show the four forces acting on the bicycle. Treat the bicycle and cyclist as a single object. One force has been added for you.

(3)



(b) The cyclist stops pedalling and comes to rest in a time of 5.2 s.

(i) Sketch a graph to show how the cyclist's velocity changes during this time.

Assume the deceleration is constant.

(2)



(ii) The cyclist travels 7.80 m while coming to rest.

Calculate the average resistive force on the cyclist and bicycle.

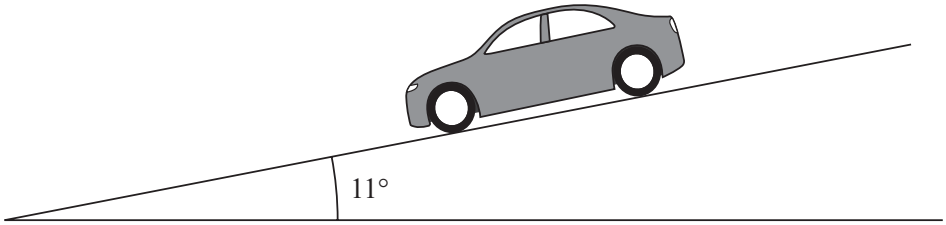
mass of cyclist and bicycle = 28.0 kg

(4)

Average resistive force = ...

(Total for Question 12 = 9 marks)

13 The diagram shows a car being driven down a slope at a constant speed.



(a) (i) Complete the free-body force diagram for the car.

(3)

driving force

(ii) The total resistive force acting on the car is 2530 N.

Calculate the driving force required for the car to maintain a constant speed.

weight of car = 1.2×10^4 N

(3)

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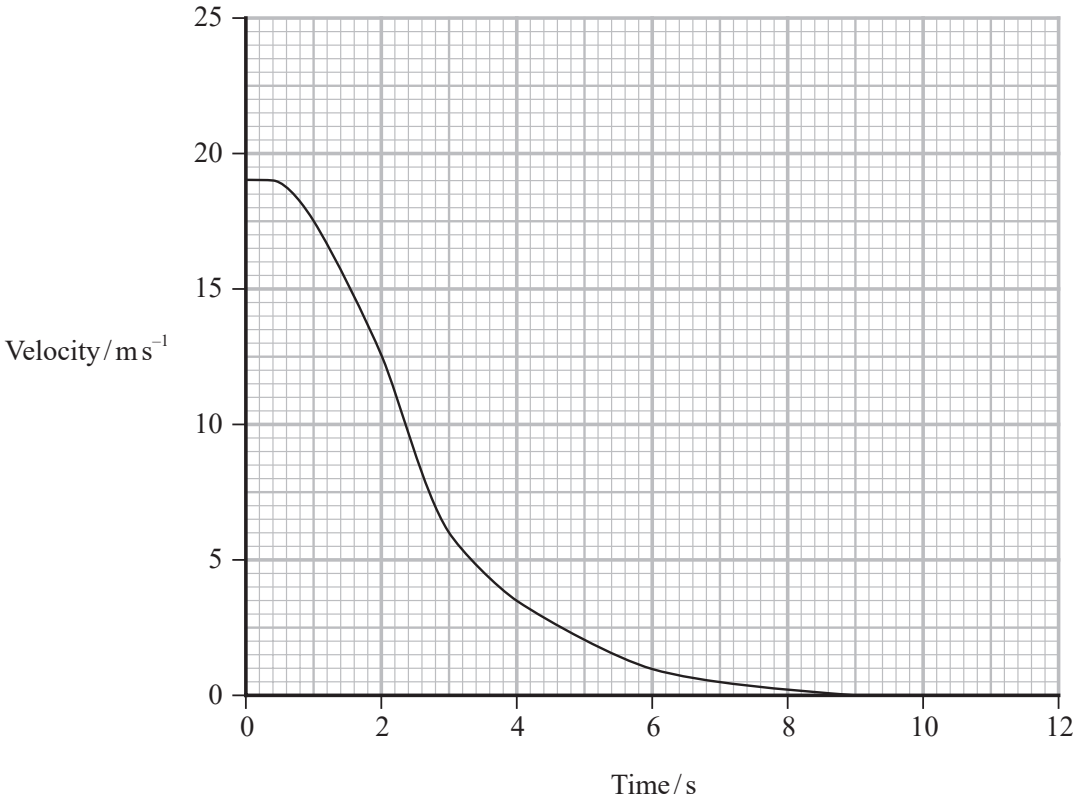
.....

.....

Driving force = ...

(b) A very steep road may have a lane to the side, filled with deep gravel. A vehicle with brake failure can drive onto the lane and will be brought to rest as the vehicle's wheels sink into the gravel.

The graph shows the decrease in velocity of a van as it comes to rest in the gravel.



(i) Calculate the maximum decelerating force on the van.

mass of van = 2400 kg

(4)

Maximum decelerating force = ... N

(ii) Describe the energy transfers taking place as a vehicle comes to rest in the gravel.

(1)

(Total for Question 13 = 11 marks)

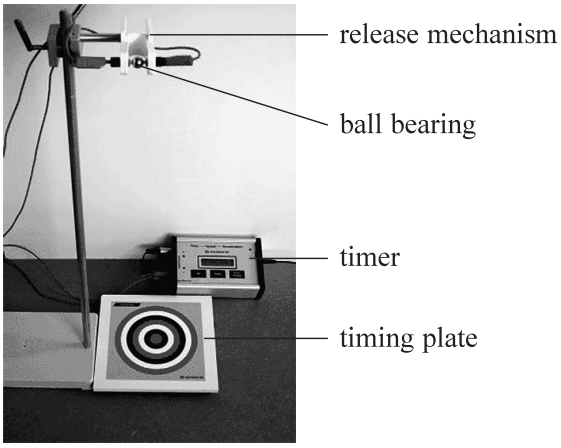
SUB-TOPIC 2.6

CORE PRACTICAL 1: DETERMINING G BY FREE FALL

Sub-topic 2.6 · 2 questions · 16 marks · lowest tariff first

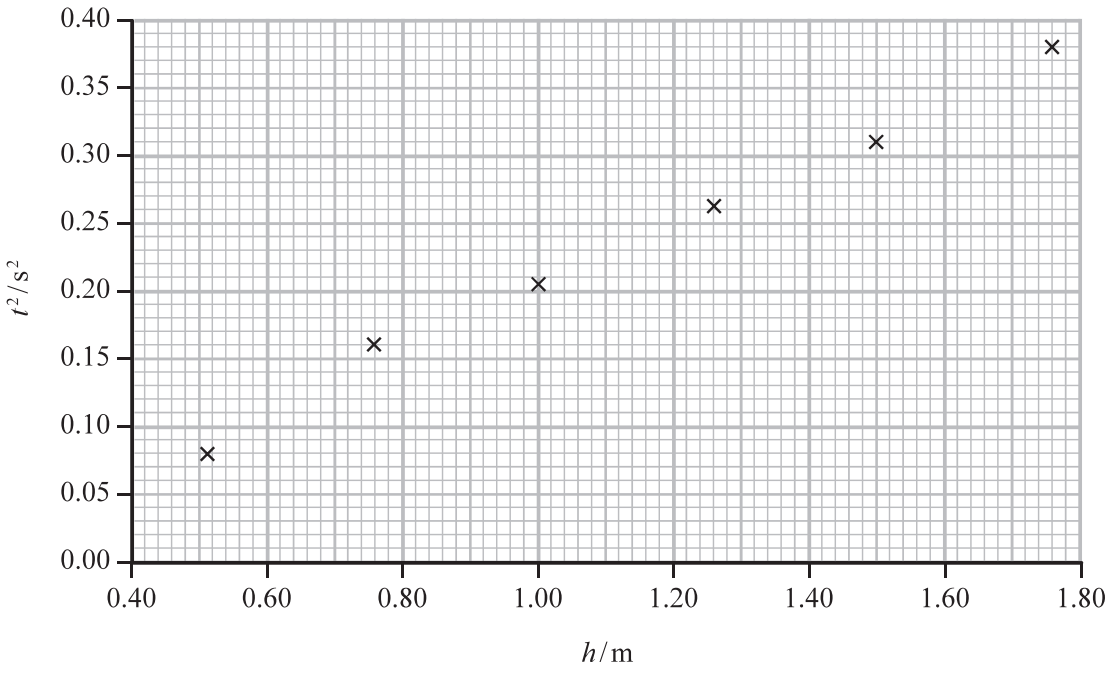
10 A student carried out an experiment to determine the acceleration of free-fall g using the apparatus shown in the photograph.

A ball bearing was released from a measured height h and a timer automatically started. On hitting a timing plate, the ball bearing stopped the timer and the time t was displayed on the timer. This was repeated for different values of h.



The uncertainty in t was ± 3%. The uncertainty in h was ± 1%.

The student plotted a graph of t^2 against h and used it to determine a value for g.



The student concluded that her value for g was consistent with the accepted value.

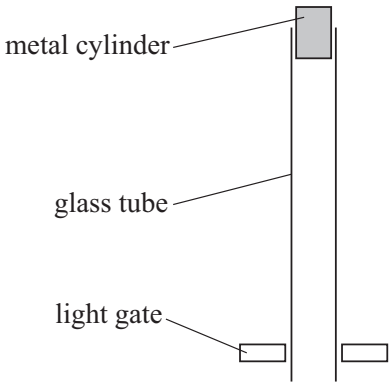
Comment on the student's conclusion. Your answer should include a calculation of g from the student's data.

You may assume that the percentage uncertainty in your value of g is the same as if the value were calculated from just one pair of readings.

(5)

(Total for Question 10 = 5 marks)

12 In an experiment to determine the acceleration of free-fall, g, a metal cylinder was dropped from rest down a glass tube. A light gate was positioned close to the outside of the glass tube, as shown.



The light gate was connected to a data logger that recorded the time t taken for the cylinder to pass the gate.

(a) A student recorded the following data.

t_1 / ms	t_2 / ms	t_3 / ms	t_4 / ms
7.85	7.81	7.79	7.80

(i) The student omitted t_1 when calculating the mean time. He justified this by stating that t_1 is an anomalous result.

Another student stated that the correct mean time should use all the data in the table.

Explain who is correct.

(2)

.....

.....

.....

.....

(ii) Calculate the percentage uncertainty in the mean time t_{mean}.

(3)

Percentage uncertainty in t_{mean} = ...

(iii) The student used the mean time to calculate the velocity of the metal cylinder as it moved past the light gate.

State the extra measurement the student must have made to calculate this velocity.

(1)

(b) The metal cylinder fell through a distance 0.75 m before reaching the light gate.

(i) Calculate the velocity of the metal cylinder as it reached the light gate.

(2)

Velocity = ...

(ii) Explain why a light gate and data logger were used in this experiment rather than a stopwatch. You should refer to your answer to (b)(i).

(3)

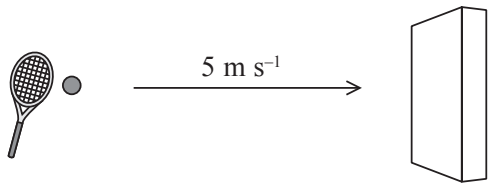
(Total for Question 12 = 11 marks)

SUB-TOPIC 2.7

MOMENTUM AND CONSERVATION OF MOMENTUM

Sub-topic 2.7 · 14 questions · 108 marks · lowest tariff first

2 A tennis ball of mass 0.06 kg moves towards a wall at a velocity of 5 m s^{-1} as shown.



The tennis ball hits the wall perpendicularly and rebounds at the same speed.

What is the change in momentum of the ball?

☒ **A** 0.60 kg m s^{-1}

☒ **B** 0.30 kg m s^{-1}

☒ **C** −0.30 kg m s^{-1}

☒ **D** −0.60 kg m s^{-1}

(Total for Question 2 = 1 mark)

7 A car is fitted with an airbag which will inflate if the car stops very suddenly.



(Source: © KAIROS, LATIN STOCK/SCIENCE PHOTO LIBRARY)

Which of the following is increased if the airbag inflates because the car suddenly stops?

- ☒ **A** change in momentum of the driver
- ☒ **B** change in velocity of the driver
- ☒ **C** force on the driver
- ☒ **D** time that the driver takes to stop

(Total for Question 7 = 1 mark)

2 Two ice skaters, P and Q, are close together and stationary on an ice rink. P pushes Q and they move away from each other.

The mass of P is greater than the mass of Q.

Assume the frictional force between the ice and the skates is negligible.

Which of the following statements is correct?

- ☒ **A** P and Q both move at the same speed.
- ☒ **B** P and Q have the same magnitude of momentum.
- ☒ **C** P has a greater magnitude of momentum than Q.
- ☒ **D** P moves faster than Q.

(Total for Question 2 = 1 mark)

8 A shopping trolley moves at velocity v. The trolley collides and combines with a stack of 5 identical stationary trolleys.

Which of the following expressions gives the velocity of the combined stack of trolleys?

☒ **A** $6v$

☒ **B** $5v$

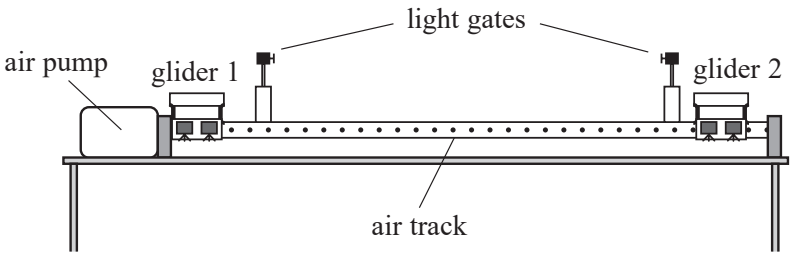
☒ **C** $\frac{v}{5}$

☒ **D** $\frac{v}{6}$

(Total for Question 8 = 1 mark)

12 A teacher uses a linear air track to provide a frictionless surface for two gliders, each of mass m. She uses this, with a pair of light gates connected to a computer, to investigate a collision between the gliders.

The gliders are each given a small push and travel towards the centre of the track. The gliders collide and move off together.



(a) The computer displays the velocity of the gliders as they pass through the light gates.

Calculate the velocity of the gliders after the collision, using the principle of conservation of linear momentum.

(3)

initial velocity of glider 1 = 0.30 m s^{-1} to the right
initial velocity of glider 2 = 0.70 m s^{-1} to the left

Magnitude of velocity = ...

Direction of velocity = ...

(b) The teacher asked a student to justify the change in velocity of glider 1 using Newton's laws of motion.

The student began his explanation with the statement:

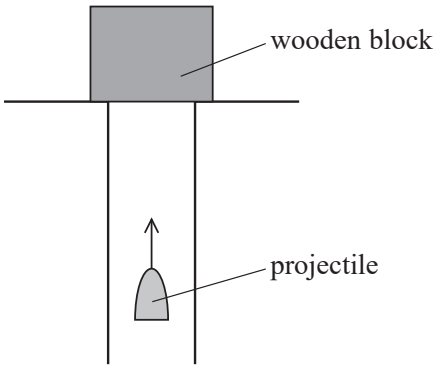
"During the collision there is a force on glider 2"

Complete the explanation to justify the change in velocity of glider 1, making reference to Newton's laws of motion where appropriate.

(4)

(Total for Question 12 = 7 marks)

7 A projectile of mass 65 g is fired vertically upwards into a stationary wooden block of mass 2.400 kg, as shown.



(a) The projectile becomes embedded in the block. They both move vertically upwards through a vertical displacement of 55 cm before momentarily coming to rest.

Calculate the energy dissipated as the projectile hits the block.

(6)

Energy dissipated = ...

(b) Explain how the principle of conservation of energy applies to this collision.

(2)

.....

.....

.....

.....

.....

(Total for Question 7 = 8 marks)

13 Two ice skaters are gliding across the horizontal ice surface at an ice rink.



(Source: © ITAR-TASS News Agency/Alamy Stock Photo)

(a) Initially the skaters move together with a speed of $5.6\,m\,s^{-1}$.

The male skater pushes the female skater forwards. After being pushed, she has a forward speed of $7.5\,m\,s^{-1}$.

Calculate the speed of the male skater immediately after pushing the female skater forwards.

mass of male skater = 66 kg
mass of female skater = 52 kg

(3)

Speed of male skater = ...

(b) Explain why the male skater experiences a change in his velocity when he pushes the female skater forwards.
You should make reference to Newton's laws of motion in your explanation.

(4)

(c) When the male skater pushes the female skater forwards, the total kinetic energy of the skaters increases.

Explain why kinetic energy is not conserved in this interaction.

(2)

(Total for Question 13 = 9 marks)

15 (a) Solar sails are a form of propulsion for spacecraft. The sail is made of a thin sheet of reflective material. When photons of light from the Sun reflect from the material a force is exerted on the sail. The photons reflect with a momentum equal to their initial momentum but in the opposite direction.

(i) Show that a single photon of frequency 1.5×10^{15} Hz has a momentum of about 3×10^{-27} N s.

(2)

.....

.....

.....

.....

(ii) Hence determine the momentum transferred to the solar sail by this photon.

(1)

.....

Momentum transferred = ...

(b) An alternative method of producing a momentum change is being investigated. Researchers have suggested that 'larger changes in momentum could be produced by directing laser light at graphene oxide'. Electrons are emitted from the graphene oxide surface, resulting in a force being exerted on the graphene oxide in the opposite direction.

A researcher has suggested that one possible mechanism for the emission of the electrons is the photoelectric effect.

(i) Show that the maximum velocity for a photoelectron emitted after absorption of a photon of light of frequency 1.5×10^{15} Hz is about 8×10^{5} m s^{-1}.

work function of graphene oxide = 6.7×10^{-19} J

(3)

(ii) Hence calculate the momentum of the photoelectron.

(2)

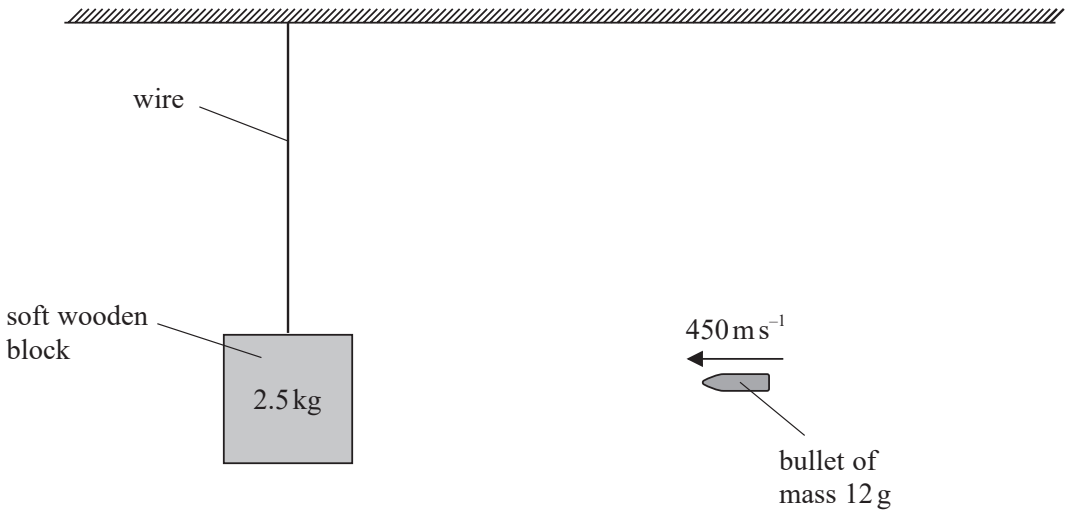
Momentum of photoelectron = ...

(c) Explain whether the suggestion in (b) that 'larger changes in momentum could be produced by directing laser light at graphene oxide' is true.

(2)

(Total for Question 15 = 10 marks)

15 A bullet of mass 12 g moved at a speed of 450 m s^{-1}. The bullet hit a soft wooden block of mass 2.5 kg which was attached to a wire, as shown. The bullet became stuck in the wooden block which swung upwards.



(a) (i) Show that the momentum of the bullet is about 5 kg m s^{-1}.

(2)

.....

.....

(ii) Determine the maximum change in vertical height of the wooden block.

(3)

.....

.....

.....

.....

.....

Maximum change in vertical height = ...

(b) The soft wooden block was replaced with a hard steel block of the same mass.

An identical bullet was fired at the steel block with the same speed as before. The bullet rebounded from the steel block.

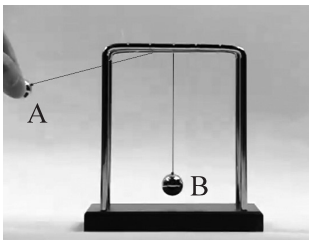
Explain why the steel block moved through a greater maximum vertical height than the wooden block.

(5)

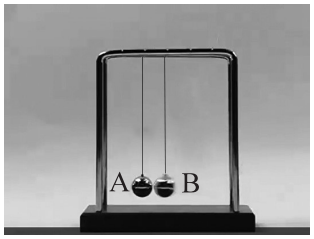
(Total for Question 15 = 10 marks)

14 Two small identical solid metal spheres, A and B, are suspended by light inextensible threads from a frame.

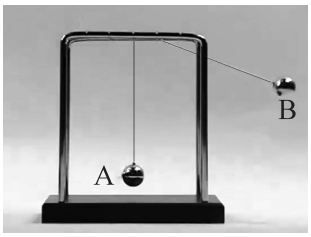
*(a) Sphere A is pulled to one side as shown and released. Sphere A collides with sphere B and stops and sphere B swings upwards. The time intervals between the photographs below are the same.



Photograph 1



Photograph 2

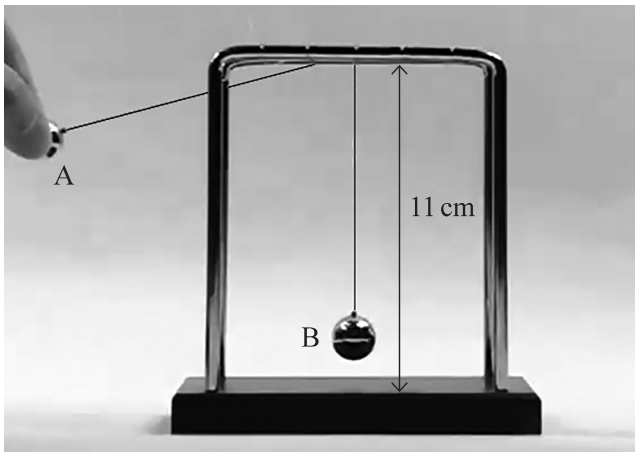


Photograph 3

Using Newton's laws of motion, explain the motion of the spheres during the collision in terms of the forces acting on them.

(6)

(b) The photograph shows sphere A just before it was released.



Determine the momentum of sphere A just before the collision. You should take measurements from the photograph.

height of frame = 11 cm
mass of sphere = 0.022 kg

(5)

Momentum of sphere A = ...

(Total for Question 14 = 11 marks)

8 A student investigated the behaviour of a pendulum. The student used a 'spring gun' to fire a small sphere of modelling clay at the wooden pendulum bob, as shown in Figure 1. The clay stuck to the pendulum bob, which swung to one side, as shown in Figure 2.

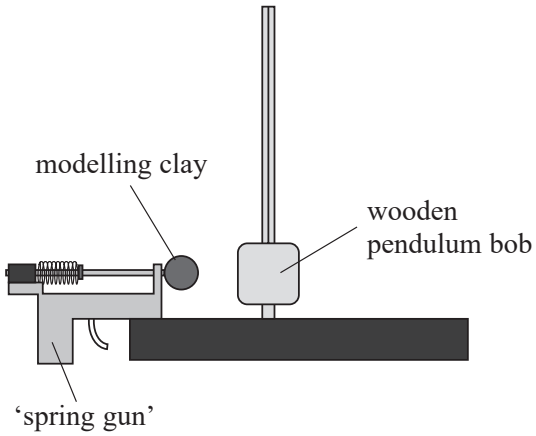


Figure 1

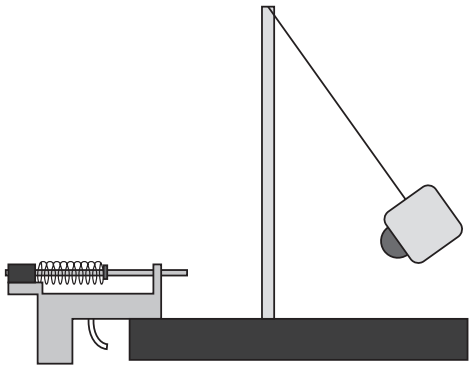


Figure 2

*(a) Describe how the principle of energy conservation and the principle of momentum conservation apply to this situation.

Consider the situation from the instant the spring gun is released to the instant the bob reaches its maximum height.

(6)

(b) When the modelling clay hits the pendulum bob, the pendulum swings to one side.

(i) Show that the time taken for the pendulum bob to move from its lowest position to its highest position is about 0.6 s.

effective length of pendulum = 1.25 m

(3)

(ii) The pendulum bob was then attached to a spring of stiffness 0.12 N m^{-1}. When the bob was displaced vertically and released, it oscillated with a time period equal to that of the pendulum.

Calculate the mass of the pendulum bob.

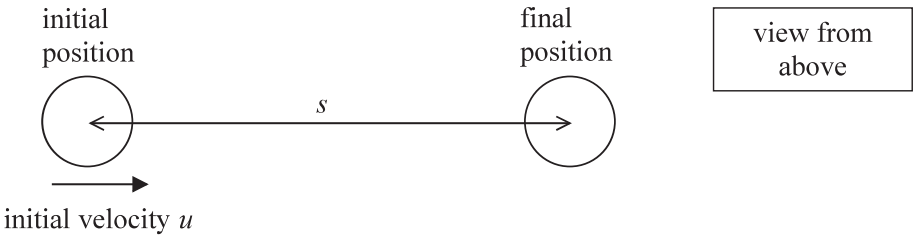
(2)

Mass of pendulum bob = ...

(Total for Question 8 = 11 marks)

14 A student carried out an experiment with coins.

(a) She gave a 2p coin a sharp tap, so that it slid along a horizontal surface and came to rest as shown.



The student recorded the distance s moved by the coin.

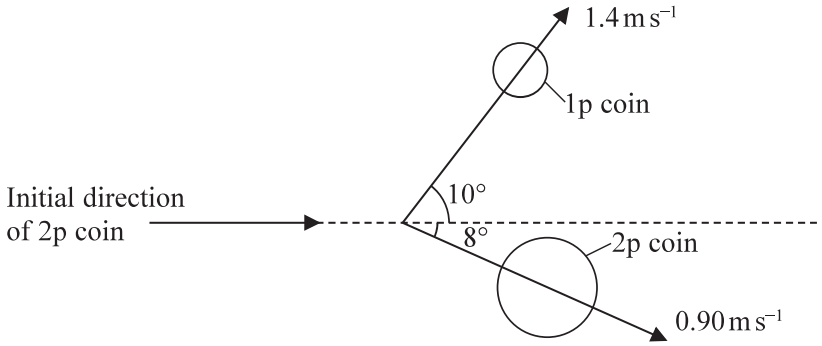
She then replaced the 2p coin with a 1p coin and repeated the process.

The student read that the frictional force between an object and a surface is directly proportional to the mass of the object. She suggested that, in her experiment, u is directly proportional to $\sqrt{s}$ and is independent of the mass of the coin.

Discuss the validity of this suggestion.

(6)

(b) She arranged a collision between a 2p coin and a stationary 1p coin. She noted the directions in which the coins moved after the collision and determined their velocities.



(i) Show that the velocity of the 2p coin just before the collision was about 2 m s^{-1}.

mass of 2p coin = 7.1 g

mass of 1p coin = 3.6 g

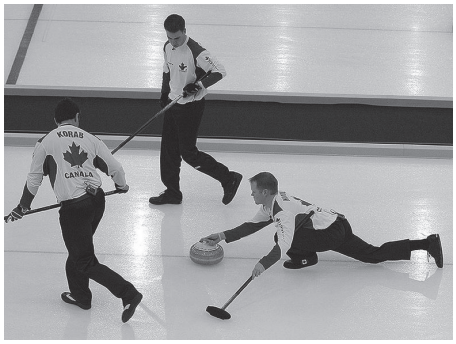
(4)

(ii) Show that the collision was inelastic.

(2)

(Total for Question 14 = 12 marks)

8 In the sport of curling, two teams of 'curlers' take turns sliding polished granite stones across an ice surface towards a circular target marked on the ice.



commons.wikimedia.org

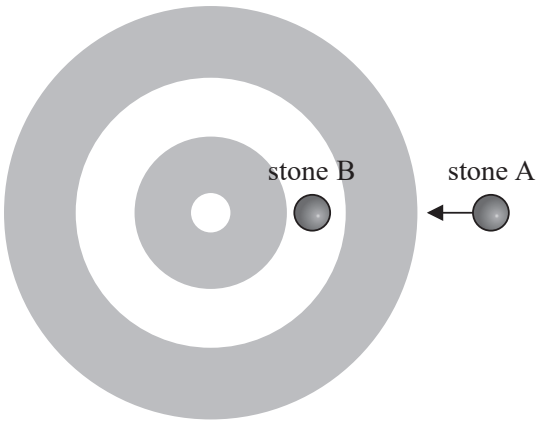
(a) A stone of mass 19.6 kg is accelerated uniformly for 1.25 s before being released by a curler. The stone then decelerates uniformly to rest, travelling 32.5 m in a time of 17.5 s.

Calculate the average useful power developed by the curler in accelerating the stone.

(4)

Average power = ...

*(b) Stone B is stationary. Stone A travels towards the target and makes a direct hit on stone B as shown. Both stones have mass m.



The collision is elastic. Just before the collision stone A has a velocity v. After the collision stone B moves off with velocity v.

Discuss how the relevant conservation laws apply to this collision.

(6)

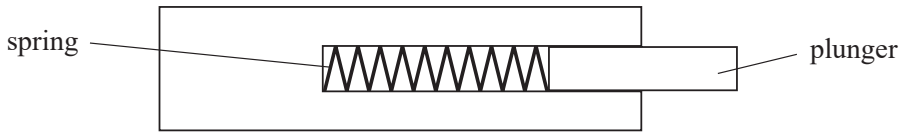
(c) While a stone is moving towards the target, the curlers vigorously sweep the ice directly in front of the stone.

Explain why this may make the stone travel further.

(2)

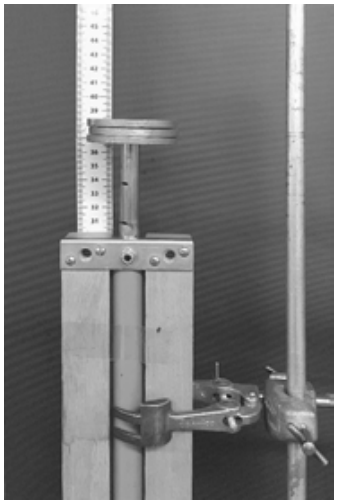
(Total for Question 8 = 12 marks)

16 A school dynamics trolley has a plunger attached to a spring. When the plunger is pushed in, the spring is compressed. When the plunger is released, it is pushed back out by the spring.



(a) A student investigated the spring to determine whether it obeys Hooke's law in compression.

The trolley was placed vertically in front of a scale and weights were added in turn to the top of the plunger, as shown. The position of the end of the plunger was recorded each time.



The recorded results are shown in the table.

Weight / N	Position of plunger / cm	
0.00	37.3	
2.00	37.0	
4.00	36.6	
6.00	36.2	
8.00	35.9	
10.00	35.5	

(i) Use the results to plot a graph of weight against compression. You may use the additional column for your processed data.

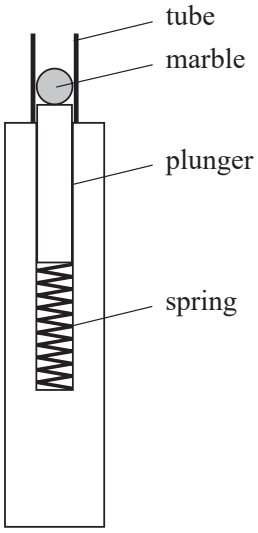
(5)

(ii) The student concluded that the spring obeys Hooke's law with a spring constant of about 600 $N\,m^{-1}$.

Determine whether the student's conclusion is justified.

(4)

(b) Another trolley was adapted by placing a tube around the plunger so that it could be used to launch marbles. A marble was placed in the tube while the plunger was depressed. When the plunger was released it launched the marble.



Determine the maximum possible launch velocity of the marble when the spring is compressed by 5.4 cm.

spring constant = 610 N m^{-1}

mass of marble = 4.1 g

mass of plunger = 35.4 g

(4)

Maximum launch velocity = ...

(c) The launch velocity was measured using a light gate and data logger. This produced a smaller value for the launch velocity than that calculated in (b).

Give a reason why this method produced a smaller value for the launch velocity.

(1)

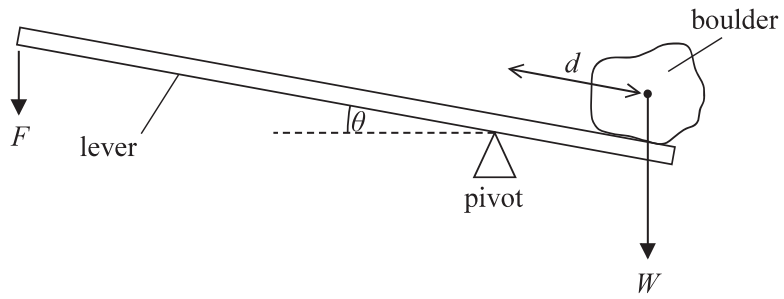
(Total for Question 16 = 14 marks)

SUB-TOPIC 2.8

MOMENTS AND EQUILIBRIUM

Sub-topic 2.8 · 18 questions · 122 marks · lowest tariff first

2 A person uses a pivoted lever to lift a boulder of weight W as shown.



The centre of gravity of the boulder is a distance d from the pivot. The angle of the lever to the horizontal is θ.

Which expression is equal to the moment of W about the pivot?

☒ **A** Wd

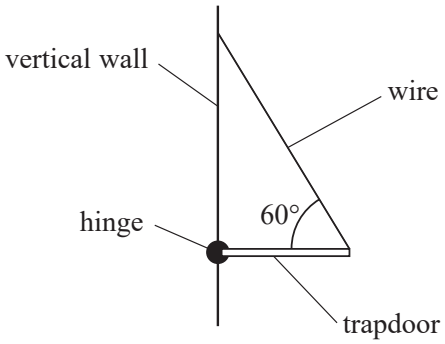
☒ **B** $Wd\cos\theta$

☒ **C** $Wd\sin\theta$

☒ **D** $Wd\tan\theta$

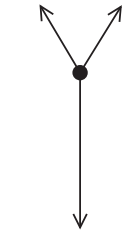
(Total for Question 2 = 1 mark)

6 A trapdoor is fixed to a vertical wall with a hinge. A wire is attached to the other end of the trapdoor and inclined at an angle of 60°, as shown. The wire holds the trapdoor horizontal.

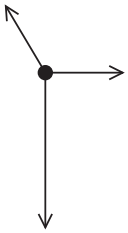


Which of the following shows the free-body force diagram for the trapdoor?

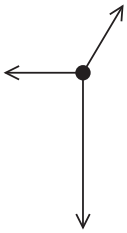
A



B



C



D

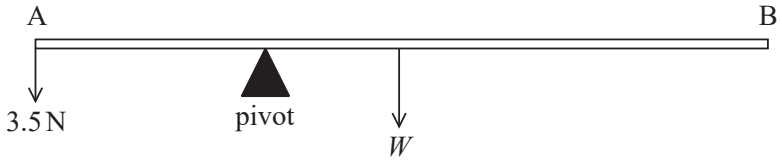


- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 6 = 1 mark)

9 A uniform rigid rod AB of length 1.50 m has a weight W of 6.5 N. A force of 3.5 N applied at A balances the rod on a pivot as shown.

Diagram not to scale



Calculate the distance of the pivot from A when the rod is in equilibrium.

(2)

.....

.....

.....

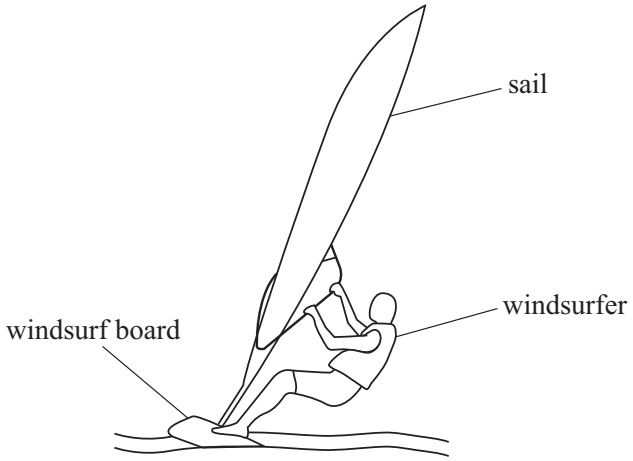
.....

.....

Distance of pivot from A = ...

(Total for Question 9 = 2 marks)

9 A windsurfer stands on a windsurf board and holds onto the sail, as shown.



As the force from the wind increases, the windsurfer leans back further.

Explain how leaning back further keeps the windsurfer in equilibrium. Your explanation should make reference to moments.

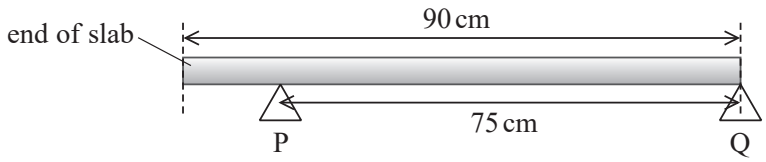
(Total for Question 9 = 3 marks)

11 A uniform paving slab is to be used as a garden step.

(a) State what is meant by the centre of gravity of an extended body.

(1)

(b) The paving slab has a weight of 310 N and a length of 90 cm and will be supported at two points, P and Q, as shown. The distance between P and Q will be 75 cm.



This might be unsafe because a person who places all their weight at the end of the slab might tip the slab.

A person of mass 70 kg stands at the end of the slab.

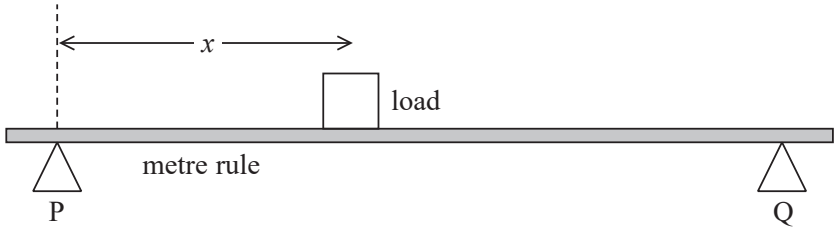
Deduce whether the slab will tip.

(4)

(Total for Question 11 = 5 marks)

16 A student investigated how the supporting forces on a bridge vary as traffic moves across the bridge.

The student made a simple model of a bridge using a metre rule. The metre rule rested on two supports, P and Q, as shown.



The upward force on the metre rule at P was F_P. The upward force on the metre rule at Q was F_Q.

A load was placed on the metre rule a distance x from support P. Forces F_P and F_Q were measured for different values of x.

Explain how F_P and F_Q changed as x was increased.

(Total for Question 16 = 5 marks)

11 A film involves a gang of bank robbers making a getaway on a bus loaded with gold bars. The bus spins out of control and ends up balancing on the edge of a cliff, as shown.



(Source: © maforche/Shutterstock)

(a) State what is meant by the moment of a force about a point.

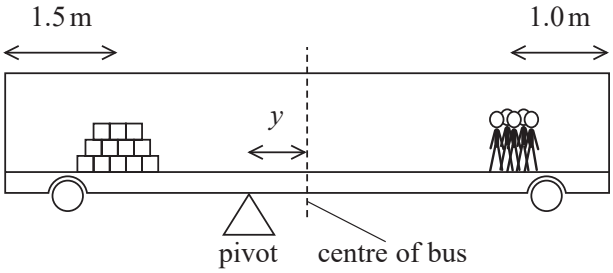
(1)

.....

.....

(b) The bus is balanced on a pivot that is a distance y from the centre of the bus.

The centre of mass of the gold is 1.5 m from one end of the bus. The centre of mass of the bank robbers is 1.0 m from the other end of the bus, as shown.



The unloaded bus can be treated as a uniform body with a weight of 32 000 N.

Calculate the distance y when the bus is balanced.

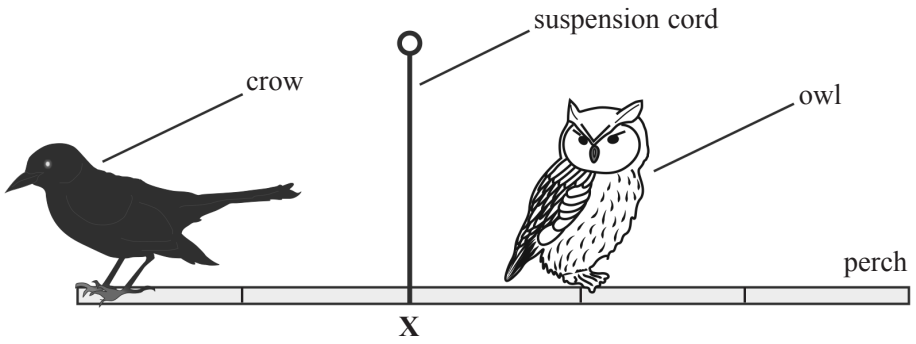
length of bus = 11.0 m
weight of gold bars = 31 000 N
weight of bank robbers = 8700 N

(4)

y = ...

(Total for Question 11 = 5 marks)

10 In a 'balancing birds' puzzle, model owls and crows are each placed in one of six equally spaced positions marked on a perch. The perch has negligible mass, and is suspended from another of the six marked positions. With the birds placed, and the perch suspended, as shown, the puzzle is in equilibrium.



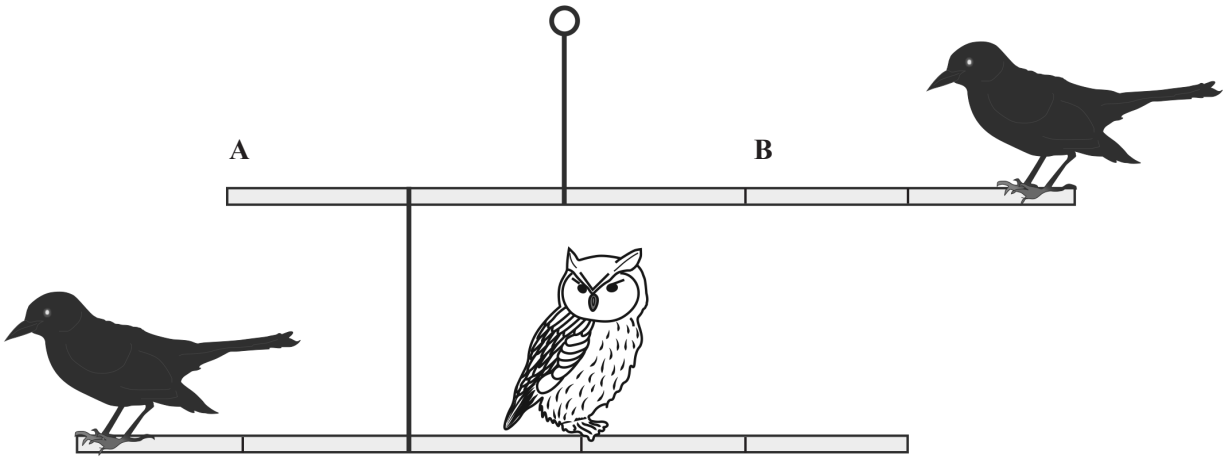
(a) State what is meant by 'in equilibrium'.

(2)

(b) (i) The owl has a mass $2M$ and the crow has a mass M. Show that the perch will balance when suspended as shown from position X.

(1)

(ii) The perch is then attached to a second perch and suspended as shown. Two more birds, not shown, are placed at A and B, and the whole arrangement is in equilibrium. Each crow has the same mass M. The mass of an owl is $2M$.



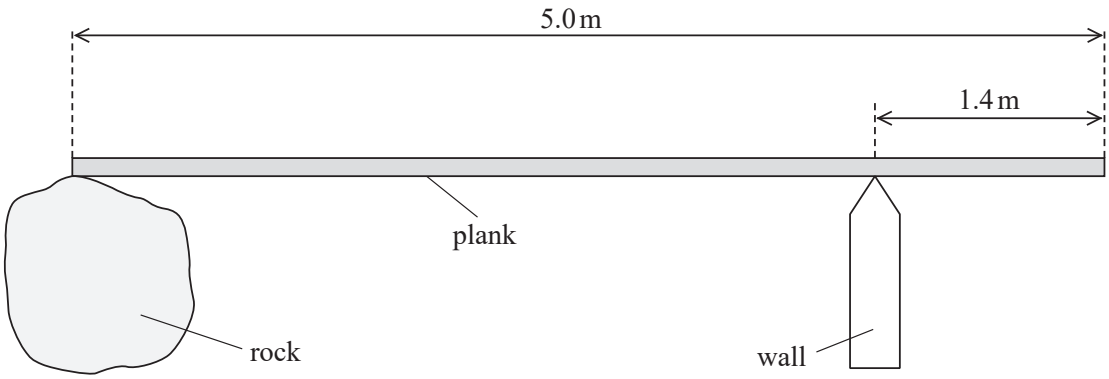
Explain, with the aid of a calculation, which type of bird sits at A and which type of bird sits at B to ensure the whole arrangement is in equilibrium.

(3)

(Total for Question 10 = 6 marks)

13 Some students used a plank to make a bridge to cross a stream. The plank rested on a rock and a wall as shown.

Assume the plank is uniform.



(a) (i) Show that the weight of the plank is about 250 N.

mass of plank = 25 kg

(1)

.....

.....

(ii) Determine the force exerted by the wall on the plank.

(3)

.....

.....

.....

.....

.....

Force exerted by wall on plank = ...

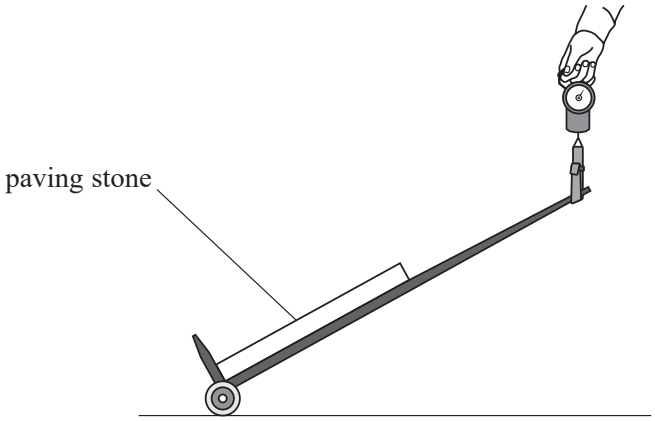
(b) A student of weight 550 N states that the plank will tip if she walks from the rock to the other end of the plank.

Justify the student's statement.

(3)

(Total for Question 13 = 7 marks)

13 A gardener used a trolley to move a paving stone.



A force meter was attached to the handle of the trolley.

The gardener recorded the following measurements when the trolley was at rest in the position shown in the diagram.

mass of trolley and paving stone = 18.5 kg

length of trolley = 97 cm

force on handle = 50 N

(a) Determine the distance of the centre of gravity of the loaded trolley from the wheels.

(3)

.....

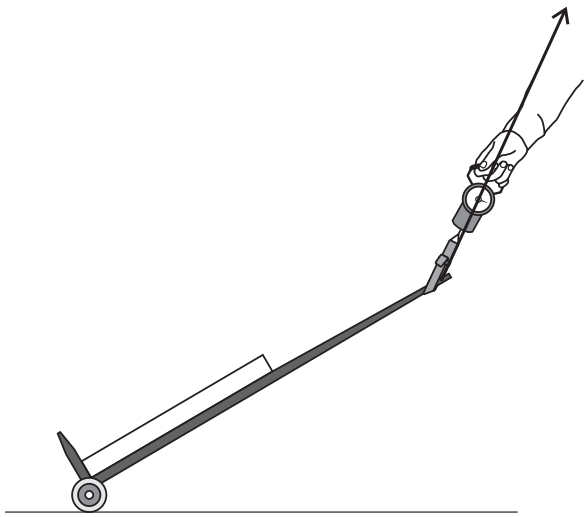
.....

.....

.....

Distance = ...

(b) The gardener then pulled the trolley and measured the applied force while the trolley was moving.



The direction of the applied force is 25° to the vertical, as shown by the arrow.

(i) Calculate the magnitude of the applied force.

Assume the magnitude of the vertical component of the force remains at 50 N.

(2)

Magnitude of applied force = ...

(ii) The gardener continues to walk and pulls the trolley a distance of 15 m in a time of 4.2 s.

Calculate the power developed while pulling the trolley.

(3)

Power = ...

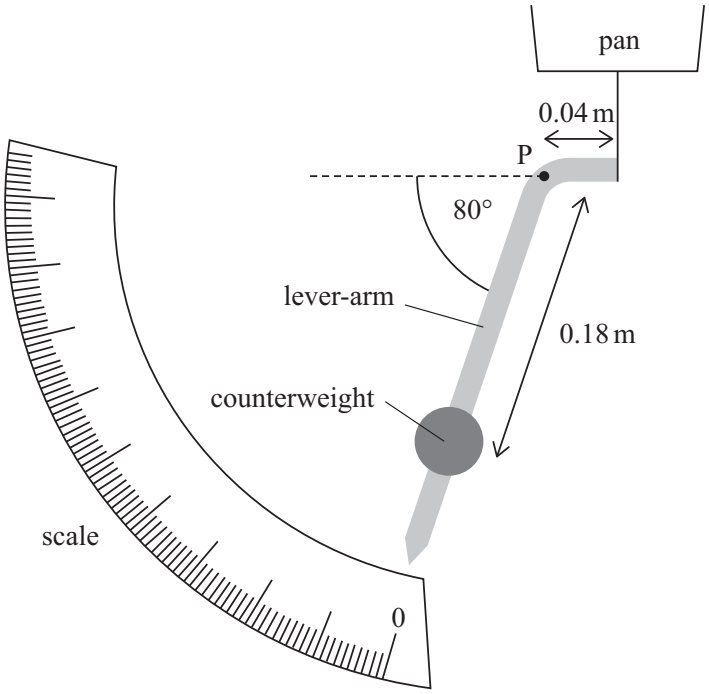
(Total for Question 13 = 8 marks)

12 The photograph shows a lever-arm balance. The balance can be used to measure the mass of objects to the nearest gram.



(Source: © sasaperic/Getty Images)

The lever-arm is a length of metal, bent at one end as shown in the diagram below. The lever-arm can rotate around the pivot, P.



The arrangement is in equilibrium.

(a) State the two conditions needed for the arrangement to be in equilibrium.

(2)

.....

.....

.....

.....

(b) Determine the weight of the counterweight.

Assume the mass of the lever-arm is negligible.

mass of pan = 260 g

(4)

Weight of counterweight = ...

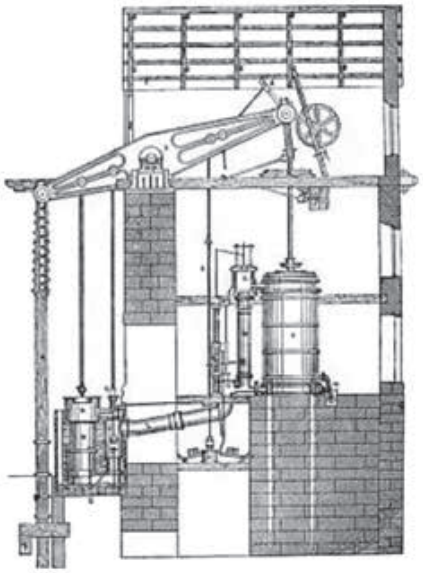
(c) An object is placed in the pan. The lever-arm moves along the scale.

Explain why the lever-arm pointer moves through a large distance whilst the pan moves a much shorter distance.

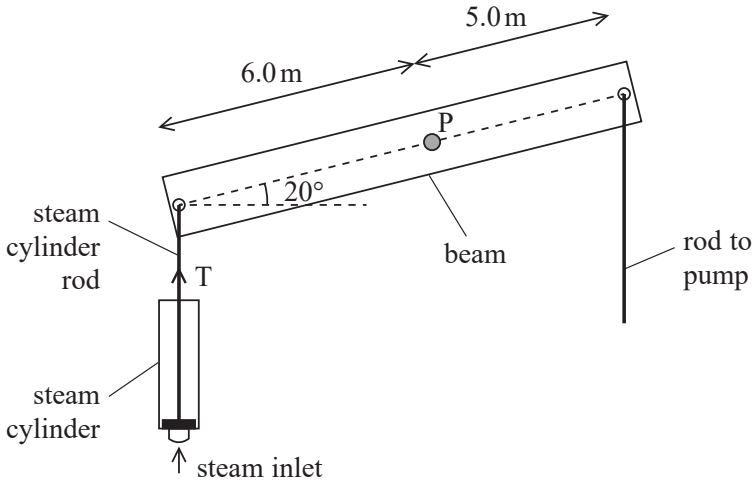
(2)

(Total for Question 12 = 8 marks)

13 Beam engines contributed to powering the Industrial Revolution in Britain in the 18th century. A beam engine consisted of a beam which could rock to and fro around a well-oiled pivot. Attached to the beam there are two rods, one connected to a piston in a steam cylinder and the other connected to a pump.



The diagram below shows a simplified arrangement of a beam engine.



(a) The beam has a constant thickness and a mass of 3.05×10^4 kg. The length of the beam is 11.0 m. The pivot P is positioned 6.0 m from the steam cylinder end of the beam.

In its resting position the steam cylinder rod is supported by the base of the steam cylinder with the beam at an angle of 20° to the horizontal.

The steam cylinder rod exerts a force T on the beam. The force exerted on the beam by the pump rod can be neglected.

Calculate the force T.

(4)

$T =$ .....

(b) The engine, which ran continuously, could lift a mass of 2500 kg of water through 12 m each minute.
The engine used 1250 kg of coal a day. 1 kg of coal can release 22.3 MJ of energy.
The beam engine was said to have an efficiency of 10 %.

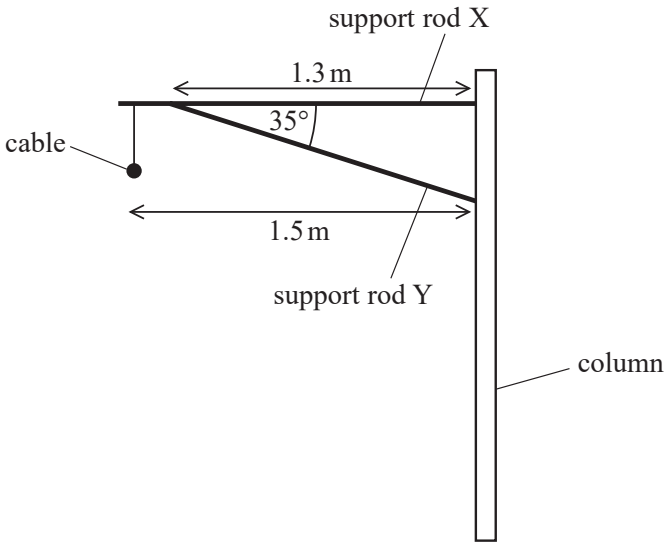
Deduce whether this claim for efficiency was correct.

(5)

(Total for Question 13 = 9 marks)

14 Overhead electricity cables for railway lines are supported by structures like the one shown.

An electric cable of mass 45 kg is suspended from a support rod X. A second support rod Y is attached to X. X and Y are attached at one end to a column.



Not to scale

The masses of support rods X and Y are negligible.

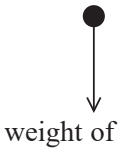
(a) (i) Determine, by taking moments, the force exerted on rod X by rod Y.

(4)

Force = ...

(ii) Complete the free-body force diagram for support rod X.

(2)



(b) A website gives a value of the electric field strength E, at two distances from the electric cable.

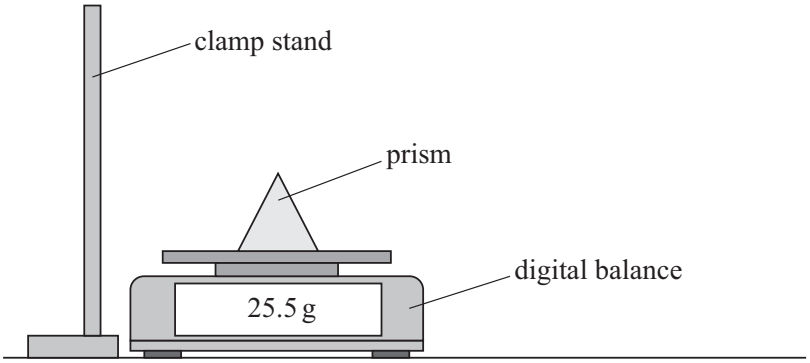
Distance / m	E / N C^{-1}
3	1200
25	100

Deduce whether these data are consistent with an inverse square law.

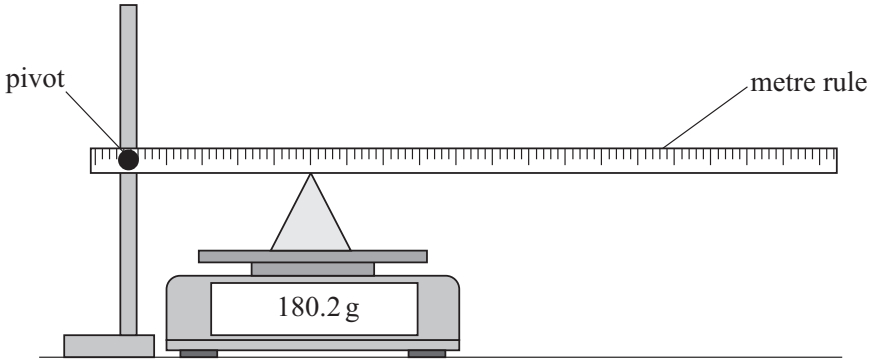
(3)

(Total for Question 14 = 9 marks)

3 A student uses a digital balance. She sets the balance to zero and then places a prism on the balance, as shown.



A uniform metre rule is pivoted at its 5.0 cm mark. The metre rule is then supported horizontally at the 30.0 cm mark by the prism, as shown below.



(a) (i) The metre rule is in equilibrium.

Explain why the increase in mass recorded by the balance is not equal to the mass of the metre rule.

(2)

.....

.....

.....

.....

.....

(ii) Calculate the weight of the metre rule. You should take moments about the pivot.

(4)

Weight of metre rule = ...

(b) The student wants to reduce the percentage uncertainty in the value obtained for the weight of the metre rule.

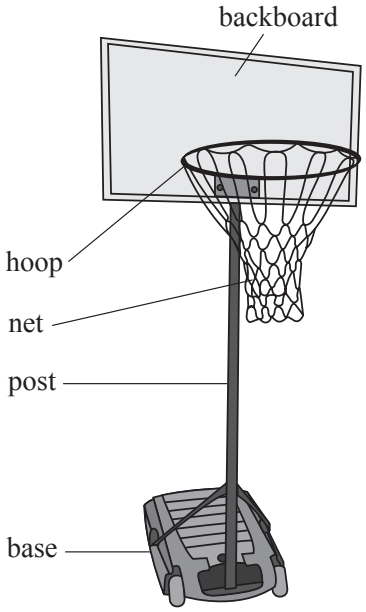
The student repeated her determination of the weight of the metre rule. She moved the prism towards the centre of gravity of the metre rule before taking moments about the pivot.

Deduce whether the percentage uncertainty in the value obtained for the weight of the metre rule is reduced by the student moving the prism. No calculations are required.

(3)

(Total for Question 3 = 9 marks)

11 A portable basketball set has a base and a post arrangement. The post arrangement consists of a post, backboard, hoop and net. The base can be filled with water to increase stability.



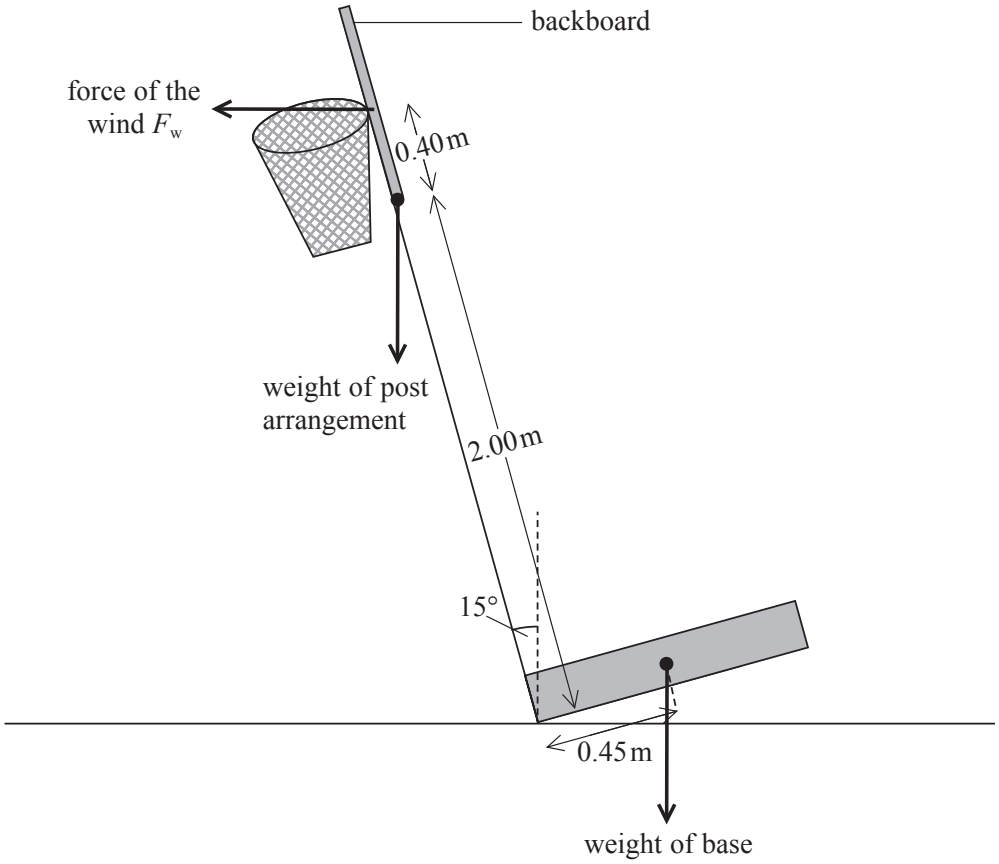
(a) The base has a capacity of 85.0 litres.

Show that the maximum weight of the base is about 870 N.

mass of 1.00 litre of water = 1.00 kg
mass of base when empty = 3.50 kg

(2)

(b) Due to the large area of the backboard, the basketball set may topple over when the wind blows.



Calculate the minimum force of the wind F_w that will cause the basketball set to be blown over when it is at the angle shown. Ignore the effect of the wind on the base.

weight of post arrangement = 27.0 N

(5)

Minimum force of the wind F_w = ...

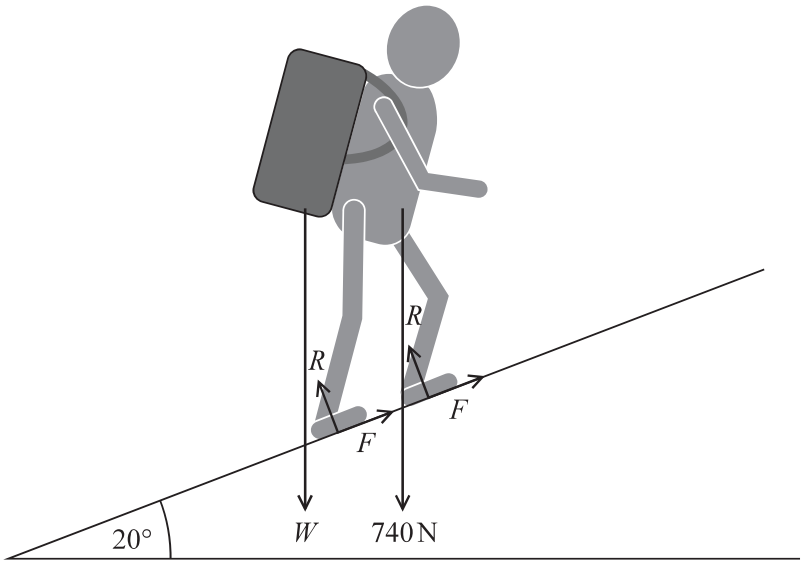
(c) The base is filled with sand instead of water. The density of sand is greater than the density of water.

State and justify what would happen to the value of F_w calculated in part (b).

(3)

(Total for Question 11 = 10 marks)

13 A hiker of weight 740 N walks up a hill carrying a large bag of weight W. The hiker stops for a moment in the position shown.



The normal force R of the ground on the hiker is the same at each foot. The frictional force between each foot and the ground is F. The hill is at an incline of 20° to the horizontal.

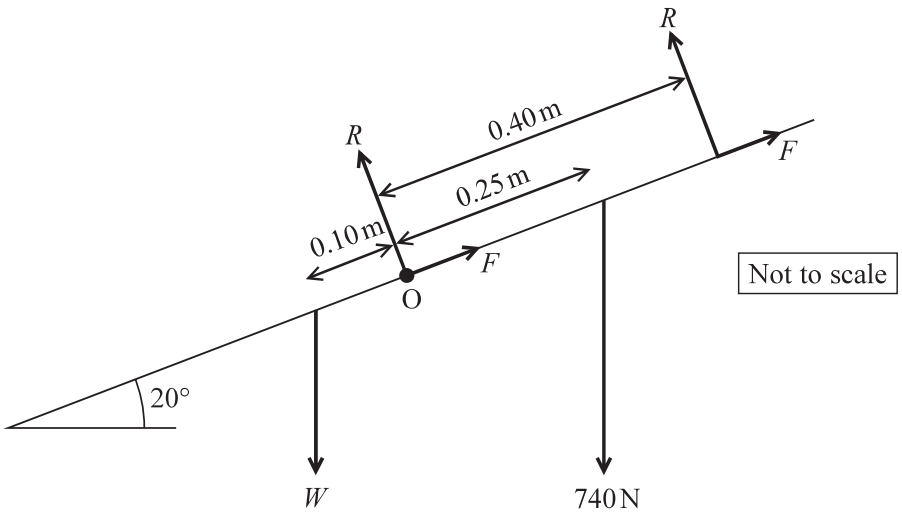
(a) An expression for the components of force perpendicular to the ground acting on the hiker is

$$740\cos 20 + W\cos 20 - 2R = 0$$

(i) Explain why this expression is correct.

(2)

(ii) The diagram shows the lines of action of the forces acting on the hiker and backpack. Position O represents the middle of the back foot of the hiker.



Determine W. You should take moments about O.

(6)

$W =$ .....

(b) The hiker repacks his bag, placing the heavier items at the bottom of the bag.

Explain why this may cause R on the front foot to decrease.

(2)

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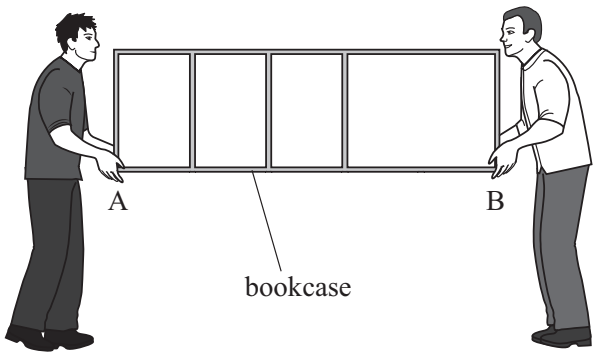
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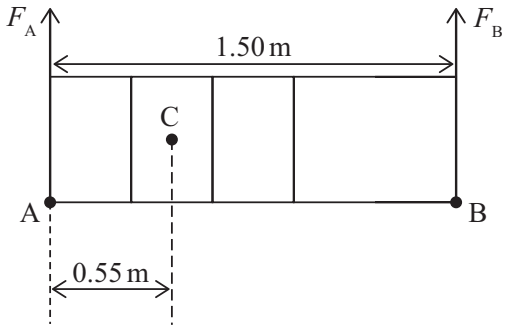
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(Total for Question 13 = 10 marks)

12 Two people are carrying a bookcase. They are holding the bookcase at points A and B, as shown.



(a) The length of the bookcase is 1.50 m. The centre of gravity C of the bookcase is 0.55 m from one end. The people exert forces F_A and F_B on the bookcase at points A and B, as shown below.



Calculate F_A and F_B.

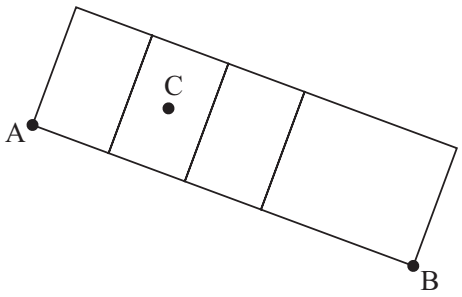
mass of bookcase = 25 kg

(5)

F_A = ...

F_B = ...

(b) The two people now support the bookcase so that it is tilted with point A higher than point B, as shown. The bookcase is stationary and the forces exerted at points A and B are still vertical.

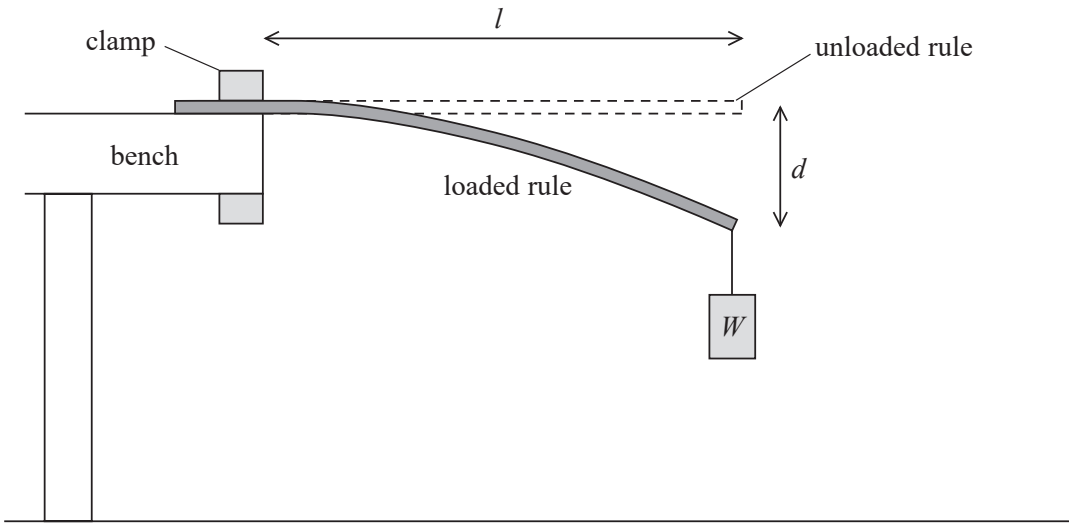


Explain how the magnitude of the forces exerted at points A and B change. You should consider moments about point A.

(5)

(Total for Question 12 = 10 marks)

17 The diagram shows a wooden metre rule which is clamped horizontally to a bench. The other end of the rule is loaded with a weight W. The length l of the metre rule between the clamp and W can be varied. The loaded end of the rule is displaced through a vertical distance d as shown.



A student investigated how d varied with l.

(a) Describe how the student should use set squares and a second metre rule to determine d. You may add to the diagram.

(2)

(b) The student used the following equation for the relationship between the deflection d and the length l.

$$d = \frac{4Wl^3}{Ebt^3}$$

E is the Young modulus of the wood, b is the width of the rule and t is the thickness of the rule.

(i) The student measured t several times and calculated its mean value $\bar{t}$.

t / mm				$\bar{t}$ / mm
6.25	6.27	6.29	6.24	6.26

Calculate the percentage uncertainty in the thickness of the rule.

(2)

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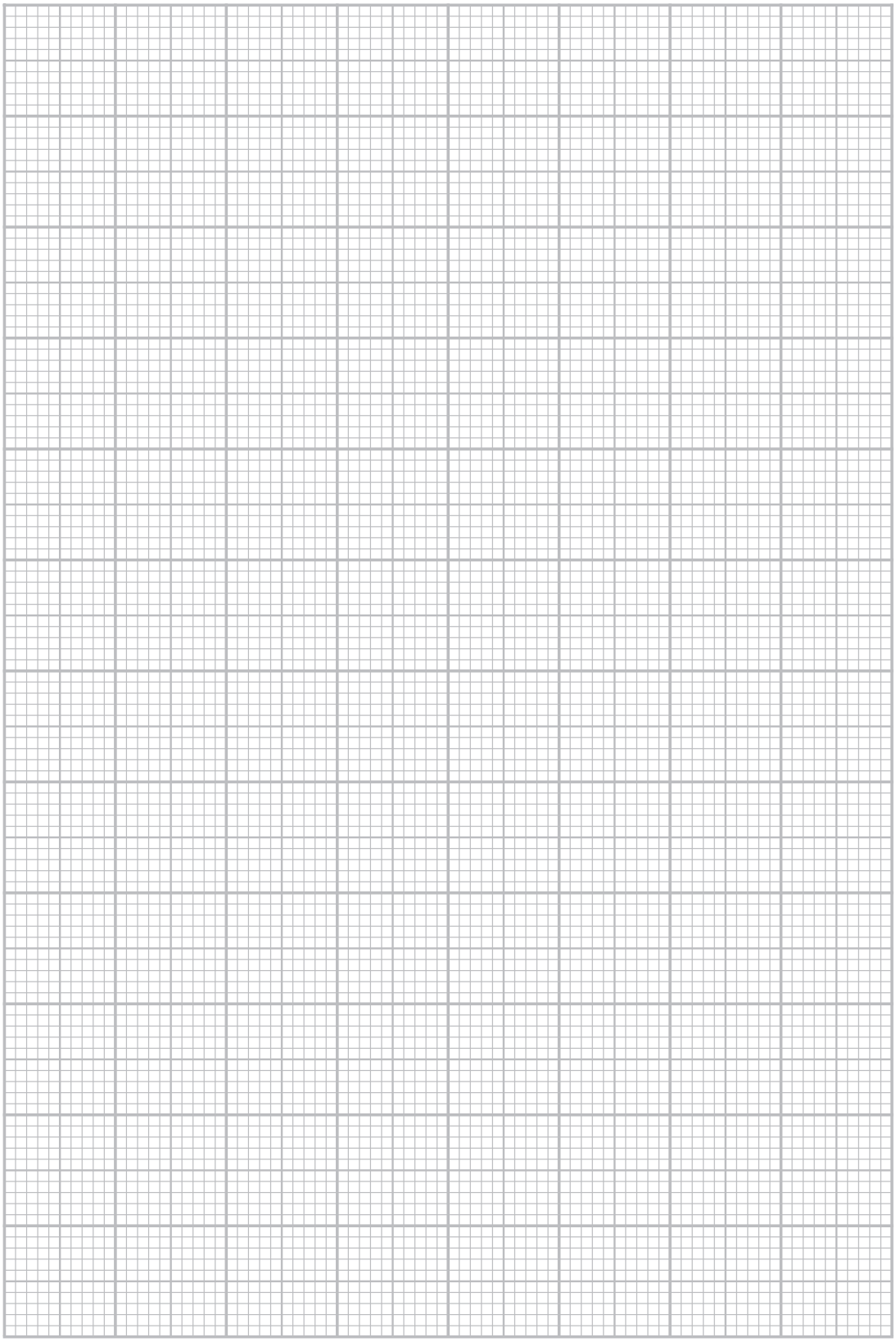
Percentage uncertainty = ...

(ii) The student's results are shown in the table.

l / m	d / mm	
0.300	6	
0.400	18	
0.500	39	
0.600	68	
0.700	107	
0.800	166	

Plot a graph of d on the y-axis against l^3 on the x-axis on the grid opposite.
Use the additional column of the table for your processed data.

(5)



(iii) The table gives the value of E for several types of wood.

Wood type	E / GPa
Pine	6.9
Douglas fir	9.7
Spruce	11.1
Birch	13.9

Deduce the type of wood from which the rule was made.

$W = 5.6\,\text{N}$
$b = 3.02\,\text{cm}$
$t = 6.26\,\text{mm}$

(5)

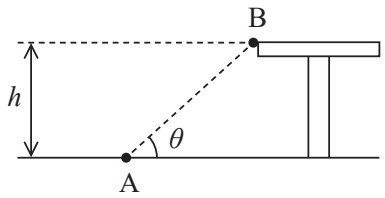
(Total for Question 17 = 14 marks)

SUB-TOPIC 2.9

WORK, ENERGY AND POWER

Sub-topic 2.9 · 31 questions · 199 marks · lowest tariff first

4 An object of mass m is moved from point A on the ground, to point B on a bench of height h as shown in the diagram.



Which of the following is a correct expression for the work done on the object?

☒ **A** $\frac{mgh}{\sin\theta}$

☒ **B** $\frac{mgh}{\cos\theta}$

☒ **C** mgh

☒ **D** $mgh\sin\theta$

(Total for Question 4 = 1 mark)

6 A car of mass 1.2×10^3 kg is travelling at a speed of $18\,m\,s^{-1}$. The driver applies the brakes and the car comes to rest.

What is the work done by the brakes in stopping the car?

☒ **A** 11 kJ

☒ **B** 22 kJ

☒ **C** 190 kJ

☒ **D** 390 kJ

(Total for Question 6 = 1 mark)

2 A student measured the mass, in grams, of a small projectile, and its velocity in kilometres per hour.

To calculate the kinetic energy E_k of the projectile he substituted these quantities into the equation $E_k = ½ mv^2$.

Which of the following should the student multiply the answer by to obtain an answer in joules?

☒ **A** $\frac{1000}{3600^2}$

☒ **B** $\left(\frac{1000}{3600}\right)^2$

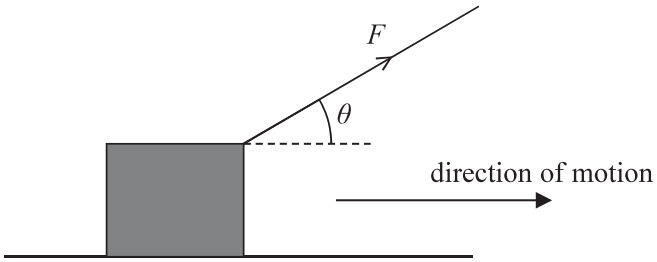
☒ **C** $\frac{3600^2}{1000}$

☒ **D** $\left(\frac{3600}{1000}\right)^2$

(Total for Question 2 = 1 mark)

8 A rope is used to pull a box a distance d along a horizontal surface at a constant speed.

A force F is applied to the rope and the rope is at an angle θ to the horizontal.



Which of the following could be used to determine the work done on the box?

☒ **A** $\frac{Fd}{\cos\theta}$

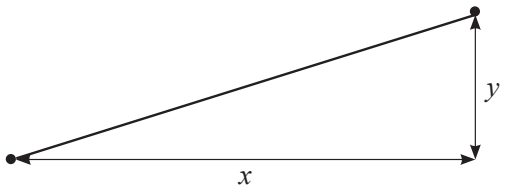
☒ **B** $Fd\cos\theta$

☒ **C** $\frac{Fd}{\sin\theta}$

☒ **D** $Fd\sin\theta$

(Total for Question 8 = 1 mark)

2 An object of mass m is moved from the bottom to the top of a slope. The vertical height of the slope is y.
The horizontal distance between the bottom and top of the slope is x.



Which of the following gives the gain of gravitational potential energy of the object as it moves from the bottom to the top of the slope?

☒ **A** mgx

☒ **B** mgy

☒ **C** $mg(x + y)$

☒ **D** $mg\sqrt{(x^2 + y^2)}$

(Total for Question 2 = 1 mark)

3 A car of mass 1.5×10^3 kg is travelling at a speed of 25 $m\,s^{-1}$. The driver applies the brakes and the car comes to rest.

Which of the following gives the decrease in kinetic energy, in joules, as the car is brought to rest?

☒ **A** $750 \times (25)^2$

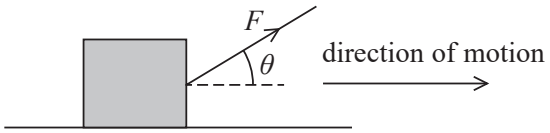
☒ **B** $750 \times \left(\frac{25}{2}\right)^2$

☒ **C** $1500 \times (25)^2$

☒ **D** $1500 \times \left(\frac{25}{2}\right)^2$

(Total for Question 3 = 1 mark)

4 A rope is used to apply a force F to a box as shown. The box is pulled a distance d along a horizontal surface.



Which of the following could be used to determine the work done on the box?

☒ **A** $Fd \sin\theta$

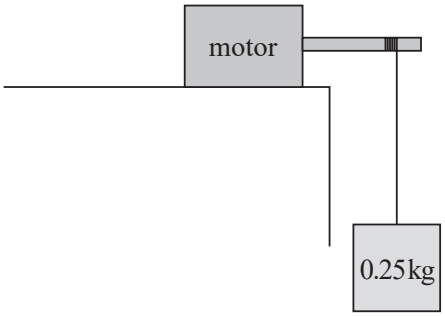
☒ **B** $\dfrac{Fd}{\sin\theta}$

☒ **C** $Fd \cos\theta$

☒ **D** $\dfrac{Fd}{\cos\theta}$

(Total for Question 4 = 1 mark)

8 A motor is used to lift an object as shown. The object is raised through a vertical height of 75 cm at a constant speed of $0.40\,m\,s^{-1}$.



Which of the following gives the rate of increase of potential energy of the object in watts?

☒ **A** $0.25 \times 9.81 \times 0.40$

☒ **B** 0.25×0.75

☒ **C** $0.25 \times 9.81 \times 0.75$

☒ **D** $0.5 \times 0.25 \times (0.40)^2$

(Total for Question 8 = 1 mark)

8 A power station provides electrical power at a mean rate of 3500 MW.

Which of the following gives the best estimate of the energy provided to consumers over a period of a year?

1 year = 3.2×10^7 s

- ☒ **A** 1×10^6 J
- ☒ **B** 1×10^{11} J
- ☒ **C** 1×10^{13} J
- ☒ **D** 1×10^{17} J

(Total for Question 8 = 1 mark)

6 In a boiler, energy is transferred to water at a rate of 40 kW. The corresponding power loss from the boiler to the surroundings is 4.0 kW.

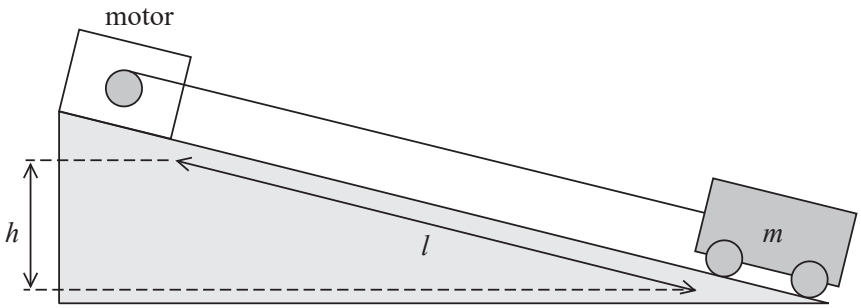
Which of the following is the efficiency of this boiler?

- ☒ **A** 0.10
- ☒ **B** 0.11
- ☒ **C** 0.90
- ☒ **D** 0.91

(Total for Question 6 = 1 mark)

6 The diagram shows an electric motor pulling a truck of mass m along a slope. The truck moves through a vertical height h and a distance l along the slope, during a time t.

There is a potential difference V across the motor and a current I in the motor.



Which of the following expressions gives the efficiency of the motor?

☒ **A** $\frac{VIt}{mgl}$

☒ **B** $\frac{VIt}{mgh}$

☒ **C** $\frac{mgl}{VIt}$

☒ **D** $\frac{mgh}{VIt}$

(Total for Question 6 = 1 mark)

3 A toy car moves up a slope at a constant speed, as shown. The car is moved by a motor with a power output of 5.2 W. The car gains a gravitational potential energy of 0.40 J in a time of 1.1 s.



Which of the following expressions gives the work done, in J, against resistive forces?

☒ **A** $5.2 - (0.40 \times 1.1)$

☒ **B** $(5.2 \times 1.1) - 0.40$

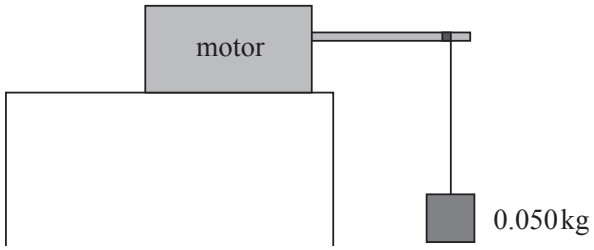
☒ **C** $(5.2 \div 1.1) + 0.40$

☒ **D** $(5.2 \times 1.1) + 0.40$

(Total for Question 3 = 1 mark)

9 A motor lifts a block of mass 0.050 kg at a constant velocity of 0.40 m s^{-1}.

The current in the motor is 85 mA and the potential difference across it is 3.0 V.



Calculate the efficiency of the motor.

(3)

Efficiency of the motor = ...

(Total for Question 9 = 3 marks)

10 A person pushes a baby in a pram.

(a) The person pushes the pram with a constant force. The force is applied at an angle of 50° to the horizontal, as shown.



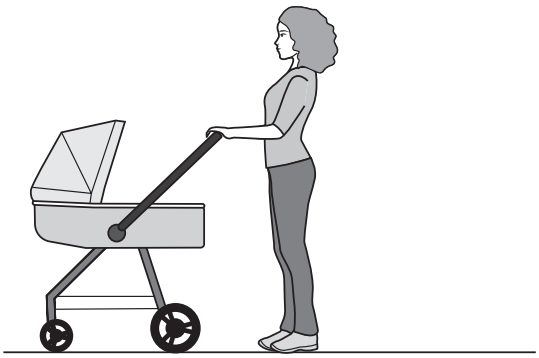
When a force of 35 N is applied, the pram moves at constant speed.

Calculate the work done to push the pram at constant speed for 500 m.

(3)

Work done = ...

(b) The pram is then moved along the same surface, at the same constant speed, by a different person. This person pushes the pram by applying a force horizontally, as shown.



Explain how applying a force horizontally changes the magnitude of the force needed to push the pram at the same constant speed.

(2)

.....

.....

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.....

(Total for Question 10 = 5 marks)

11 A student drives a go-kart up a slope.

(a) The slope is at an angle of 5.7° to the horizontal. The go-kart moves with a constant velocity of 2.8 m s^{-1}.

Calculate the power of the go-kart.

mass of go-kart and driver = 60 kg
resistive force on the go-kart = 18 N

(4)

Power = ...

(b) The go-kart is powered by a battery connected to a motor. The rate of thermal energy transfer by the wiring in the motor is 55 W.

Calculate the resistance of the wiring in the motor.

current in motor = 24 A

(2)

Resistance of the wiring in the motor = ...

(Total for Question 11 = 6 marks)

10 A coin is given a push and moves across a table.

(a) The coin moves 65 cm before coming to rest. There is a mean resistive force of 2.2×10^{-3} N on the coin as it moves.

Calculate the initial speed of the coin.

mass of coin = 8.5 g

(3)

Initial speed = ...

(b) The coin is pushed again, but with a larger force. The coin moves beyond the edge of the table and falls to the floor through a vertical height of 1.2 m.

The speed of the coin as it reaches the edge of the table is 0.40 m s^{-1}.

Calculate the horizontal distance travelled by the coin as it falls to the floor.

(3)

Horizontal distance travelled by coin = ...

(Total for Question 10 = 6 marks)

12 A student investigates how the efficiency of an electric motor being used to raise a load varies with the weight of the load.

The time taken for the motor to lift a load from the floor to the maximum height was measured using a stopwatch. The load was varied by adding weights, each marked '1.00 N'.

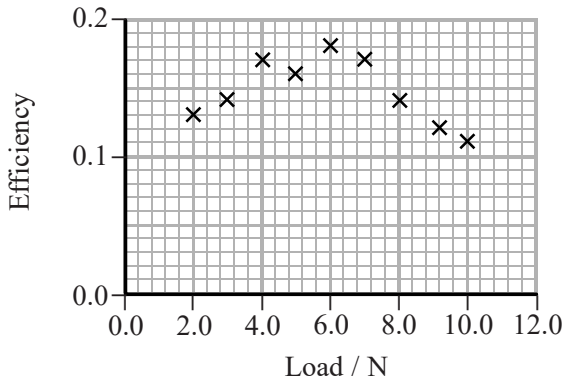
(a) The spreadsheet shows the student's results (columns A to E) and calculation (column F).

	A	B	C	D	E	F
1	load / N	current / A	potential difference / V	time / s	change in height / m	efficiency
2	2.00	1.8	4.6	1.52	0.825	0.13
3	3.00	1.9	4.4	2.05	0.825	0.14
4	4.00	2.1	4.3	2.19	0.825	0.17
5	5.00	2.3	5.1	2.26	0.825	0.16
6	6.00	2.5	4.5	2.48	0.825	0.18
7	7.00	3.1	5.2	2.17	0.825	0.17
8	8.00	3.7	4.8	2.68	0.825	0.14
9	9.00	3.9	4.8	3.36	0.825	0.12
10	10.00	4.2	4.7	3.72	0.825	0.11

Explain how the value in cell F4 has been determined using the results obtained.

(3)

(b) The student uses the spreadsheet to plot a graph.



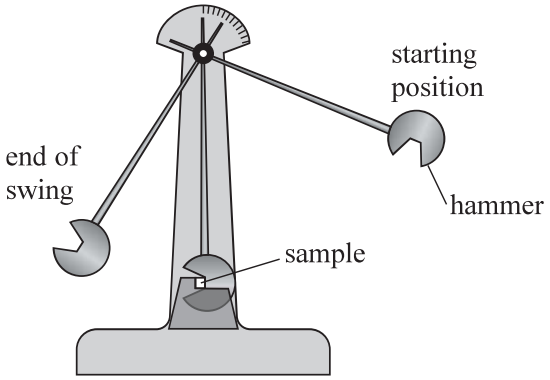
The student concludes that 'the efficiency of the motor increases with the weight of the load up to a maximum when the load is 6.00 N'.

Critcise the student's investigation and conclusion.

(5)

(Total for Question 12 = 8 marks)

15 Read the passage and answer the questions below.



(ref: Physics Review April 2015 p22)

The Charpy test is used by scientists to measure the fracture toughness of a material. A simple pendulum, with a hammer on the end, is held high and released so that it swings down and strikes the sample. The height from which the hammer is released is increased until the sample fractures. Some energy is absorbed by the sample in the impact but the hammer continues to move until it comes to rest at the top of its swing. Due to the law of conservation of energy the hammer will not swing up as high as its starting position. The difference in height between the start and end is proportional to the energy absorbed in the impact – the fracture toughness.

(a) "The difference in height between the start and end is proportional to the energy absorbed in the impact – the fracture toughness."

Justify this statement.

(2)

(b) The hammer is released from a height of 13.0 cm above the lowest point of the swing.

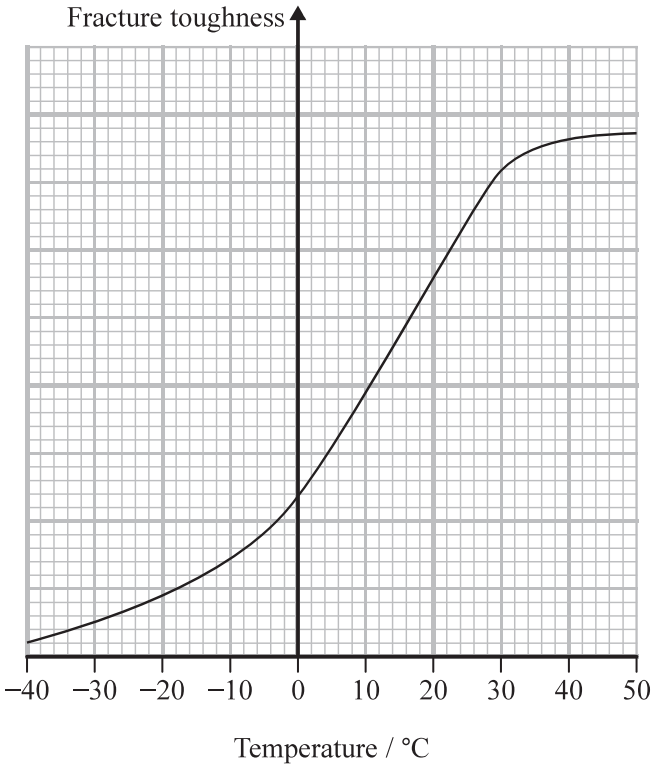
Calculate the momentum of the hammer when it strikes the sample.

mass of hammer = 31 kg

(3)

Momentum of hammer = ...

(c) The sketch graph shows how the fracture toughness of a sample of steel varies with temperature.



A material with a low fracture toughness can absorb less energy before fracture than a material with high fracture toughness.

The ship *Titanic* sank in 1912 following a collision with an iceberg in the icy waters of the Atlantic. The steel hull of the ship was fractured by the impact.

Deduce why the steel was likely to have been fractured by the impact.

(3)

(Total for Question 15 = 8 marks)

9 A vehicle that skids can leave a mark on the road surface. This skid mark can be used to calculate the velocity of the vehicle at the start of the skid.

At a test track a car of mass 1500 kg was collided into the back of a stationary car of mass 1200 kg. The two cars skidded along the road together, leaving skid marks of length 7.5 m. The cars decelerated at 5.6 m s^{-2} to a stop at the end of the skid.

(a) Show that the velocity of the two cars at the start of the skid was about 9 m s^{-1}.

(3)

(b) Calculate the velocity with which the car of mass 1500 kg collided with the stationary car.

(3)

Velocity = ...

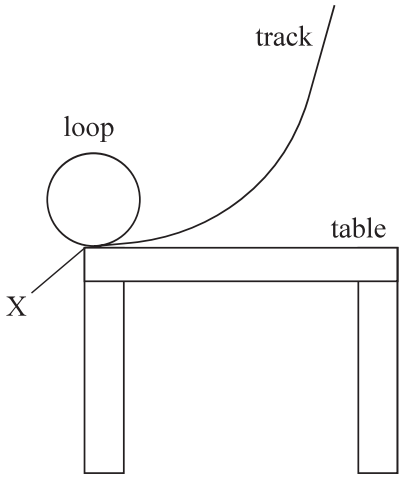
(c) In practice, the velocity of the car is not exactly the same as that calculated in (b).

Explain why.

(2)

(Total for Question 9 = 8 marks)

11 A track for toy cars can be built with a circular loop as shown.



A toy car is placed on the track at various heights. It travels around the loop before leaving the track horizontally at X.

(a) The loop has radius r and the mass of the toy car is m. It is possible for a toy car to complete the loop without losing contact with the inside of the track.

For this to occur the minimum speed of the toy car at the top of the loop v_{top} is given by

$$v_{top} = \sqrt{gr}$$

Explain why.

(2)

(b) The toy car just completes the loop without losing contact with the track.

Show that the speed of the toy car at the bottom of the loop is about $3\,m\,s^{-1}$.

$r = 0.15\,m$

(3)

(c) The toy car leaves the track at X with a horizontal velocity of $3.0\,m\,s^{-1}$.

X is 0.65 m above the floor.

Calculate the horizontal displacement of the car from X when it hits the floor.

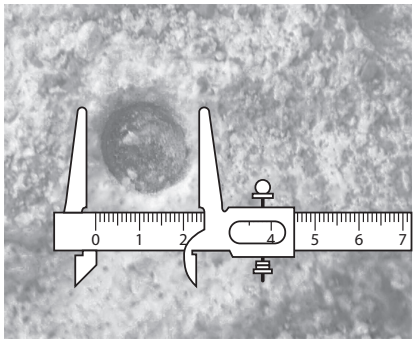
(4)

Horizontal displacement = ...

(Total for Question 11 = 9 marks)

12 Impact craters are formed when meteorites strike the surface of a planet. A student investigated some factors that might influence the formation of impact craters. He did this by dropping spheres of modelling clay into a tray of sand.

The diameter of the crater produced by each sphere was measured using vernier calipers as shown.



This process was repeated for spheres of different diameters.

(a) In one test, the spheres were dropped from the same height.

Determine the factor by which the kinetic energy of the sphere just before impact increases when the sphere diameter is increased from 2.0 cm to 4.0 cm.

(3)

Factor = ...

*(b) The student also dropped the spheres from different heights. His results are shown in the table.

Drop height / m	Sphere diameter / cm	Crater diameter / cm
0.30	2.0	3.6
	4.0	7.0
	6.0	6.8
0.60	2.0	4.8
	4.0	7.5
	6.0	7.3
0.90	2.0	5.6
	4.0	8.0
	6.0	8.3

The student wrote the following conclusion:

"The greater the drop height, the greater the diameter of the crater formed when a sphere hits the sand. This is because the impact velocity increases as the drop height is increased. As the speed of the sphere increases the diameter of the crater formed also increases. Also, the bigger the sphere the bigger the crater."

Assess the validity of the student's conclusion.

(6)

(Total for Question 12 = 9 marks)

17 Some sports place high stresses on the bones in the body, which can result in injury.

(a) A gymnast of mass 45 kg dismounts from a beam. Her centre of mass is displaced through 1.6 m vertically before her feet touch the ground.
As she lands, the bones in the lower part of her legs experience a force from the ground. The time between hitting the ground and coming to rest is 0.90 s.

(i) Calculate the mean force from the ground on the gymnast.

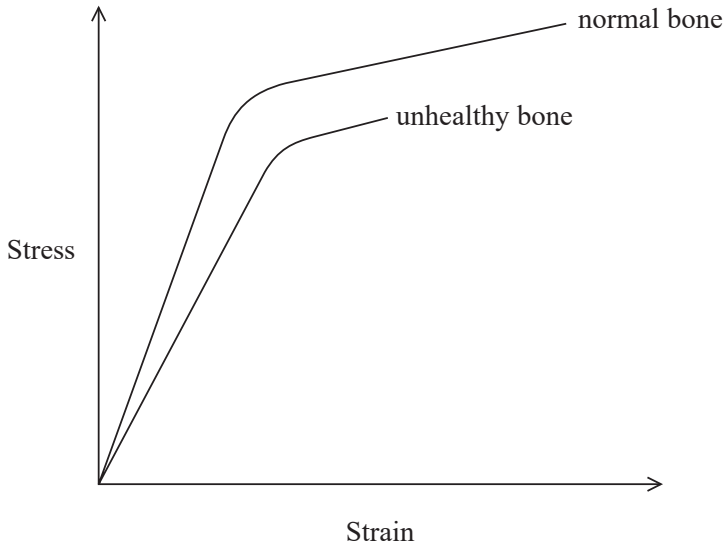
(4)

Mean force from the ground = ...

(ii) Explain how bending both knees when landing helps the gymnast prevent an injury.

(3)

(b) The graph shows how stress varies with strain for normal bone and for unhealthy bone.



Describe how the graph shows that unhealthy bone under stress is more likely to break than normal bone.

(3)

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(Total for Question 17 = 10 marks)

16 Read the extract and answer the questions that follow.

Gravitricity is developing a new technology to capture and store the excess power generated by renewable energy resources. A large load is suspended by cables in a disused mineshaft. During periods of low power demand, excess generated power is used to winch the load upwards. During periods of high demand, the load is lowered down the shaft, causing electricity to be generated. The system can produce electricity at low power for several hours, or a short burst of electricity at high power.

(Source based on: https://gravitricity.com/)

(a) One such system is planned to use a load of mass 2500 tonnes. The load will be at the top of a shaft. The load will be lowered down the shaft at a steady speed. A useful power output of 15 MW will be generated. The system will have an efficiency of 80%.

Calculate the speed of the load.

1 tonne = 1000 kg

(3)

Speed = ...

(b) The system can generate "a short burst of electricity at high power".

Explain why high power can be generated for only a short time.

(2)

(c) A load of 5.0×10^3 tonnes is held stationary by several vertical steel cables. The strain on the cables is 5.0×10^{-3}.

Calculate the total cross-sectional area of the cables holding the load.

Young modulus of steel = 180 GPa
1 tonne = 1.0×10^3 kg

(2)

Cross-sectional area = ...

(d) The speed of the load in the shaft will depend on the variation of the electricity supply and demand throughout the day.

Explain why the total area of the cables will need to be greater than that calculated in (c) to limit the strain to no more than 0.005

(3)

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(Total for Question 16 = 10 marks)

17 Read the following article and then answer the questions that follow.

"The fastest, tallest and longest dive coaster, on which amusement park thrill seekers can experience free fall, is set to open next summer at Cedar Point in Sandusky, Ohio. Valravn is designed to take riders up to a 66 m peak from which they plummet vertically with an acceleration *g* and feel weightless.

The advent of steel-frame roller coasters in 1959 made taller structures possible.

Whereas height remains one of the best ways to attain intense speeds, a coaster car can also be shot from its starting point via electromagnetic propulsion or a catapult. Cars on these launched coasters have the potential to go from zero to 130 km h^{-1} in two seconds.

Although coasters can definitely go faster, they're limited by the acceleration those higher speeds would require. Roller coasters reach their peak speeds in a matter of seconds. The achieved acceleration is what causes *g*-forces, which allows riders to feel an increased or decreased sense of their mass. These *g*-forces can be dangerous but they are also well understood by physicists, so roller coasters are built according to strict standards that keep them well within safe levels.

Coasters are only permitted to accelerate up to 6*g*."

(Source: Shriek Science: Simple Physics Powers Extreme Roller Coasters Hackett Jennifer, Oct 14, 2015)

(a) The article claims that a rider will feel weightless as they plummet from a height of 66 m. It takes 2.62 s for the car to fall 33.0 m from rest.

Deduce whether the claim about weightlessness is true.

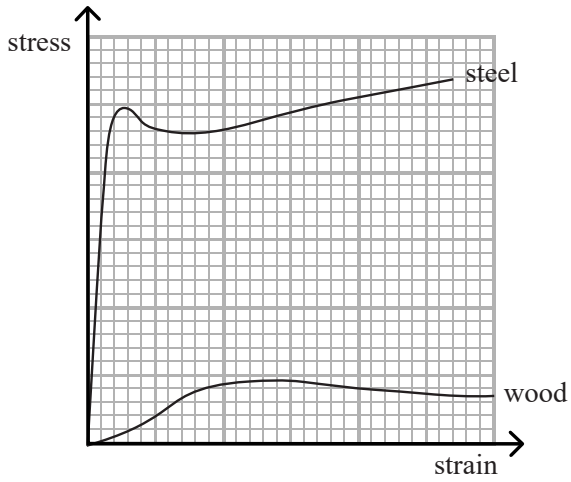
(3)

(b) As mentioned in the passage, large accelerations can also be achieved by *launched coasters* which launch the cars horizontally from their starting position.

Use the data in the passage to deduce whether the acceleration achieved in this way meets roller coaster standards.

(3)

(c) The graph shows typical stress-strain curves for wood and steel.



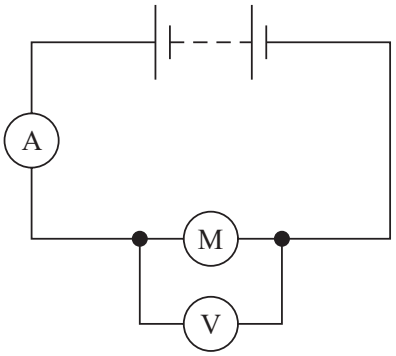
Discuss how the use of steel, rather than wood, has made the construction of faster and taller roller coasters possible.

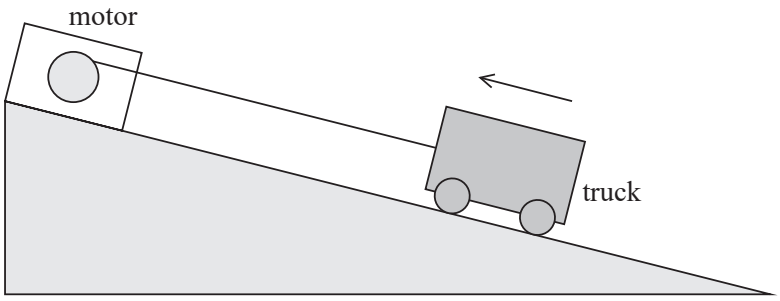
(5)

(Total for Question 17 = 11 marks)

15 An electric motor is used to pull a truck up a slope at a constant speed.

The electric motor circuit includes a battery with no internal resistance, an ammeter and a very high resistance digital voltmeter as shown.





(a) The truck moves through a vertical height of 0.20 m in 15 s. The current in the motor is 8.1 mA and the potential difference across the motor is 12 V.

mass of truck = 550 g

Calculate the efficiency of the motor.

(4)

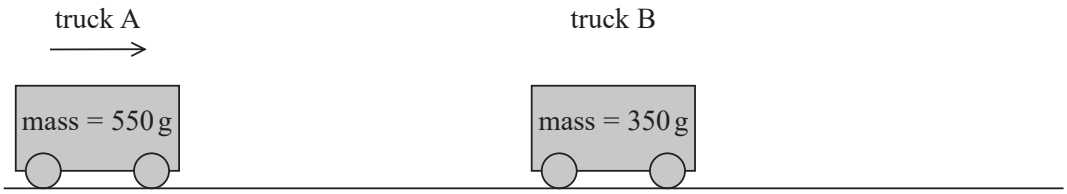
Efficiency = ...

(b) The digital voltmeter is replaced with an analogue voltmeter with much less resistance.

Deduce how this will affect the efficiency of the motor circuit.

(4)

(c) The string pulling the truck was cut. The truck (A) travelled down the slope onto a horizontal surface and collided with a second truck (B), which was stationary, as shown.



The velocity of truck A just before the collision was $5.4\,m\,s^{-1}$ and just after the collision was $2.1\,m\,s^{-1}$.

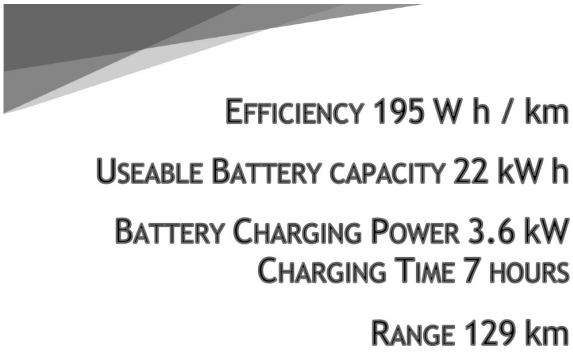
Determine the velocity of truck B after the collision.

(3)

Velocity of truck B = ...

(Total for Question 15 = 11 marks)

13 A website advertises an electric car with the following information.



(a) State why the 'efficiency' given on the website cannot be a value of efficiency as defined in physics.

(1)

.....

.....

(b) Explain why the kilowatt-hour (kW h) is a unit of energy.

(2)

.....

.....

.....

.....

(c) Calculate the efficiency of the battery.

(3)

.....

.....

.....

.....

.....

Efficiency = ...

.

(d) A comparable petrol car has a petrol consumption of 21 km / litre.

Show that the electric car is cheaper to run.

cost of 1 litre of petrol = £1.20

cost of 1 kW h of electricity = 13 p

(2)

(e) Give one environmental advantage of an electric car.

(1)

(f) The website provides the following additional information.

Maximum Engine Power 80 kW
Maximum Performance 0 to 28 ms^{-1} in 11.5 s
Mass of Car 1500 kg

Deduce whether the power of the engine is capable of producing this performance.

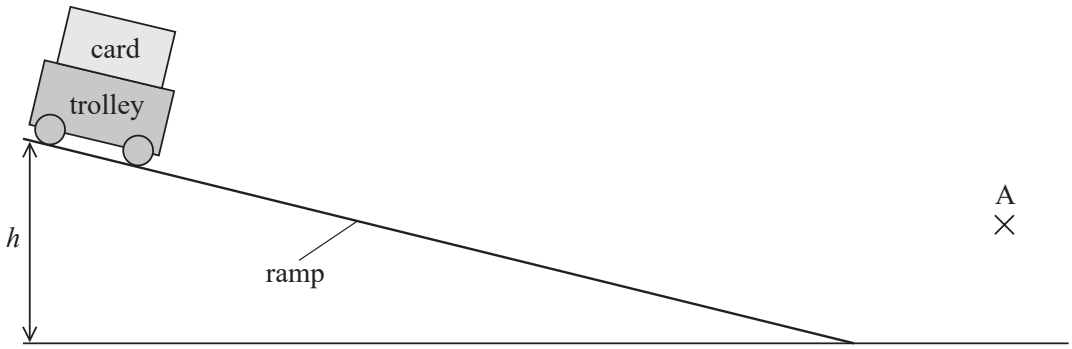
(3)

(Total for Question 13 = 12 marks)

16 A student released a trolley from the top of a ramp of length of about 1.5 m, as shown.

The student investigated how the speed v of the trolley at the bottom of the ramp varied as the height h of the ramp was increased.

The student placed a light gate connected to a data logger at position A to measure v as the card passed through the light gate.



(a) Describe how the student could measure h accurately.

(2)

(b) The student derived the following equation for the motion of the trolley

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

where g is the acceleration due to gravity.

(i) Explain why plotting a graph of h against v^2 will produce a straight line.

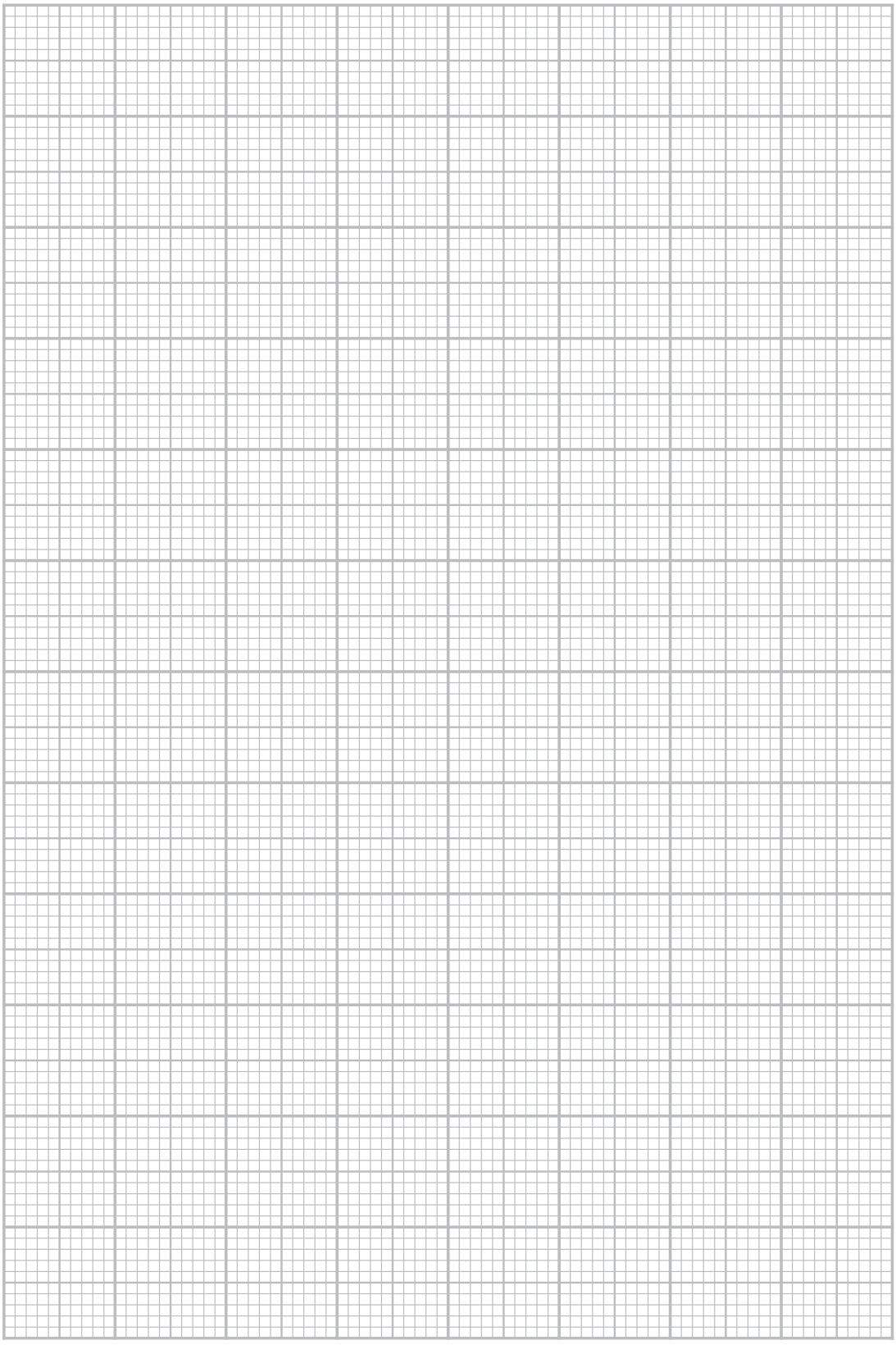
(2)

(ii) The student varied h and measured corresponding values of v. The results are recorded below.

h / cm	v / m s^{-1}	
10.8	1.38	
18.9	1.98	
28.7	2.45	
40.3	2.86	
49.8	3.22	
58.7	3.46	

Plot a graph of h on the y-axis against v^2 on the x-axis on the grid opposite. Use the additional column in the table for your processed data.

(5)



(iii) The student used her results to plot a graph and determine a value for g.

She concluded that her value was consistent with the value of g given on the data sheet at the back of this paper.

Comment on the student's conclusion.

(3)

.....

.....

.....

.....

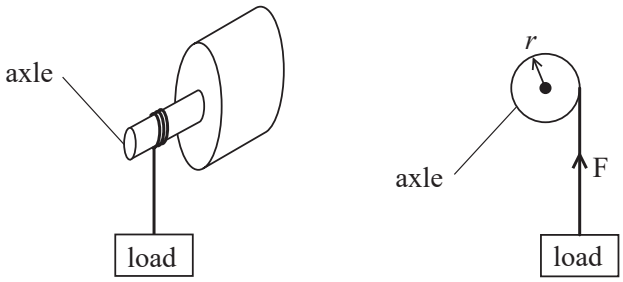
.....

.....

(Total for Question 16 = 12 marks)

18 Motors usually have a rotating component which can do work W.

(a) A motor lifts a load in a time t. The axle of the motor has a radius r and exerts a force F.



The power produced by a motor can be calculated by using the following word equation.

Power = moment of the force exerted by the rotating axle × angular velocity

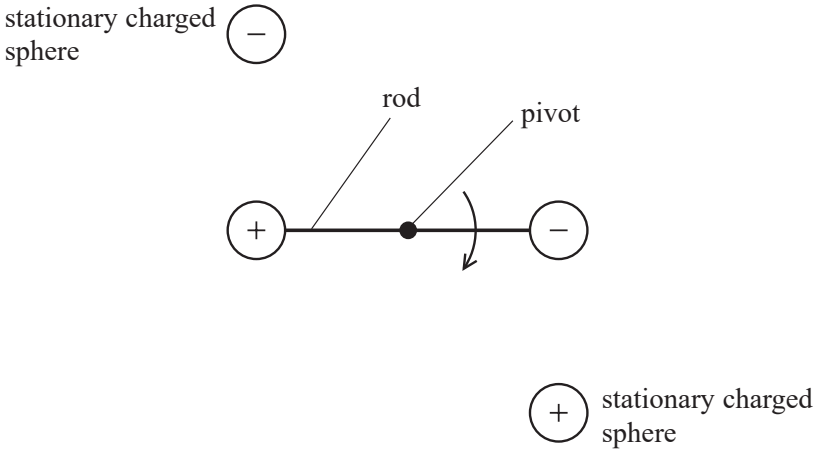
Derive this equation, starting with power $P = \frac{W}{t}$.

(4)

(b) An electrostatic motor was first demonstrated by Benjamin Franklin in 1750.

The diagram shows a simplified version of part of this motor.

This consists of a rod, with an oppositely charged sphere at either end, which rotates around a fixed pivot. Two stationary charged spheres apply a force on the spheres at either end of the rod.

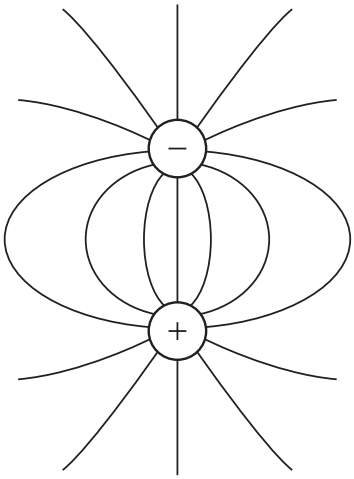


(i) In the diagram below, electric field lines have been drawn around one pair of these spheres.

Add to the diagram to show

- the directions of the field lines
- the lines of equipotential.

(3)



(ii) The distance between the centres of each charged sphere in this pair is 5.0 cm.

Show that the force between this pair of charged spheres is about 0.04 N.

charge on each sphere = 0.10 μC

(2)

(c) The table shows the typical power and the corresponding angular velocity required for three different appliances.

	Power / W	**Angular velocity / rad s^{-1}**
Electric car	2.0×10^4	300
Vacuum cleaner	1.4×10^3	1000
Small pond pump	0.5	200

Deduce which of these appliances, in principle, could use the electrostatic motor in (b).

You should use the word equation in (a) and assume that the length of the rod in the electrostatic motor is 8.0 cm.

Assume that the electrostatic motor would deliver a constant force throughout one complete rotation.

(4)

(Total for Question 18 = 13 marks)

14 Since 2008, the Scottish island of Eigg has generated almost all its electrical power from renewable energy sources. The main source of power for the island is produced by hydroelectric generators.

(a) Water falls through a height of 124 m as it flows through a pipe to a hydroelectric generator.

(i) Calculate the maximum power input of the generator.

mass flow rate of the water = 130 kg s^{-1}

(2)

Maximum power input = ...

(ii) Explain why the power input of the generator is always less than this value.

(2)

(b) When demand for power is low on Eigg, excess energy is stored in a number of batteries. The batteries have a total capacity of 4400 Ah when fully charged.

When demand for power is greater than the output from the renewable sources, energy is supplied by the batteries. The batteries supply an average power of 20 kW.

Calculate the total time, in hours, for which the batteries can supply energy before they need recharging.

total output potential difference of batteries = 48 V

(3)

Total time = ... hours

(c) Each house on Eigg is allowed a maximum power of 5 kW.

(i) Show that the maximum current in an electrical cable to a house is about 22 A.

mains potential difference = 230 V

(2)

(ii) On Eigg the cables to the houses are made of aluminium instead of copper.

The rate of energy transfer to the environment is limited to 0.05 W per metre of cable.

The engineers claimed that using aluminium instead of copper reduced the cost of the electrical cables by 90%.

Evaluate this claim by comparing a 1 m length of cable made from each material.

Assume the current in each cable is 22 A.

Material	Resistivity / Ω m	Cost in £ per m^3
Copper	1.68×10^{-8}	77 090
Aluminium	2.65×10^{-8}	6070

(5)

(Total for Question 14 = 14 marks)

15 Read the passage and answer the questions below.



© Reuters

The Solar Impulse 2 is a solar-powered plane that completed a round the world trip in 2016 without using fossil fuels.
The wings are covered in thin solar panels, keeping the total mass of the plane and pilot at 1600 kg. The need to reduce the weight limits the efficiency of the solar panels to 23%. However, in daylight, these panels generate enough energy to run the four 7.5 kW electric motors that keep the plane airborne and to fully charge the batteries that power the plane during the night. The batteries take about 6 hours to fully charge.
In daylight the plane flies at a height of 8500 m to harness the most sunlight, and at night descends to 1500 m. This descent makes use of the gravitational potential energy gained during the day to help the plane get through the night.
(Source: www.solarimpulse.com)

(a) The solar panels consist of a series of photocells connected to an external circuit that includes the batteries. When light strikes the photocells, electrons gain energy and are able to move through the external circuit so that the batteries charge up.

Explain why the batteries charge more quickly in high intensity light.

(4)

(b) The solar panels are illuminated with an average light intensity of 1300 W m^{-2} over an 8 hour period in any day.

Calculate the electrical energy generated by the solar panels in one day. (4)

upper area of wings = 200 m^2

Energy = ...

(c) During the night the motors are switched off for 4 hours.
Calculate the battery energy saved by switching off the motors. (2)

Battery energy saved = ...

(d) The plane flies at the greater height during the day. At night it glides down to the lower height over a period of 4 hours, with the motors switched off.

Calculate the change in gravitational potential energy as the plane glides down. (2)

Change in gravitational potential energy = ...

(e) After four hours the engines are switched on again.

Explain whether the plane should fly at a slower horizontal speed at its lower height.

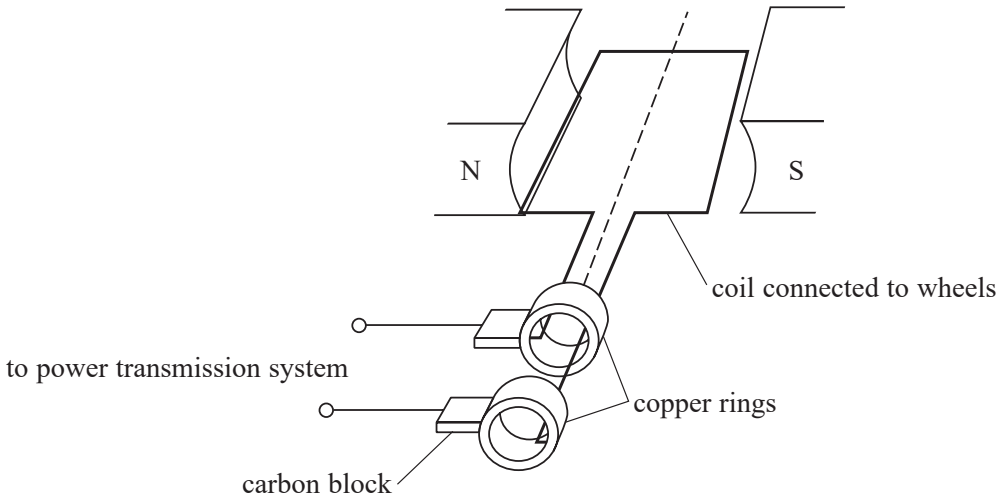
(3)

(f) Comment on how projects such as the Solar Impulse 2 might be of benefit to society at large.

(1)

(Total for Question 15 = 16 marks)

18 Regenerative braking supplies a current back to the power transmission system whilst slowing a vehicle. The arrangement shown can be used as a regenerative braking system on a train.



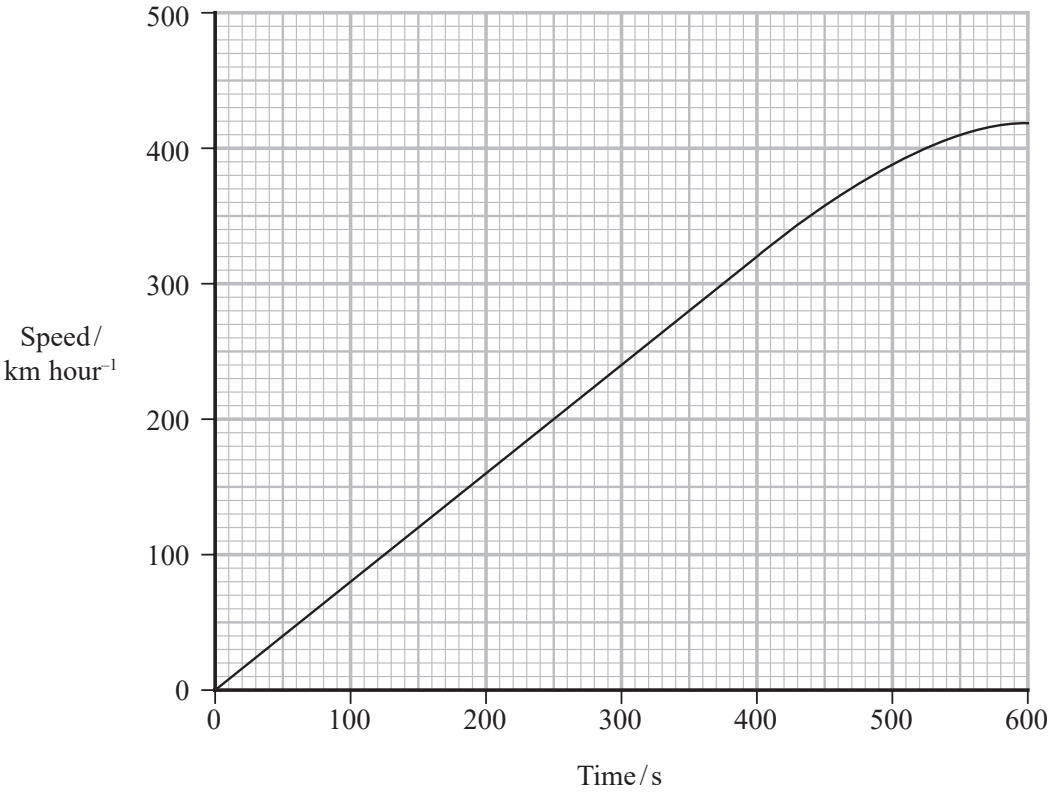
The coil rotates with the wheels of the train. Two copper rings are connected to the ends of the coil. The rings rotate with the coil and two carbon blocks make electrical contact with the rings as they rotate.

(a) Describe how this arrangement can be used as a regenerative brake.

(4)

(b) A specification for a new train states that the train should be able to accelerate to a speed of 360 km hour^{-1} from rest, and that this acceleration should be completed within 40 km of level track.

The graph shows the performance of the train on a test run.



(i) Calculate the acceleration of the train as it accelerates to a speed of 360 km hour^{-1}.

(3)

Acceleration of train = ...

(ii) Deduce whether the performance of the train met the specification on this test run.

(3)

(c) On curved tracks there is a maximum safe speed for the train.

(i) Explain why there is a maximum safe speed for a train travelling on a curved track.

(4)

(ii) When the train travels at 200 km hour^{-1}, the minimum safe radius of curvature of the track is 1800 m.

Calculate the minimum safe radius of curvature for a speed of 360 km hour^{-1}.

(2)

Minimum safe radius of curvature = ...

(Total for Question 18 = 16 marks)

MARK SCHEMES

official mark schemes

Question Number	Acceptable Answer	Additional Guidance	Mark
1	**B** Average speed		**1**

Question Number	Answer	Mark
2	**A area under an acceleration-time graph**	**1**
	Incorrect Answers: B – this is equivalent to the displacement C – this is equivalent to the rate of change of acceleration D − this is equivalent to the acceleration	

Question Number	Acceptable answers	Additional guidance	Mark
3	C		1

Question Number	Answer	Mark
4	**D**	**1**
	Incorrect Answers: **A** – both sections of graph incorrect **B** – both sections of graph incorrect **C** – second section of graph incorrect	

Question Number	Acceptable answers	Additional guidance	Mark
3	**The only correct answer is A** B is not correct as the rebound velocity wil be about $0.7 \times v_{initial}$ C is not correct as the velocity must switch sign on rebound D is not correct as the velocity must switch sign on rebound		1

10	**The only correct answer is B** A is not the correct answer, as the gradient of the velocity graph must increase. C is not the correct answer, as the gradient of the velocity graph must increase. D is not the correct answer, as as the gradient of the velocity graph must increase.		**1**

(Total for Multiple Choice Questions = 10 marks)

Question Number	Answer	Mark
3	**B** Incorrect Answers: A – this answer is incorrect C – this answer is incorrect D – this answer is incorrect	1

8	**The only correct answer is A – The v-t graph is a graph of the gradient of the s-t graph.** **B** *is not correct because this answer shows a decreasing positive velocity, followed by an increasing negative velocity* **C** *is not correct because this answer shows a constant positive velocity followed by a constant negative velocity then an increasing negative velocity* **D** *is not correct because this answer shows a velocity of zero, then an infinite velocity, followed by a velocity of zero again.*	**1**

(Total for Multiple Choice Questions = 8 marks)

Question Number	Answer	Mark
5	**B -**	1
	Incorrect Answers: A – the second section of the graph is constant velocity so acceleration = 0 C - the second section of the graph is constant velocity so acceleration = 0 D – the gradient is decreasing for the first section of the graph, so velocity is decreasing and so it is has negative acceleration	

Question Number	Acceptable answers		Additional guidance	Mark
10	• Use of distance = area under graph	**(1)**	Example of Calculation Distance (2 cm square) = 2.0 ms^{-1} × 0.20 s = 0.40 m	**3**
	• Use of scales on axes	**(1)**	Number of squares = 15 Distance = 15 × 0.40 m = 6.0 m	
	• Distance in range 6.0 m – 6.2 m MP3 dependent on MP1	**(1)**		

(Total for Question 10 = 3 marks)

Question Number	Acceptable answers	Additional guidance	Mark
11(a)	• Initial <u>acceleration</u> due to a resultant force **(1)** • Decreasing acceleration as resistive forces increase **Or** Decreasing acceleration as resultant force decreases **(1)** • No acceleration as resultant force is zero **Or** constant velocity as resultant force is zero **(1)**	Accept reference to gradient of graph for acceleration for MP2 & MP3. Accept terminal velocity for constant velocity	**3**
11(b)	• Work done (by cyclist) results in a <u>transfer</u> of energy **(1)** • initially there is an increase in E_k of (cyclist and bicycle) **Or** work done is transferred/converted to other forms of energy **(1)** • when the velocity of the cyclist is constant, all the energy is being transferred to other forms **(1)**		**3**

(Total for Question 11 = 6 marks)

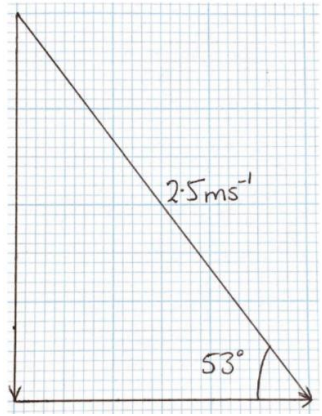
Question Number	Acceptable Answer		Additional guidance	Mark
11(a)	• Tangent drawn at t = 4.0 s • Gradient of tangent determined • a in the range 1.4 – 1.6 m s^{-2}	(1) (1) (1)	Example of calculation $a = \frac{(35.0-25.0)\text{m s}^{-1}}{(10.0-0.0)\text{ s}} = 1.50\text{ m s}^{-2}$	3
11(b)	• Use of displacement = area under line • 1 square = 20 m **Or** area divided into regular shapes • *s* in the range 410 – 430 m	(1) (1) (1)	Example of calculation Number of squares = 42 1 square = 2 s × 5 m s^{-1} = 10 m s = 42 × 10 m = 420 m	3

(Total for Question 11 = 6 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
2(a)(i)	An explanation that makes reference to the following points: • Identify when the distance fallen between frames has become constant **(1)** • Measure the distance fallen over a number of frames **Or** measure the distance fallen between frames a number of times and calculate an average distance **(1)** • Calculate terminal velocity by dividing the distance fallen by the time taken **(1)** • Use $\frac{1}{60}$ s as time between frames. **(1)**	MP3: Allow reference to $v = \frac{s}{t}$ to calculate terminal velocity	**4**
2(a)(ii)	An explanation that makes reference to the following points: • There may be parallax error in reading the ball position **(1)** **Or** the metre rule may not be vertical • Recorded distance may be greater than actual distance, so calculated terminal velocity would be greater than true value. **(1)** **OR** **(1)** • The frame rate may be not be 60 s^{-1} • Time between frames may be less than 1/60 s, so calculated terminal velocity may be greater than true value **(1)**	Recorded distance may be less than actual distance, so terminal velocity would be less than true value Time between frames may be more than 1/60 s, so calculated terminal velocity may be less than true value	**2**

2(b)	An explanation that makes reference to the following points: • With a phone camera there won't be reaction time errors (when starting and stopping the stopwatch) **Or** with a phone camera the recording can be replayed (a number of times) **(1)** • So the uncertainty in the measured times will be reduced **Or** this may lead to a more accurate value/time/velocity **(1)**		**2**

(Total for Question 2 = 8 marks)

Question Number	Acceptable answers		Additional guidance	Mark
10(a)	• Height = area under the triangle • Height = 67.5 m	**(1)** **(1)**	Example of calculation height = (4.5 s × 30 m s^{-1}) / 2 height = 67.5 m	**2**
10(b)	• Straight horizontal line at −2 m s^{-1} • Ending at 38.5 s	**(1)** **(1)**	Example of calculation Time of descent = 67.5/2 = 33.8 s End of motion = 33.8 + 4.5 = 38.3 s	**2**
10(c)	• Scale to cover at least half of the grid either vertically or horizontally • Downward and horizontal velocity arrows **and** corresponding resultant velocity arrow drawn • Magnitude of velocity = 2.5 (m s^{-1}) • Angle to the horizontal = 53(°) [allow ±1°]	**(1)** **(1)** **(1)** **(1)**	Example 	**4**

(Total for Question 10 = 8 marks)

8	**A** $\frac{6^2}{2 \times 9.81}$ Incorrect Answers: B – this answer is incorrect C – this answer is incorrect D – this answer is incorrect	**1**

(Total for Multiple Choice Questions = 8 marks)

6	**A – (9.81 x 3.5^2) / 2 this is from using $s = ut + ½ at^2$** Incorrect Answers: B – this gives v, not s, using $v = u+at$, C – this uses $s = ut + ½ at^2$ incorrectly D - this rearranges $s = ut + ½ at^2$ incorrectly	**1**

Question Number	Acceptable answers	Additional guidance	Mark
12	• Use of $V_{grav} = -\frac{GM}{r}$ **(1)** • Recognises that $\Delta E_{grav} = m \times \Delta V_{grav}$ **(1)** • $\Delta E_{grav} = (-)\ 3.4 \times 10^7$ J **(1)** **OR** • Use of $g_{Mars} = -\frac{GM}{r^2}$ with justification that change in g is minimal • Use of $\Delta E_{grav} = m \times g \times \Delta h$ • $\Delta E_{grav} = (-)\ 3.4 \times 10^7$ J	Example of calculation $\Delta V_{grav} = -\frac{GM}{r_2} + \frac{GM}{r_1}$ $\Delta V_{grav} = GM\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$ $\Delta V_{grav} = 6.67 \times 10^{-11}$ N m^2 kg^{-2} $\times$ 6.39×10^{23} kg $\left(\frac{1}{(3.39 \times 10^6 + 11.0 \times 10^3)\text{m}} - \frac{1}{(3.39 \times 10^6 + 2.1 \times 10^3)\text{m}}\right)$ $\therefore \Delta V_{grav} = -3.29 \times 10^4$ J kg^{-1} $\therefore \Delta E_{grav} = -3.29 \times 10^4$ J kg^{-2} $\times 1030$ kg $= -3.39 \times 10^7$ J	**3**

(Total for Question 12 = 3 marks)

Question Number	Acceptable Answer	Additional guidance	Mark
11(a)	• Use of $v = u + at$ **(1)** • Max acceleration from 0-60 time = 2.8 (m s^{-2}) **(1)**	Example of calculation $\frac{(60 \times 1600)\text{ m}}{(60 \times 60)\text{ s}} = 0 + a \times 9.5\text{ s}$ Max acceleration = 2.8 m s^{-2}	**2**
11(b)	• Use of $v^2 = u^2 + 2as$ **(1)** • Max speed with manufacturer's acceleration = 18 m s^{-1} **Or** acceleration shown by police = 3.3 m s^{-2} **(1)** • Decision **and** evidence required consistent with calculated values **(1)**	Examples for MP3: e.g. 18.3 m s^{-1} is lower than 20 m s^{-1} so should be challenged e.g. 18.3 m s^{-1} is lower than the maximum speed so should be challenged e.g. The police are suggesting a greater acceleration than the manufacturers, so it should be challenged e.g. The maximum speed achievable is less than that suggested by the police, so it should be challenged MP2: maximum manufacturer's speed with show that value of acceleration = 19.0 m s^{-1} Example of calculation $v^2 = 0^2 + 2 \times 2.8\text{ m s}^{-2} \times 60\text{ m}$ $v = 18.3\text{ m s}^{-1}$	**3**
11(c)	• Air resistance increases with speed so acceleration decreases (at higher speeds) **(1)** • The car could brake with greater negative acceleration/force than the positive acceleration/force **(1)**	Ignore references to the mass of the car Accept friction for air resistance	**2**

(Total for Question 11 = 7 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
14 (a)	• Attempts to find area under graph **(1)** • Height = 19 m **(1)**	Range for base of triangle between 1.8 and 2s to recognise area Example of calculation:	**2**

Question Number	Acceptable answers	Additional guidance	Mark
17(a)	• *V* at top/start = 0V **Or** recognition "potential divider" **Or** *V* increases (by implication) **Or** *V* at bottom = 1.5V **(1)** • Two sections of wire act as series resistors **Or** $R=\rho l/A$ **Or** comment about *R* proportional to length **Or** $\frac{V}{1.5}=\frac{R}{R_T}$ **(1)** • potential difference proportional to length of wire **(1)**	**Alternative MS** Constant Current (*I*) in wire (1) p.d. across section of wire = *Ir* between A and loop (1) Increases from 0V to 1.5V linearly (1)	**3**
17(b)	• Tangent drawn at 1.5 s **(1)** • Scales p.d. to give distance **(1)** • Gradient determined using a base of triangle of at least 1.0 s **Or** use of $s=\frac{(u+v)}{2}t$ **and** correct *V* read from graph **(1)** • velocity = 1.0 m s^{-1} – 1.3 m s^{-1} **(1)**	Example of calculation Gradient = $\frac{1.1\text{V}-0.2\text{V}}{1.0\text{s}}=0.9\text{Vs}^{-1}$ As 1.5 V represents 2.00 m v = 0.9 Vs^{-1} × $\frac{2.00\text{m}}{1.5\text{V}}$ = 1.2 ms^{-1}	**4**
17(c)	• Use of $v=u+at$ **(1)** • Use of $a=g\sin\theta$ **(1)** • Calculates a value for *a*, θ or *v* (using a SUVAT AND $a=g\sin\theta$) **(1)** • Valid comparison of their calculated quantity and the stated quoted uncertainty. **(1)**	Example of calculation $1.5\,\text{ms}^{-1}=1.2\,\text{m s}^{-1}+\text{a}\times0.5\,\text{s}$ $a=\frac{0.3\,\text{m s}^{-1}}{0.5}=0.6\,\text{m s}^{-2}$ $0.6\,\text{m s}^{-2}=9.81\,\text{m s}^{-2}\sin\theta$ $\theta=3.6^{\circ}$	**4**

(Total for Question 17 = 11 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
10(a)(i)	• Use of $v = u + at$ • $a = 0.81$ m s^{-2}	**(1)** **(1)**	Example of calculation $a = \frac{v-u}{t} = \frac{97 \text{ m s}^{-1}}{120 \text{ s}} = 0.808 \text{ m s}^{-2}$	**2**
10(a)(ii)	• Use of $s = ut + \frac{1}{2}at^2$ **Or** $v^2 = u^2 + 2as$ **Or** $s = \left(\frac{(v+u)}{2}\right)t$ • Use of $v_{av} = \frac{s}{t}$ with $t = 320$ s • $v_{av} = 75$ m s^{-1}	**(1)** **(1)** **(1)**	Ecf acceleration from (a)(i) Example of calculation $s = ut + \frac{1}{2}at^2 = 0.5 \times 0.808 \text{ m s}^{-2} (120 \text{ s})^2 = 5820 \text{ m}$ $s_2 = 29900 \text{ m} - 5820 \text{ m} = 24\,080 \text{ m}$ $t = 440\text{s} - 120 \text{ s} = 320 \text{ s}$ $v_{av} = \frac{24\,080 \text{ m}}{320 \text{ s}} = 75.3 \text{ m s}^{-1}$	**3**
10(b)	An explanation that makes reference to the following: • (Magnetic levitation) reduces frictional forces (acting on the train as it moves) • This reduces the work done against friction **Or** this makes it more efficient **Or** there is less time to reach maximum speed **Or** there is a higher maximum speed	**(1)** **(1)**	MP1: accept removes/no frictional forces MP2: accept there is less fuel used **Or** less energy is wasted	**2**

***10(c)**

This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The table shows how the marks should be awarded for indicative content and structure and lines of reasoning.

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5–4	3
3–2	2
1	1
0	0

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Indicative content:

1. Removing the magnet from the ring changes the magnetic flux (linked with the ring)
2. This induces an e.m.f. (in the ring)
3. E.m.f. causes a current in the ring
4. Which produces a magnetic field
5. The magnetic fields interact/combine
6. This opposes the change, causing an attractive force to act

IC Points	IC Mark	Max linkage mark avail.	Max final mark
6	4	2	**6**
5	3	2	**5**
4	3	1	**4**
3	2	1	**3**
2	2	0	**2**
1	1	0	**1**
0	0	0	**0**

IC1: accept references to flux cutting

Alternative indicative content for IC4 – IC5

4. The current is in the magnetic field produced by the magnet
5. The current experiences a magnetic force

6

(Total for Question 10 = 13 marks)

Question Number	Acceptable answers	Additional guidance	Mark
14(a)	• Attempt to find area under the graph **(1)** • Length from 18 000 m to 20 000 m **(1)** • Comparison of calculated value to 23 km **(1)** e.g. The length is long enough	MP1: use of triangles or counting squares MP3: conclusion to be consistent with calculated value <u>Example of calculation</u> Area under the graph (counting large squares) $= 18.7 \times 100 \text{ m s}^{-1} \times 10 \text{ s} = 18\,700 \text{ m}$	**3**
14 (b)(i)	• 26 - 28 s **(1)**	Unit required	**1**
14(b)(ii)	• Use of gradient of the graph between 28 and 46 s **(1)** • Acceleration = 16 - 17 m s^{-2} **(1)**	<u>Example of calculation</u> Gradient of tangent $= \frac{490 \text{ m s}^{-1} - 0 \text{ m s}^{-1}}{52 \text{ s} - 22 \text{ s}}$ Acceleration = 16.3 m s^{-2}	**2**
14(b)(iii)	• Use of $\Sigma F = ma$ using a from (ii) **(1)** • $\Sigma F = (89 + 120) \times 10^3 \text{ N} -$ frictional force **(1)** • Frictional force = 80 kN to 84 kN (full ecf for acceleration) **(1)**	<u>Example of calculation</u> $(89 + 120) \times 10^3 \text{ N} - F = 7790 \text{ kg} \times 16.3 \text{ m s}^{-2}$ $F = 82.0 \times 10^3 \text{ N}$	**3**

***14(c)**

This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5 - 4	3
3 - 2	2
1	1
0	0

Indicative content

- At greater speed, the drag force is greater
- Resultant force decreases **Or** acceleration decreases
- When the rocket is started the (resultant) force/thrust increases
- The mass/weight of the car decreases as fuel is used up
- Increasing the acceleration (for a given applied force)
- When the brakes are applied, there is a deceleration
  Or when the brakes are applied the resultant force is in the opposite direction
  Or deceleration (due to drag forces) decreases due to smaller drag forces acting on the car at lower speeds

The following table shows how the marks should be awarded for structure and lines of reasoning

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

6

(Total for Question 14 = 15 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
7	**D** 		**1**

Question Number	Answer	Mark
1	**B distance**	**1**
	Incorrect Answers: A – acceleration is a vector quantity C – momentum is a vector quantity D – velocity is a vector quantity	

8	**C 42 m**	**1**
	Incorrect Answers: A – 141 m is ¾ of the internal circumference of the track (¾ × 2 × π × 30 = 141 m) B – 141 m is ¼ of the internal circumference of the track (¼ × 2 × π × 30 = 47 m) D – 30 m (the radius) is the displacement travelled in one direction (downwards from the start position)	

(Total for Multiple Choice Questions = 8 marks)

Question Number	Acceptable answers	Additional guidance	Mark
5	**B**		1

Question Number	Acceptable answers	Additional guidance	Mark
1	**The only correct answer is B** **energy**	A,C,D are vectors	**1**

Question Number	Answer	Mark
3	**C**	**1**
	Incorrect Answers: **A** – incorrect normal force direction **B** – incorrect normal force direction and frictional force direction **D** – incorrect frictional force direction	

Question Number	Answer	Mark
5	**B** momentum	**1**
	Incorrect Answers: **A** – scalar quantity **C** – scalar quantity **D** – scalar quantity	

Question Number	Answer	Additional Guidance	Mark
6	**C is the only correct answer**	A is incorrect because the wrong trigonometric function has been used B is incorrect because the wrong trigonometric function has been used D is incorrect because the wrong forces have been used	**1**

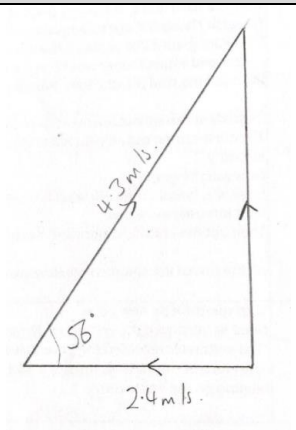
7	**The only correct answer is C** *A is not correct because charge is a scalar quantity* *B is not correct because mass is a scalar quantity* *D is not correct because time is a scalar quantity*		**1**

Question Number	Answer	Mark
3	**D 4 mm**	**1**
	Incorrect Answers: A – distance has been measured and has not been scaled. B – the displacement has not been scaled C – distance has been used	

Question Number	Answer	Mark
2	**C – power, time, work done** Incorrect Answers: A – displacement is a vector B – momentum is a vector D – acceleration is a vector	1

Question Number	Answer	Mark
1	**The only correct answer is A Energy as this is the only scalar quantity** **B** *is not correct because moment is a vector quantity* **C** *is not correct because momentum is a vector quantity* **D** *is not correct because velocity is a vector quantity*	1

Question Number	Acceptable Answer	Additional Guidance	Mark
2	**The only correct answer is A** (charge) B is not the correct answer, as displacement is a vector C is not the correct answer, as electric field strength is a vector D is not the correct answer, as force is a vector		1

Question Number	Acceptable answers	Additional guidance	Mark
12(a)	• Correct combination of vectors drawn **(1)** • Both vectors drawn to scale **(1)** • Angle = 56° (range 55° - 58°) **(1)**		**3**
12(b)	• Angle θ will need to decrease **Or** (Component of boat) velocity along river must increase **(1)** • There is further to travel (relative to the water) **Or** (Component of boat) velocity across river decreases **(1)** • time increases (Dependent on either MP1 or MP2) **(1)**		**3**

(Total for Question 12 = 6 marks)

Question Number	Acceptable answers	Additional guidance	Mark
10(a)	• Weight of the picture is equal to the vertical component of tension **(1)** • $mg/2 = T\cos\theta$ where θ is the angle between the wire and the vertical **(1)** • As the angle (to the vertical) is the smaller in arrangement 1, the cosine of the angle will be larger **(1)** • Arrangement 1 as the tension in the wire is lower than in arrangement 2 **(1)**	MP1: may be implied in an equation, accept $mg = T\cos\theta$ MP1/2: $mg/2 = T\cos\theta$ with θ defined scores 2 marks MP2/3: the angle used must be defined in words or on the diagram. Answer can be in terms of sin θ if θ defined as the angle between the wire and the horizontal e.g.MP2: $mg = 2T\sin\theta$ MP3: angle larger in 1 so sine of angle is larger MP4 conditional MP2 or MP3	**4**
10(b)	• The weight does not act through the nail/pivot **Or** the centre of gravity is not in line/below the nail/pivot **Or** there is a perpendicular distance between the weight and the nail/pivot **(1)** • There is now a moment of the weight **Or** the anticlockwise moment is greater than the clockwise moment **(1)** • The idea that the picture stops moving when the c of g is below the nail **(1)**	Accept centre of mass for centre of gravity (Allow annotations to a diagram with additional explanation for MP1/3) MP3 Accept: the turning moment being 0 **Or** the clockwise moments equal to the anti-clockwise moments	**3**

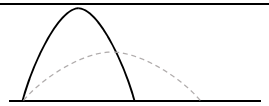
(Total for Question 10 = 7 marks)

Question Number	Acceptable answers		Additional guidance	Mark
17(a)	• Use of $W = mg$	**(1)**	Example of Calculation $W = 9.36\ \text{kg} \times 9.81\ \text{N kg}^{-1}$	
	• Calculation of θ	**(1)**	$W = 91.8\ \text{N}$ $\sin\theta = (0.5(5.94\ \text{m} - 2.20\ \text{m})) / (0.5(6.06\ \text{m} - 2.20\ \text{m})$	
	• Resolve forces vertically	**(1)**	$= 1.87/1.93$ $\theta = 75.7°$	
	• $T = 186\ \text{N}$	**(1)**	$2T\cos 75.7° = 91.8$ $T = 186\ \text{N}$	**4**
17(b)	An explanation that makes reference to the following points: • Weight of blanket decreases as it dries	**(1)**	Allow mass for weight	
	• Tension in line decreases	**(1)**		
	• So stress decreases and Young modulus is constant so strain decreases	**(1)**		
	• extension decreases **Or** line gets shorter	**(1)**	MP4 dependent on MP3	
	• height of the blanket from the ground increases	**(1)**	MP5 dependent on MP4	**5**

(Total for Question 17 = 9 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
6	**C** Rolling up one ramp and down a second ramp.		**1**

6	**C** $\boldsymbol{vt\ sin\ 35°}$	**1**
	Incorrect Answers: A – correct formula but initial vertical velocity and not horizontal velocity used B – incorrect formula used with initial vertical velocity D – incorrect formula used with initial horizontal velocity	

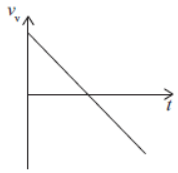
Question Number	Answer	Mark
2	**B** 	1
	Incorrect Answers: A – this is the trajectory for a ball kicked at an angle greater than θ, at a greater speed C – this is the trajectory for a ball kicked at an angle greater than θ, at a greater speed D – this is the trajectory for a ball kicked at an angle lower than θ, at a lower speed	

Question Number	Acceptable answers	Additional guidance	Mark
3	**The only correct answer is D** *A is not correct because the acceleration in the vertical plane is g* *B is not correct because the horizontal component of velocity is constant* *C is not correct because of $v = 0 - at$ gives $t = v / g$*		**1**

10	**The only correct answer is B** A is not the correct answer, as this is a correct equation of motion in the vertical plane. C is not the correct answer, as this is a correct equation of motion in the vertical plane. D is not the correct answer, as this is a correct equation of motion in the vertical plane. .		**1**

(Total for Multiple Choice Questions = 10 marks)

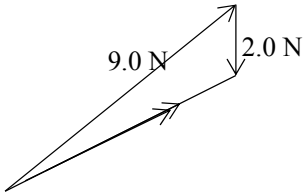
Question Number	Answer	Mark
6	**The only correct answer is C $\sqrt{(2 \times 9.81 \times 0.83) + 1.72^2}$ from combining the vertical velocity (from $v^2 = u^2 + 2as$) and horizontal velocity of the ball** **A** *is not correct because the first part of the expression represents the (vertical velocity)^2 and so should not be squared.* **B** *is not correct because the first part of the expression represents the (vertical velocity)^2 and so should not be squared.* **D** *is not correct because this should be square rooted, as Pythagoras theorem is being used.*	**1**

10	**The only correct answer is A**  B is not the correct answer, as the acceleration in the vertical plane is g C is not the correct answer, as the acceleration in the vertical plane is g D is not the correct answer, as the acceleration in the vertical plane is g		**1**

(Total for Multiple Choice Questions = 10 marks)

Question Number	Acceptable answers		Additional guidance	Mark
12(a)	• Use of $v\cos\theta$ where θ is angle between v and vertical or sin equivalent • Component = 8.55 (m s^{-1})	**(1)** **(1)**	Example of calculation Component = 14.2 cos53° Component = 8.546 m s^{-1}	**2**
12(b)	• Use of $s = ut + ½ at^2$ (ecf value from (a)) • Using a = $-9.81\,m\,s^{-2}$ • h = 2.3 m above ground	**(1)** **(1)** **(1)**	If show that value used h = 2.2 m Example of calculation $s = 8.55\ m\,s^{-1} \times 1.98\,s + ½ \times (-9.81\,m\,s^{-2}) \times 1.98^2 s^2$ s = 16.93 m - 19.23 m s = -2.3 m	**3**
12(c)	• Horizontal component velocity = v cos37° • R = horizontal component x time • R = 22.5 m	**(1)** **(1)** **(1)**	Example of calculation $R = 14.2\cos 37° \times 1.98$ R = 22.5 m	**3**

(Total for Question 12 = 8 marks)

Question Number	Acceptable answers	Additional guidance	Mark
11(a)	• Use of $v = s/t$ for the horizontal motion **Or** see $u_h = 25$ m s^{-1} **(1)** • Use of $s = ut + ½\ at^2$ with $s = 0$ **Or** $v = u + at$ with $t = 1.0$ s **Or** see $u_v = 9.81$ m s^{-1} **(1)** • Combining of horizontal velocity and vertical velocity expressions **(1)** **Or** see $\tan\theta = \left(\frac{9.81}{25}\right)$ **(1)** • $\theta = 21°$	<u>Example of calculation</u> horizontal motion: $u_h = \frac{50\text{ m}}{2.0\text{ s}} = 25$ m s^{-1} vertical motion: $0 = (u_v)\ (2.0\text{ s}) + ½(-9.81\text{ m s}^{-2})(2.0\text{ s})^2$ $u_v = 9.81$ m s^{-1} $\tan\theta = \frac{u_v}{u_h} = \frac{9.81\text{ m s}^{-1}}{25\text{ m s}^{-1}}$ $\theta = 21.4°$	**4**
11(b)	• Construction of vector diagram with 2 N/weight and 9N / catapult force labelled and all three directions shown **(1)** • Correct scaling of 9 N and 2 N forces **(1)** • Magnitude = 7.6 N to 8.0 N **(1)** • Direction = 27° to 31°	 MP2: Award if MP3 awarded. Otherwise, the ratio of the lengths should lie between 4.3 and 4.8 (if no diagram, only MP3/4 can be awarded if answers obtained by calculation)	**4**

(Total for Question 11 = 8 marks

Question Number	Acceptable answers	Additional guidance	Mark
12 (a)	• Use of efficiency = $\frac{\text{useful power output}}{\text{total power input}}$ **(1)** • Use of $\Delta E_{grav} = mg\Delta h$ **(1)** • Use of $E_k = ½ mv^2$ **(1)** • Use of (output) power = $\frac{\Delta E_{grav}}{1\text{ s}} + \frac{E_k}{1\text{ s}}$ **(1)** • v = 7.8 (m s^{-1}) **(1)**	Example of calculation Output power = 0.76 × 160 W = 121.6 W 121.6 W = (3.5 kg s^{-1})(9.81 N kg^{-1})(0.45 m) + ½(3.5 kg s^{-1})v^2 v = 7.78 m s^{-1}	**5**
12 (b)	• Use of trig to determine the vertical or horizontal component of the initial velocity **(1)** • Use of equation(s) of motion to determine time the water in air **(1)** • Use of $s = vt$ **(1)** • s = 4.8 m **(1)** Allow ecf from (a) (Using show that value, s = 5.0 m)	Example of calculation u_h = 7.8 m s^{-1} × sin 25 = 3.30 m s^{-1} u_v = 7.8 m s^{-1} × cos 25 = 7.07 m s^{-1} 0 = (7.07 m s^{-1})t + ½ (–9.81 N kg^{-1})t^2 t = 1.44 s s = 1.44 s × 3.30 m s^{-1} = 4.75 m	**4**
12(c)	• There is friction between the water and the pipes **(1)** • This will reduce the (initial) velocity of the water **(1)**	MP2 is dependent on MP1	**2**

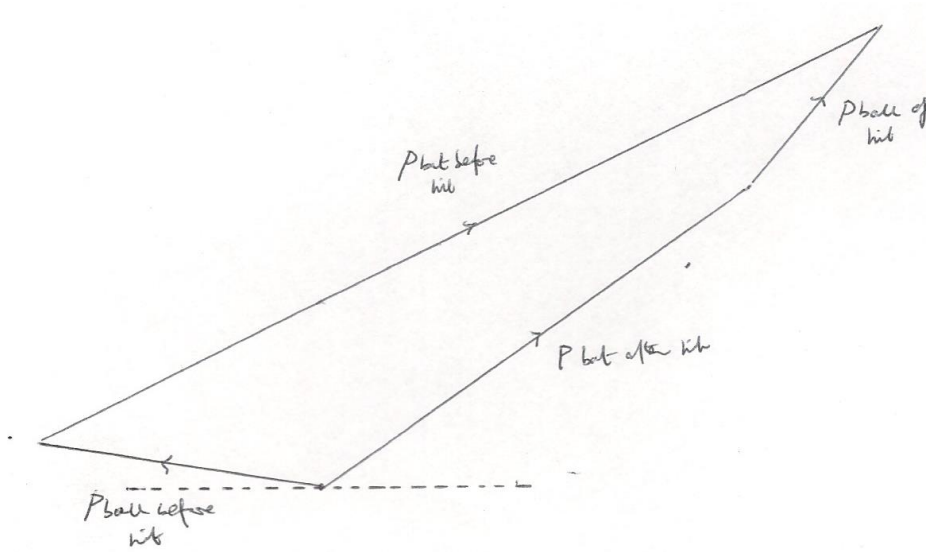
(Total for Question 12 = 11 marks)

Question Number	Acceptable Answer	Additional guidance	Mark
13(a)	**Max 2** • Beam/sling/counterweight also gain kinetic energy **(1)** • Beam/sling/rock also gain gravitational potential energy **(1)** • Work done against friction so some energy transferred to surroundings **(1)**		**2**
13(b)	• Use of trig to determine the vertical or horizontal component of the initial velocity **(1)** • Use of equation(s) of motion to determine the time of flight **(1)** • Use of s=ut for horizontal motion **(1)** • s = 150 m **(1)**	<u>Example Calculation</u> $u_v = 41.5\ ms^{-1} \sin 30 = 20.8\ ms^{-1}$ $u_H = 41.5\ ms^{-1} \cos 30 = 35.9\ ms^{-1}$ $v = u + at$ $0\ ms^{-1} = 20.8\ ms^{-1} - 9.81 ms^{-2}\ t$ t (to max height) = 2.12s $s = 35.9\ ms^{-1} \times 2$ x 2.12s s = 152 m	**4**
13(c)	• Counterweight transfers less gravitational potential energy **(1)** • So transfer of kinetic energy to rock is reduced **(1)** • (When released) rock has smaller vertical (component of) velocity **(1)** • Time of flight will be reduced **(1)** • (And) horizontal (component) of velocity will be smaller	Additional Guidance. Accept references to force and acceleration for MP1 and MP2 eg Force on rock is decreased (so) acceleration of rock in sling is decreased	**5**

(Total for Question 13 = 11 marks)

Question Number	Acceptable answers	Additional guidance	Mark
17(a)	• Uses correct components of velocity **(1)** • Uses $v = d/t$ in the horizontal plane **Or** Uses any equation of motion in the horizontal plane **(1)** • Uses $s = ut + ½\ at^2$ **(1)** • the ut term has the opposite sign to the term at^2 **(1)** • $s = 2.1$ m so fielder can catch the ball because it is less than 3 m **(1)** (allow rounding error in final answer)	Example of calculation Initial vertical component velocity = 23.8 sin50 = 18.23 m s^{-1} Horizontal component velocity = 23.8 cos50 = 15.30 m s^{-1} t = 55.0 m / 15.30 m s^{-1} = 3.595 s $s = 18.23\text{m s}^{-1} \times 3.595\text{ s} - \frac{9.81\text{ m s}^{-2} \times 3.595^2\text{ s}^2}{2}$ s = 65.5 m – 63.4 m = 2.1 m Or starts the same with v_H and v_V $3.0\text{ m} = 18.23\text{m s}^{-1} \times t - \frac{9.81\text{ m s}^{-2} \times t^2}{2}$ t = 3.54 s s = 15.30 m s^{-1}×3.54 s = 54.2 m So at s = 55 m the ball will be below 3 m and can be caught	**5**
17(b)(i)	• p = 3.33 (N s) **(1)**	Example of calculation $p = 0.140\text{ kg} \times 23.8\text{ m s}^{-1}$ p = 3.33 kg m s^{-1}	**1**
17(b)(ii)	• Draws labelled vector line with a ruler representing $p_{\text{ball after}}$ **(1)** • at approximately the correct angle (50°) **(1)** • length of line scaled correctly **Or** recognises the scale is 1 cm = 1 N s **(1)** • either $p_{\text{ball after}}$ line **or** $p_{\text{bat after}}$ line should start at the start of the $p_{\text{ball before}}$ line. **(1)**	Accept a label such as "ball after" ie length of $p_{\text{ball after}}$ should be about 3(.3) cm This can only be given if there is a correct arrow and either label	**5**

	• Momentum = 8.3 (N s) ∓ 0.3 and angle = 34° ∓ 3° **(1)**		



Or

(Total for Question 17 = 11 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*13(a)</td>
<td>
This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.
Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning.
<table>
<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
<tr><td>4</td><td>3</td><td>1</td><td>4</td></tr>
<tr><td>3</td><td>2</td><td>1</td><td>3</td></tr>
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<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
Indicative content:

IC1 There is a constant horizontal distance moved in each time interval on the diagram
IC2 So the horizontal (component of) velocity is constant
Or Horizontal (component of) acceleration is zero
IC3 And there is no horizontal force on the projectile
IC4 The vertical distance moved in each equal time interval changes
IC5 So there is a change in vertical (component of) velocity
Or There is a vertical (component of) acceleration
IC6 So there is a vertical force on the projectile (which is weight)
</td>
<td>
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative points seen in answer</th><th>Number of marks awarded for indicative points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
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<tr><td>Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkage between points and is unstructured</td><td>0</td></tr>
</table>
</td>
<td>6</td>
</tr>
</table>

13(b)	• Use of $s = ut + \frac{1}{2}at^2$ for vertical motion **Or** Use of $v = u + at$ with $v = 0$, and $t = 7.5/2$ s **(1)** • Use of $s = ut$ for horizontal motion **(1)** • Use of $\tan\theta = \frac{\sin\theta}{\cos\theta}$ **Or** Use of pythoagoras theorem **(1)** • Use of a trigonometric function **(1)** • $\theta = 48°$ **and** $u = 50$ m s^{-1} **(1)**	<u>Example of calculation</u> Vertically $0 = (u_V \times 7.5\text{ s}) + (0.5 \times -9.81\text{ m s}^{-2} \times 7.5^2)$ $u_V = u\sin\theta = 36.8$ m s^{-1} Horizontally 250 m = $u_H \times 7.5$ s $u_H = u\cos\theta = 33.3$ m s^{-1} $\frac{u\sin\theta}{u\cos\theta} = \tan\theta = \frac{36.8}{33.3} = 1.11$ $\theta = 47.9°$ 250 m = $u \cos 48° \times 7.5$ $u = 49.6$ m s^{-1}	**5**

(Total for Question 13 = 11 marks)

Question Number	Acceptable answers		Additional guidance	Mark
16(a)(i)	• calculate difference in positions on y axis • use velocity = distance/0.1s	**(1)** **(1)**	might show this with a calculation: $v = (3.0 - 2.0)\ m / 0.1\ s = 10\ m\ s^{-1}$	**2**
16(a)(ii)	• this velocity is an average	**(1)**		**1**
16a)(iii)	• the horizontal distances between the points vary • the graph is not symmetrical around the vertical **Or** the graph is not parabolic • velocity-time graph is not straight line **Or** gradient of velocity-time graph is not constant • horizontal component of velocity should be constant • Acceleration in vertical direction should equal *g*	**(1)** **(1)** **(1)** **(1)** **(1)**	2 max from MP1,2,3 1 max from MP4,5	**3Max**
16(a)(iv)	• attempt to find an area under graph • finds area up to $v = 0$ • height in range 2.80 - 2.95 m	**(1)** **(1)** **(1)**	Example of calculation area of approximate triangle = ½ 0.5 × 11.5 = 2.88 m	**3**

16(b)	• feathers will cause turbulent air flow **Or** feathers increase surface area • this results in (high) drag force • horizontal velocities decrease **Or** vertical acceleration is no longer *g*	**(1)** **(1)** **(1)**		**3**

(Total for Question 16 = 12 marks)

Question Number	Acceptable answers		Additional guidance	Mark
16 (a)(i)	• distance between at least two pairs of images	**(1)**	MP1 and 2 could come from marks on the diagram	**4**
	• distances between images are the same in x direction	**(1)**		
	• distance between images varies in y direction showing a changing velocity	**(1)**		
	• velocity in the x direction is constant so x direction is independent of y direction	**(1)**		
16 a)(ii)	• use of $v^2 = u^2 + 2as$ or $s = ut + \frac{1}{2}at^2$	**(1)**	alt to MP2 : 0.5 m s^{-1} (allow 0.4 to 0.6) if using distance taken from first two images and $v_H = d/t$ Example of calculation: $0 = u^2 - 2 \times 9.81\ \text{m s}^{-2} \times 0.011\ \text{m}$ $u_V = 0.465\ \text{m s}^{-1}$ $v_H = \frac{0.08\ \text{m}}{0.08\ \text{s}}$ $v_H = 1.0\ \text{m s}^{-1}$ $v = \sqrt{(0.47^2 + 1.0^2)}$ Resultant velocity = 1.1 m s^{-1}	**5**
	• initial vertical component velocity = 0.47 m s^{-1}	**(1)**		
	• use of $v_H = d/t$ in the horizontal	**(1)**		
	• Use of Pythagorus with v_H and u_V	**(1)**		
	• Resultant velocity = 1.1 m s^{-1}	**(1)**		

Question Number	Acceptable answers		Additional guidance	Mark
16(a)(iii)	• Use of $\Delta W = F \Delta s$	**(1)**	Allow ECF from 16(a)(ii) Example of calculation: $2 \times F \times 0.003\text{m} = \frac{1}{2} \times 150 \times 10^{-6}\text{kg} \times 1.1^2$ $(\text{m s}^{-1})^2$ $F = 0.015$ N "show that" value gives $F = 0.013$ N Alternative 1.1^2 $(\text{ms}^{-1})^2 = 2 \times a \times 0.003$ m $a = 202$ m s^{-2} $2 \times F = 150 \times 10^{-6}$ kg×202 ms^{-2} $F = 0.015$ N	**3**
	• Use of $E_k = ½ mv^2$	**(1)**		
	• $F = 0.015$ N	**(1)**		
	Alternative • Use of $v^2 = u^2 + 2as$	**(1)**		
	• Use of $F = ma$ (dependent on MP1)	**(1)**		
	• $F = 0.015$ N	**(1)**		
16(b)	• the tension will equal the mass (of spider) ×acceleration (as the thread brings spider's fall to a stop)	**(1)**		**2**
	• plus the weight (of the spider) so is incorrect	**(1)**		

(Total for Question 16 = 12 marks)

Question Number	Acceptable answers	Additional guidance	Mark
14(a)(i)	• $v \sin\theta = 2.2$ (m s^{-1}) **(1)**	Example of calculation $v \sin\theta = 2.6\ \text{m s}^{-1} \times \sin 57° = 2.18\ \text{m s}^{-1}$	**1**
14(a)(ii)	• Use of $v = u + at$ **(1)** • Use of $v \cos\theta$ **(1)** • Use of $s = ut + \frac{1}{2}at^2$ **(1)** • Number of body lengths = range/body length **(1)** • 12.7 body lengths, so not twenty lengths **(1)**	Example of calculation $t = \frac{(0 - 2.2)\text{m s}^{-1}}{-9.8\ \text{m s}^{-2}} = 0.224\ \text{s}$ $v \cos\theta = 2.6\ \text{m s}^{-1} \times \cos 57° = 1.42\ \text{m s}^{-1}$ $s = 1.42\ \text{m s}^{-1} \times 2 \times 0.224\ \text{s} = 0.636\ \text{m}$ $\text{number of lengths} = \frac{0.636\ \text{m}}{0.05\ \text{m}} = 12.7$	**5**
14(b)	An explanation that makes reference to the following points: • Energy released does not change, so same final velocity **(1)** • Same increase in velocity over longer time means a smaller acceleration **(1)** • Smaller force exerted by legs during jump **(1)** • So smaller force on ground **(1)** MP3 and MP4 dependent upon MP2	Alternative explanation. • Energy released does not change so work done does not change • Work done = Force x displacement • As legs are longer, force exerted by legs during jump is smaller • So smaller force on ground	**4**

14(c)	• Vertical velocity component increases by factor of 1.2, so time in air increases by a factor of 1.2 **(1)** • Horizontal component of velocity increases by factor of 1.2, **(1)** • Horizontal distance travelled increases by a factor of 1.2×1.2 = 1.44 **(1)** • So jump length would increase by 44%, not by 100% **(1)** **OR** • (20% increase in v means that) new jump velocity = 1.2 v **(1)** • Use of expressions for time to greatest height and horizontal distance **(1)** • Jump length is proportional to v^2 **(1)** • New jump length = 1.44 × original jump length, so not double the length **(1)**	Example of calculation $u \rightarrow 1.2u$ $t \rightarrow 1.2t$ $s = ut$ $\therefore s \rightarrow 1.2u \times 1.2t$ $s \rightarrow 1.44s$	**4**

(Total for Question = 14 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
5	**D** kg m s^{-2}		**1**

Question Number	Acceptable answers	Additional guidance	Mark
3	**The only correct answer is C** A *is not correct because acceleration* ***is*** *0* as *v* constant B *is not correct because there* ***is*** *a resistive force opposing weight* D *is not correct because there* ***is*** *a weight*	There is a resultant force acting on the object.	**1**

Question Number	Acceptable answers	Additional guidance	Mark
3	B		**1**

Question Number	Answers	Mark
1	**The only correct answer is A** ***B*** *is incorrect because the drag force increases as the skydiver falls through the air* ***C*** *is incorrect because the drag force increases as the skydiver falls through the air* ***D*** *is incorrect because the drag force increases as the skydiver falls through the air*	1

Question Number	Answer	Mark
6	**B P and Q will have the same maximum velocity**	**1**
	A – the graph is incorrect C – the graph is incorrect	
	D – the graph is incorrect	

7	**C (2.5 × 4.3) + (2.5 × 9.81)** A – this answer is incorrect B – this answer is incorrect D – this answer is incorrect	**1**

Question Number	Answer	Mark
1	**C** Incorrect Answers: A – this answer is incorrect, there is no force upwards on the ball B – this answer is incorrect, there is no force upwards on the ball D – this answer is incorrect, there is also a downward air resistance force as the ball is moving upwards	**1**

Question Number	Answer	Mark
5	**B** Incorrect Answers: A – normal force and friction are different types of forces and not in opposite directions C – weight and normal force on the road, are in the same direction and are different types of force. D – weight and normal force on the car are different types of force and are both on the same object.	1

9	**The only correct answer is D** A is not the correct answer, as $mg - R = ma$ B is not the correct answer, as $mg - R = ma$ C is not the correct answer, as $mg - R = ma$		**1**

Question Number	Answer	Mark
3	**The only correct answer is A the only force on the ball is weight** **B** *is not correct because the only force on the ball is weight* **C** *is not correct because the only force on the ball is weight* **D** *is not correct because the only force on the ball is weight*	1

9	**The only correct answer is D**  A is not the correct answer, as the only force acting on the ball is weight B is not the correct answer, as the only force acting on the ball is weight C is not the correct answer, as the only force acting on the ball is weight		**1**

Question Number	Answer	Mark
1	**A – The resultant force decreases as the ball-bearing falls.**	1
	Incorrect Answers: B – resultant force = weight − drag force, drag force increases with speed, so the resultant force decreases C – resultant force = weight − drag force, drag force increases with speed, so the resultant force decreases D – resultant force = weight − drag force, drag force increases with speed, so the resultant force decreases	

Question Number	Acceptable answers	Additional guidance	Mark
11	An explanation that makes reference to the following points: • The balloon applies a force to the (released) air **(1)** • By Newtons 3rd law the air applies a force to the balloon in the opposite direction **(1)** • There is a (resultant) force on the car **(1)** • By Newtons 2nd Law the car accelerates **(1)**	MP4 dependent on MP3	**4**

(Total for Question 11 = 4 marks)

***5**

This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

Number of indicative points seen in answer	Number of marks awarded for indicative points
6	4
5-4	3
3-2	2
1	1
0	0

Indicative content:

- Newton's 3rd law pair of forces must be of the same type
  Or Newton's 3rd law pair of forces must act on different bodies
- The two forces mentioned are not a 3rd Law pair
  Or gravity is not a good description of force
- The lift on the plane should be paired with the push of the plane on the air
  Or the gravitational force of Earth on plane should be paired with the gravitational force of plane on Earth.
- If the vertical resultant force is zero the plane will not accelerate vertically
- So the plane could be 'at rest' or moving with uniform velocity in the vertical direction
- There must be some horizontal motion so plane can't be in same place

The following table shows how the marks should be awarded for structure and lines of reasoning

	Number of marks awarded for structure and lines of reasoning
Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkage between points and is unstructured	0

Linkage Marks

IC points 1 – 3
Two of these points could score one linkage mark

IC points 4 – 6
Two of these points could score one linkage mark

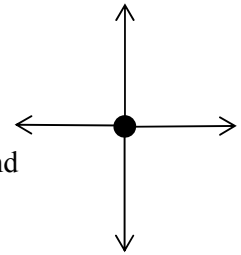
6

(Total for Question 5 = 6 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr>
<td>*14</td>
<td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

Indicative content
IC1 The student applies a force to the skateboard
IC2 By Newtons 3rd Law the skateboard also applies a force to the student
IC3 The two forces are equal in size but opposite in direction
IC4 The student accelerates according to Newtons 2nd Law
IC5 The skateboard decelerates according to Newton's 2nd Law.
IC6 The skateboard has a higher (magnitude of) acceleration than the student as it has a smaller mass</td>
<td>The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><td></td><td>Number of marks awarded for structure and lines of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkage between points and is unstructured</td><td>0</td></tr>
</table>
Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning
<table>
<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
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<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
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<td>6</td>
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(Total for Question 14 = 6 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
10(a)	Four forces correctly labelled (1 force correctly labelled scores one mark 2 or 3 forces correctly labelled scores two marks 4 forces correctly labelled scores three marks)	(normal) contact force **Or** reaction (force) **Or** *N* **Or** *R* **Or** force of ground on child  *F* /Friction (between ground and child) Force/pull of rope on child **Or** tension/*T* Weight/*W*/*mg* **Or** gravitational force	**3**

***10(b)**

This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5-4	3
3-2	2
1	1
0	0

Indicative content

- The idea that the rope is under tension
- Team A exerts a force on the rope and due to N3 the rope exerts a force on Team A
- Force of rope on team A > frictional force for Team A
- Team A now has a resultant force (to the right)
- Team A accelerates (to the right) due to N1/2
- (This is because) the frictional force between Team B and the ground is larger **Or** Team B applies a greater force (on the rope) than team A

The following table shows how the marks should be awarded for structure and lines of reasoning

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Accept tension for 'force of rope on team'

MP4: accept 'unbalanced' for 'resultant'

Accept converse for MP6 but a reference to both Team A and Team B is required for MP6

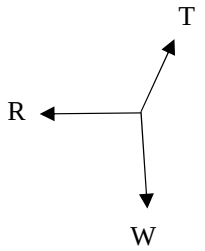
6

(Total for Question 10 = 9 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
13(a)	**Either (Energy route)** • Use of $E_k = ½ mv^2$ **and** use of $W = Fd$ • Use of $W = E_k$ • Length of the road train = 194 (m) **Or (suvat route)** • Use of $v^2 = u^2 + 2as$ with $v = 0$ to calculate the deceleration • Use of $v^2 = u^2 + 2as$ with $u = 25$ m s^{-1} and calculated a • Length of the road train = 194 or 195 (m) (Do not award MP3 using suvat route for a substitution with u and v the wrong way round i.e. a positive value for a)	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	Example of calculation $E_k = ½ \times m \times (15 \text{ m s}^{-1})^2$ $½ \times m \times (15 \text{ m s}^{-1})^2 = F \times 70$ m $m = 0.62F$ $½ \times m \times (25 \text{ m s}^{-1})^2 = F \times$ d $½ \times 0.62F \times (25 \text{ m s}^{-1})^2 = F \times$ d $d = 194$ m Example of calculation $0 = (15 \text{ m s}^{-1})^2 + (2 \times a \times 70 \text{ m})$ $a = -1.61 \text{ m s}^{-2}$ $0 = (25 \text{ m s}^{-1})^2 + (2 \times (-1.61 \text{ m s}^{-2}) \times s)$ $s = 194$ m (Reverse show that max 2 for either route)	**3**
13(b)	• Use of m s$^{-1} = \frac{3600}{1000}$ km h^{-1} • Use of correct equation(s) of motion to obtain the displacement • $s = 55$ m	**(1)** **(1)** **(1)**	(MP2 independent of MP1 and is for use of the equations using the speed in m s^{-1} or km h^{-1}) Example of calculation $(\frac{130 \text{ km h}^{-1} \times 1000 \text{ m}}{3600 \text{ s}})^2 = (30 \text{ m s}^{-1})^2 + (2 \times 3.7 \text{ m s}^{-2} \times s)$ $s = 54.6$ m	**3**

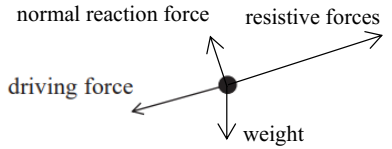
13(c)	• As the speed increases, drag increases **(1)** • There is greater fuel consumption to maintain a higher constant speed **Or** the fuel economy reduces at higher speeds to maintain a constant speed **(1)** • Statement linking fuel economy to engine efficiency **(1)**	MP1: accept 'air resistance' for 'drag' MP3 e.g. The efficiency of the engine may increase (with speed) but the fuel economy decreases **Or** you can't compare efficiency which is a ratio with fuel consumption/economy which is a volume	**3**

(Total for Question 13 = 9 marks)

Question Number	Acceptable answers		Additional guidance	Mark
16(a)	• Arrow upwards and to the right at approximately 20° to the vertical labelled Tension/T	**(1)**		
	• Arrow to left and horizontal labelled Reaction/R	**(1)**	Accept Push (from rock) /Contact	
	• Arrow vertically down labelled Weight/W/mg/540 N	**(1)**		
			Max 2 if any additional arrows drawn	**3**
16(b)(i)	• Resolve tension vertically: $T\cos 20$ **Or** $T\sin 70$	**(1)**	Example of calculation $55 \times 9.81 = T\cos 20$	
	• Equate mg and their vertical component of T	**(1)**	T = 574 N	
	• Tension = 570 (N)	**(1)**		**3**
16(b)(ii)	• Use of $\Delta E = \frac{1}{2} F \Delta x$	**(1)**	(ecf from (b)(i)) show that value gives 7.5 J	
	• Energy stored = 7.1 – 7.2 J	**(1)**	Example of calculation $\Delta E = \frac{1}{2} \times 570 \text{ N} \times 2.5 \times 10^{-2} \text{ m}$ ΔE = 7.1 J	**2**
16(b)(iii)	• Rope has extended linearly **Or** Hooke's law applies **Or** extension ∝ force **Or** has not exceeded limit of proportionality	**(1)**	Do not accept elastic limit	**1**

(Total for Question 16 = 9 marks)

Question Number	Acceptable answers	Additional guidance	Mark
12a	• Opposite horizontal force, labelled friction/resistance/drag **(1)** • Vertically downward force labelled *W*/weight/*mg* **(1)** • Vertically upwards force labelled *R*/Reaction/*N*/Normal (contact force) **(1)**	ignore extra words such as ..of bicycle	**3**
12 b(i)	• straight line starting on *v* axis with negative gradient **(1)** • intercept on *t* axis marked 5.2 with unit s **(1)**		**2**
12b(ii)	• Use of $s = \frac{(u+v)t}{2}$ with $v = 0$ **(1)** • Use of another SUVAT equation to determine *a* **(1)** • Use of $F = ma$ **(1)** • Resistance = 16 N **(1)** **Or** • Use of area = base × height / 2 **(1)** • Use of acceleration is gradient of line **(1)** • Use of $F = ma$ **(1)** • Resistance = 16 N **Or** • Use of $s = (u + v)t/2$ with $v = 0$ • Use $E_k = ½ mv^2$	<u>Example of calculation</u> Using SUVAT eg $7.8\text{ m} = (u + 0)5.2\text{ s}/2$ $u = 3.0\text{ m s}^{-1}$ $7.8\text{ m} = 3.0\text{m s}^{-1} \times 5.2\text{ s} + \frac{1}{2} a\, 5.2^2\text{ s}^2$ $a = (–)0.58\text{ m s}^{-2}$ Using area under graph $\text{Area} = 7.8\text{ m} = v \times \frac{5.2\text{ s}}{2}$ $v = 3.0\text{ m s}^{-1}$ $a = \text{gradient} = \frac{3.0\text{ m s}^{-1}}{5.2\text{ s}}$ $a = (–)0.58\text{ m s}^{-2}$ $F = 28\text{ kg} \times 0.58\text{ m s}^{-2}$ $F = 16.2\text{ N}$	**4**

Question Number	Acceptable answers		Additional guidance	Mark
13(a)(i)	• Weight vertically downwards	(1)	Accept W	
	• Resistive forces acting up the slope	(1)		
	• Normal reaction force perpendicular to the slope	(1)	Accept N or R	3
				
13(a)(ii)	• Use of $1.2 \times 10^4 \times \sin 11°$	(1)	Example of Calculation. Component of weight parallel to the slope = 1.2×10^4 N × sin11° Component of weight parallel to the slope = 2290 N Driving force = 2530 N − 2290 N Driving force = 240 N	
	• Use of total force up slope equals total force down slope	(1)		
	• Driving force = 240 N	(1)		3
13(b)(i)	• Evidence of calculation of gradient	(1)	Example of Calculation. Gradient = (25 – 0) / (3.7 – 0.4) Gradient = 7.6 Acceleration = 7.6 m s^{-2} F = 2400 kg × 7.6 m s^{-2} $F = 1.8 \times 10^4$ N	
	• Gradient identified as acceleration	(1)		
	• Use of $F = ma$	(1)		
	• $F = 1.6 \times 10^4 - 1.9 \times 10^4$ (N)	(1)		4

13(b)(ii)	• Kinetic energy (of vehicle) transferred to kinetic energy of gravel **Or** Kinetic energy (of vehicle) transferred to thermal energy (of gravel/tyres/ground)	(1)		1

(Total for Question 13 = 11 marks)

Question Number	Acceptable answers	Additional guidance	Mark
10	• calculation of gradient of the graph **(1)** • Use of $s = ½ at^2$ to obtain value for g **(1)** • Total uncertainty = 7 % **(1)** • Calculation of % difference **Or** Range of calculated g **(1)** • Judgment on accuracy of experiment with reason **(1)**	MP2: use of $\frac{2}{\text{gradient}}$ MP3: percentage uncertainty = 3 % + 3 % + 1 % MP5: e.g. comparison of total uncertainty with % difference **Or** comparison of calculated range with 9.81 m s^{-2} <u>Example of calculation</u> Gradient = $\frac{0.385\ s^2 - 0.06\ s^2}{1.8\ m - 0.4m} = 0.232\ s^2\ m^{-1}$ $g = \frac{2}{0.232\ s^2\ m^{-1}} = 8.67\ m\ s^{-2}$ Percentage difference $= \left(\frac{9.81\ m\ s^{-2} - 8.67\ m\ s^{-2}}{9.81\ m\ s^{-2}}\right) \times 100 = 12\ \%$	**5**

(Total for Question 10 = 5 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
12(a)(i)	An explanation that makes reference to the following points: • t_1 is not significantly different from the other times **Or** t_1 is only 0.6% different from t_{mean} **Or** there is not enough data to show that t_1 is anomalous **(1)** • So the student who says that all the data should be used is correct **(1)**	MP2 dependent upon MP1	**2**
12(a)(ii)	• Mean t calculated **(1)** • Uses half range **Or** Uses furthest from mean **(1)** • % U = 0.4 % given to 1 or 2 sig figs only **(1)** 0.5% using furthest from mean	Example of calculation $t_{mean} = \frac{7.85\text{ s} + 7.81\text{ s} + 7.79\text{ s} + 7.80\text{ s}}{4}$ $= 7.81\text{ s}$ Half range $= \frac{7.85\text{ s} - 7.79\text{ s}}{2} = 0.03\text{ s}$ $\%\text{ U} = \frac{0.03\text{ s}}{7.81\text{ s}} \times 100\% = 0.38\ \%$	**3**
12(a)(iii)	• Height of cylinder **Or** Length of cylinder **(1)**		**1**

12(b)(i)	• Use of $v^2 = u^2 + 2as$ **(1)** • $v = 3.8\ \text{m s}^{-1}$ **(1)**	Example of calculation $v^2 = u^2 + 2as$ $\therefore v = \sqrt{2 \times 9.81\ \text{m s}^{-2} \times 0.75\ \text{m}} = 3.84\ \text{m s}^{-1}$	**2**
12(b)(ii)	An explanation that makes reference to the following points: • The cylinder is travelling (very) quickly (when it reaches the light gate) **(1)** • Therefore the time taken for the cylinder to pass through the light gate is (very) short **(1)** • Using the light gate and a data logger there is minimal effect from reaction time **Or** Difficult/impossible to press stopwatch button again after such a short time **(1)**		**3**

(Total for Question 12 = 11 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
2	**D** -0.60 kg m s^{-1}		**1**

7	**The only correct answer is D** A is not the correct answer, as change in momentum is the same. B is not the correct answer, as change in velocity is the same. C is not the correct answer, as force decreases.		**1**

Question Number	Answer	Mark
2	**The only correct answer is B P and Q have the same magnitude of momentum.** **A** *is not correct because Q moves faster than P as it has a smaller mass and they have the same magnitude of momentum.* **C** *is not correct because Q moves faster than P as it has a smaller mass and they have the same magnitude of momentum.* **D** *is not correct because Q moves faster than P as it has a smaller mass and they have the same magnitude of momentum.*	1

8	**D $\frac{v}{6}$ using conservation of momentum**	**1**
	Incorrect Answers: A – as the mass of the stack is greater than the mass of a trolley, then the velocity of the stack must be less that *v*. B – as the mass of the stack is greater than the mass of a trolley, then the velocity of the stack must be less that *v*. C – when the trolley combines with the stack, the stack then contains 6 trollies.	

(Total for Multiple Choice Questions = 8 marks)

Question Number	Acceptable answers	Additional guidance	Mark
12(a)	• Use of $p = mv$ **(1)** • Use of principle of conservation of momentum **(1)** • Magnitude of velocity = 0.2 m s^{-1} with direction to the left **(1)**	MP1: see 0.3 m, 0.7 m or 2mv MP3: accept 'in the initial direction of glider 2' for 'to the left' <u>Example of calculation</u> (taking the initial direction of glider 1 as positive) 0.3 m – 0.7 m = 2mv v = – 0.2 m s^{-1}	**3**
12(b)	• Glider 1 exerts this force on glider 2, so according to N3 **(1)** • Glider 2 will exert an (equal and) opposite force on glider 1 **(1)** • There is now a resultant force on glider 1 **(1)** • Glider 1 accelerates according to N1 **Or** glider 1 now moves to the left according to N1 **(1)**		**4**

(Total for Question 12 = 7 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
7(a)	• Use of $E_{\text{grav}} = mg\Delta h$ **(1)** • Use of $E_{\text{K}} = \frac{1}{2}mv^2$ for block and projectile **(1)** • Use of $p = mv$ **(1)** • Use of conservation of momentum **(1)** • Use of $E_{\text{K}} = \frac{1}{2}mu^2$ for projectile **(1)** • ΔE = 490 J **(1)**	MP1: Use of suvat equation to calculate u MP2: Use of $E_{\text{K}} = \frac{1}{2}mv^2$ for block and projectile **Or** use of $E_{\text{grav}} = mg\Delta h$ Example of calculation $E_{\text{grav}} = (2.4 + 0.065)\text{kg} \times 9.81\ \text{m s}^{-2} \times 0.55\ \text{m} = 13.3\ \text{J}$ (of block and projectile) $13.3\ \text{J} = \frac{1}{2} \times (2.4 + 0.065)\text{kg} \times v^2$ $\therefore v = \sqrt{\frac{13.3\ \text{J}}{0.5 \times 2.465\ \text{kg}}} = 3.28\ \text{m s}^{-1}$ $0.065\ \text{kg} \times u = 2.465\ \text{kg} \times 3.28\ \text{m s}^{-1}$ $\therefore u = \frac{8.10\ \text{kg m s}^{-1}}{0.065\ \text{kg}} = 124.6\ \text{m s}^{-1}$ $E_{\text{K}} = \frac{1}{2} \times 0.065\ \text{kg} \times (125\ \text{m s}^{-1})^2 = 504\ \text{J}$ $\therefore \Delta E = (504 - 13.3)\ \text{J} = 491\ \text{J}$	**6**
7(b)	• Total energy is constant, but kinetic energy decreases **Or** reference to an inelastic collision **(1)** • Projectile does work on block **Or** internal energy of block increases **(1)**		**2**

(Total for Question 7 = 8 marks)

Question Number	Acceptable answers	Additional guidance	Mark
13(a)	• Use of $p = mv$ **(1)** • Use of momentum conservation **(1)** • $v = 4.1$ m s^{-1} **(1)**	Example of calculation $p_i = (66 + 52)\text{ kg} \times 5.6\text{ m s}^{-1}$ $p_f = (66\text{ kg})v + (52\text{ kg} \times 7.5\text{ m s}^{-1})$ $\therefore v = \frac{(661 - 390)\text{ kg m s}^{-1}}{66\text{ kg}} = 4.11\text{ m s}^{-1}$	**3**
13(b)	An explanation that makes reference to the following points: • (Male skater exerts a force on female skater), so according to N3 **(1)** • Female skater will exert an (equal and) opposite force on male skater **(1)** • There is now a resultant force on male skater • Male skater decelerates according to N1/N2 **(1)** **Or** male skater's velocity decreases according to N1/N2 **(1)**		**4**
13(c)	An explanation that makes reference to the following points: • Male skater does work as he pushes female skater **Or** Energy transfers from the male skater as he pushes female skater **(1)** • So there is an increase in kinetic energy **(1)**		**2**
	[MP2 dependent on MP1]		

(Total for Question 13 = 9 marks)

Question Number	Acceptable answers	Additional guidance	Mark
15(a)(i)	• Use of $\lambda = h/p$ **and** $v = f\lambda$ **(1)** • Momentum of photon = 3.3×10^{-27} (N s) **(1)**	Example of calculation Momentum of photon = $p = hf/c$ = 6.63×10^{-34} J s × 1.5×10^{15} Hz ÷ 3.00×10^{8} m s^{-1} = 3.315×10^{-27} N s	**2**
15(a)(ii)	• Momentum transfer = 6.6×10^{-27} (N s) **(1)**	Ecf momentum from (i) in parts (a)(ii) and (c)	**1**
15(b)(i)	• Use of $hf = \varphi + ½\ mv^2_{max}$ **(1)** • Use of $E_K = ½\ mv^2$ **(1)** • $v = 8.4 \times 10^{5}$ (m s^{-1}) **(1)**	Example of calculation $hf = \varphi + ½\ mv^2_{max}$ $hf = 6.63 \times 10^{-34}$ J s × 1.5×10^{15} Hz = 9.95×10^{-19} J $hf - \varphi = 9.95 \times 10^{-19}$ J − 6.7×10^{-19} J = 3.25×10^{-19} J 3.25×10^{-19} J = ½ × 9.11×10^{-31} kg × v^2 $v = 8.4 \times 10^{5}$ m s^{-1}	**3**
15(b)(ii)	• Use of $p = mv$ **(1)** • Momentum of photoelectron = 7.7×10^{-25} N s **(1)**	Example of calculation $p = 9.11 \times 10^{-31}$ kg × 8.4×10^{5} m s^{-1} Momentum of photoelectron = 7.68×10^{-25} N s MP2: Using show that value $p = 7.3 \times 10^{-25}$ N s	**2**
15(c)	An explanation that refers to the following points: • the change in momentum of the graphene oxide is the same as the change in momentum of the photoelectron **(1)** • so the (change in) momentum is much larger for the photoelectron than for the reflected photon **(1)**	Accept converse statement and answer that is consistent with candidate's values in (a) and (b)	**2**

(Total for Question 15 = 10 marks)

Question Number	Acceptable answers	Additional guidance	Mark
		12	

Question Number	Acceptable answers	Additional guidance	Mark
15(a)(i)	• Use of $p = mv$ **(1)** • $p = 5.4$ (kg m s^{-1}) **(1)**	Example of calculation $p = 0.012$ kg × 450 m s^{-1} = 5.4 kg m s^{-1}	**2**
15(a)(ii)	• Use of principle of conservation of linear momentum **(1)** • Use of ½ $mv^2 = mgh$ **(1)** • $h = 0.24$ m (ecf from (a)(i)) **(1)**	Example of calculation 5.4 kg m s^{-1} = (2.5 kg + 0.012 kg) × v $v = 2.1$ m s^{-1} ½ $mv^2 = mgh$ ½ (2.1 m s^{-1})^2 = 9.81 m s^{-2} × h $h = 0.24$ m	**3**
15(b)	An explanation that makes reference to the following points: • The final momentum/velocity of the bullet is negative **Or** The final momentum/velocity of the bullet is in the opposite direction **(1)** • The change in momentum of the bullet is greater **(1)** • The (change in) momentum of the steel block is greater (because momentum is conserved) **(1)** • So steel block has greater initial velocity **Or** steel block has greater initial E_K **(1)** • So gains greater E_P (and moves through a greater maximum vertical height) **(1)** [Dependent upon MP4]		**5**

(Total for Question 15 = 10 marks)
TOTAL FOR SECTION A = 56 MARKS

<table>
<tr><th>Question Number</th><th>Additional guidance</th><th colspan="2">Mark</th></tr>
<tr><td>*14(a)</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5 - 4</td><td>3</td></tr>
<tr><td>3 - 2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
Indicative content
• Sphere A applies a force to sphere B (on impact)
• According to Newtons third law Sphere B will apply an (equal and) opposite force to Sphere A
• This force opposes the motion of Sphere A
• Sphere A decelerates, according to N2
• The (resultant) force on sphere B accelerates B
• The forces/impulse acting (on the spheres) are equal so the change in speeds/momentum are the same for each sphere.</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table></td><td>6</td></tr>
</table>

14 (b)	• Measurement of change in height of Sphere A **(1)** • actual height = $\frac{\text{image height} \times 11}{4.8}$ **(1)** • Use of E_k gained = E_{grav} lost to determine v **(1)** • Use of $p = mv$ **(1)** • $p_A = 0.025$ kg m s^{-1} **(1)**	Initial decrease in height from photo = 2.9 ± 0.1 cm Height of frame in photo = 4.8 ± 0.1 cm MP2-4 award even if measurement for the height is out of range MP3 use of equation of motion scores 0 Example of calculation $h_A = \frac{2.9 \text{ cm} \times 11 \text{ cm}}{4.8 \text{ cm}} = 6.6$ cm ½× 0.022 kg × v_A^2 = 0.022 kg × 9.81 N kg^{-1} × 6.6 × 10^{-2} m $v_A = 1.14$ m s^{-1} $p_A = 0.022$ kg × 1.14 m s^{-1} = 0.025 kg m s^{-1} Accept p_A in range 0.024 – 0.026 kg m s^{-1}	**5**

(Total for Question 14 = 11 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*8(a)</td>
<td>This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning.

Indicative content:
IC1 Elastic P.E. (of the spring) is transferred to K.E. of the modelling clay

IC2 Clay has momentum before hitting the bob

IC3 Momentum is conserved when clay hits the bob

IC4 K.E. is transferred from the clay to the bob

IC5 Collision is inelastic
Or K.E. is not conserved
Or In the collision (some) energy is transferred to thermal energy

IC6 At the maximum height/displacement of the bob all the K.E. (after the collision) has been transferred to gravitational P.E.</td>
<td>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.

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<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
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<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>

Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning
<table>
<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
<tr><td>4</td><td>3</td><td>1</td><td>4</td></tr>
<tr><td>3</td><td>2</td><td>1</td><td>3</td></tr>
<tr><td>2</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>

(Accept responses in terms of energy stores model)</td>
<td>6</td>
</tr>
</table>

8(b)(i)	• Use of $T = 2\pi\sqrt{\frac{l}{g}}$ **(1)** • Time to reach maximum height = $T/4$ **(1)** • Time to reach maximum height = 0.56 (s) **(1)**	Example of calculation $T = 2\pi\sqrt{\frac{1.25\text{ m}}{9.81\text{ m s}^{-2}}} = 2.24\text{ s}$ $t = \frac{T}{4} = \frac{2.24\text{ s}}{4} = 0.56\text{ s}$	**3**
8(b)(ii)	• Use of $T = 2\pi\sqrt{\frac{m}{k}}$ **(1)** • m = 0.015 kg (ecf from (b)(i)) [show that value gives 0.018 kg] **(1)**	Example of calculation $2.24\text{ s} = 2\pi\sqrt{\frac{m}{0.12\text{ N m}^{-1}}}$ $\therefore m = \left(\frac{2.24\text{ s}}{2\pi}\right)^2 \times 0.12\text{ N m}^{-1} = 0.0153\text{ kg}$	**2**

(Total for Question 8 = 11 marks)

Question Number	Acceptable answers	Additional guidance	Mark
14(a)	• Use of $v^2=u^2+2as$ **(1)** • $v = 0$ so $u = \sqrt{-2as}$ **(1)** • a is a deceleration caused by friction (with surface) **(1)** • States $F = ma$ where F is friction **(1)** • As $F = km = ma$ so a must be constant **Or** $F=ma$ if F proportional to m then a must be constant **(1)** • so acceleration a the same (as 1 p coin) so statement correct **(1)**	ignore whether minus sign included or not Alternative: • Work done by friction (with surface) • States $W= Fs$ • States $E_k = ½ mu^2$ • So $Fs = ½ mu^2$ • As $F = km$ • m's cancel so statement correct	**(6)**
14(b)(i)	• Use of momentum = mv **(1)** • See component(s) in x direction **(1)** • Uses momentum conservation **(1)** • u = 1.6 (m s^{-1}) **(1)**	Example of calculation: $7.1(g)u = 7.1(g) \times 0.9(ms^{-1}) \times cos\,8 + 3.6(g) \times 1.4(ms^{-1}) \times cos\,10$ $u = \frac{(6.33 + 4.96)}{7.1}$ $u = 1.59 ms^{-1}$	**(4)**

14(b)(ii)	• Use of $E_k = ½ mv^2$ • Value of Initial $E_k = 9.0\times10^{-3}$ (J) and Final $E_k = 6.4\times10^{-3}$ (J) (Show that value gives Initial $E_k = 1.42 \times10^{-2}$ (J) allow ecf from (b)(i))	**(1)** **(1)**	Allow ecf from b(i) Example of calculation: Initial $E_k = ½ \times7.1\times10^{-3}(kg)\times1.59^2(ms^{-1})^2 = 9.0\times10^{-3}$ J Final $E_k = ½ \times7.1\times10^{-3} \times 0.9^2 + ½ \times3.6\times10^{-3} \times1.4^2 = 6.4\times10^{-3}$ J	**(2)**

(Total for Question 14 = 12 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th></th></tr>
<tr><td>8(a)</td><td>
• Use of $s = \frac{(u+v)}{2}.t$ (1)
• Use of $E_k = \frac{1}{2}mv^2$ (1)
• Use of $P = \frac{\Delta W}{\Delta t}$ (1)
• P = 110 W (1)
</td><td>
Example of calculation:
$32.5\text{ m} = \frac{(u+0)}{2} \times 17.5\text{ s}$
$\therefore u = \frac{32.5\text{ m} \times 2}{17.5\text{ s}} = 3.71\text{ m s}^{-1}$
$P = \frac{\Delta E_k}{\Delta t} = \frac{\frac{1}{2} \times 19.6\text{ kg} \times (3.7\text{ m s}^{-2})^2}{1.25\text{ s}} = 107\text{ W}$
</td><td>4</td></tr>
<tr><td>8(b)</td><td>
This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

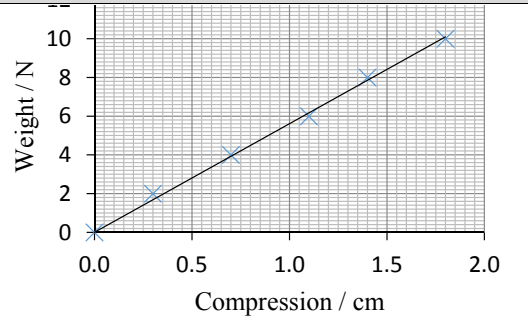
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The table shows how the marks should be awarded for indicative content and lines of reasoning.

<table>
<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark available</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
<tr><td>4</td><td>3</td><td>1</td><td>4</td></tr>
<tr><td>3</td><td>2</td><td>1</td><td>3</td></tr>
<tr><td>2</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
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</td><td>
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</table>
</td><td></td></tr>
</table>

	Indicative content: • (Collision takes place on an ice surface so) there is minimal friction **Or** External forces are negligible • Momentum is conserved in the collision • The momentum of stone A before the collision equals the momentum of (A and) B after the collision • Stone A must be at rest after the collision • All of the kinetic energy of stone A must have been transferred to stone B • Kinetic energy is conserved in an elastic collision		**6**
8(c)	An explanation that makes reference to the following points: • Sweeping the ice smooths out the surface **Or** Sweeping the ice melts the suraface of the ice. **(1)** • So frictional forces are reduced (and the deceleration of the stone is reduced) **(1)**	For MP2 accept references to a lower rate of working against friction **Or** less work done against friction for a given displacement	**2**

(Total for Question 8 = 12 marks)

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr>
<td>16(a)(i)</td>
<td>
Processing of data to calculate change in length (1)
Axes with labels & units (accept force for weight) (1)
Scales (1)
Plots (1)
Line of best fit (1)
<table>
<tr><th>Weight/ N</th><th>Compression/ cm</th></tr>
<tr><td>0.00</td><td>0.0</td></tr>
<tr><td>2.00</td><td>0.3</td></tr>
<tr><td>4.00</td><td>0.7</td></tr>
<tr><td>6.00</td><td>1.1</td></tr>
<tr><td>8.00</td><td>1.4</td></tr>
<tr><td>10.00</td><td>1.8</td></tr>
</table>
</td>
<td>


MP2: only award for a graph of weight against compression. Units may be in m or cm for compression. Allow paper to be landscape

MP3: scales only in 1,2,4,5 and must cover at least half of paper

MP4: a 2 mm square tolerance, check all points
</td>
<td>5</td>
</tr>
<tr>
<td>16(a)(ii)</td>
<td>
• States that best fit line is through the origin (1)
• So it fits Hooke's law because extension is proportional to force (1)
• Uses corresponding values from best fit line from (a)(i) to determine gradient (1)
• Spring constant = 10.0 N / 0.0176 m = 568 (N m^{-1}) (which, 1 s.f., is the stated answer) (1)
</td>
<td>
If plunger position plotted in (a)(i) then only MP2 may be awarded for attempt at gradient

MP3: values selected from at least half way along line or a triangle using over half the line is used

MP4: conditional on MP3 and allow any value that rounds to 1 sf as 600
</td>
<td>4</td>
</tr>
</table>

16(b)	• Use of $\Delta F = k\Delta x$ **(1)** • Use of $\Delta E_{el} = ½ F\Delta x$ **(1)** • Use of $E_k = ½ mv^2$ **(1)** • $v = 6.7$ m s^{-1} to 6.8 m s^{-1} **(1)**	Example of calculation $\Delta F = k\Delta x = 610$ N m^{-1} × 0.054 m = 32.94 N $\Delta E_{el} = ½ F\Delta x = ½ \times 32.94$ N × 0.054 m = 0.90 J $E_k = ½ mv^2$ so 0.90 J = ½ × (0.0041 + 0.0354) kg × v^2 $v = 6.75$ m s^{-1}	**4**
16(c)	Work may be done against friction (by the spring/marble) **Or** KE is gained by the spring **Or** GPE gained by the piston **and** marble **Or** the light gate must be above the launch position so the marble is already accelerating downwards **Or** statement of friction between two specified parts in launch system **(1)**		**1**

(Total for Question 16 = 14 marks)

Question Number	Acceptable answers	Additional guidance	Mark
2	B		**1**

Question Number	Acceptable answers	Additional guidance	Mark
6	**The only correct answer is A** B is not correct as these forces are not in equilibrium C is not correct as these forces are not in equilibrium D is not correct as these forces are not in equilibrium		1

Question Number	Acceptable answers	Additional guidance	Mark
9	• Use moment = $F\,x$ **(1)** • $x = 0.49$ m **(1)**	Example of calculation $6.5\ \text{N} \times (0.75\ \text{m} - x) = 3.5\ \text{N}\ x$ $4.875\ \text{Nm} - 6.5\ x = 3.5\ x$ $x = \frac{4.875\ \text{Nm}}{10\ \text{N}} = 0.488\ \text{m}$	**2**

(Total for Question 9 = 2 marks)

Question Number	Acceptable answers	Additional guidance	Mark
9	An explanation that makes reference to the following points: • The force from the wind produces an anticlockwise moment (about the point where the sail attaches to the board) **(1)** • The (weight of the) windsurfer produces a moment in the opposite direction **(1)** • So the windsurfer leans back until the moment due to his weight has increased to equal the (increased) moment of the wind force **(1)**		**3**

(Total for Question 9 = 3 marks)

Question Number	Acceptable answers		Additional guidance	Mark
11a	• the point through which the weight (of a body) acts **Or** The point around which the mass is equally distributed **Or** if supported at/below this point the body would be in equilibrium	**(1)**	alt. the point at which the entire mass can be assumed to be located.	**1**
11b	• take one moment around P • Use of $W = mg$ • Use of weight/mass of paving slab at centre point • It would tip because the moment of the weight of person is 103 N m / 10300 N cm and is larger than the moment of the weight of slab 93 N m / 9300 N cm	**(1)** **(1)** **(1)** **(1)**	either person or paving slab e.g. distance to P = 30 cm Example of calculation: Moment of weight of person = 70 kg×9.81 N kg^{-1}×0.15 m = 103 N m Moment of weight of paving slab = 310 N ×0.30 m = 93 N m	**4**

(Total for Question 11 = 5 marks)

Question Number	Acceptable answers	Additional guidance	Mark
16	**Either** • As x increases, the (clockwise) moment of the load about P increases **(1)** • (For equilibrium) the clockwise moment and the anticlockwise moment about P must be equal **(1)** • So F_Q must increase (to increase the anticlockwise moment) MP3 dependent on MP2. **(1)** • (For equilibrium) the resultant vertical force must be zero **Or** As x increases, the (anticlockwise) moment of the load about Q decreases **(1)** • As F_Q increases F_P must decrease **(1)**		

	OR • As x increases, the (anticlockwise) moment of the load about Q decreases **(1)** • (For equilibrium) the clockwise moment and the anticlockwise moment about Q must be equal **(1)** • So F_P must decrease (to decrease the clockwise moment) **(1)** MP3 dependent on MP2 • (For equilibrium) the resultant vertical force must be zero **Or** As x increases, the (clockwise) moment of the load about P increases **(1)** • As F_P decreases F_Q must increase **(1)**			**5**

(Total for Question 16 = 5 marks)

Question Number	Acceptable answers	Additional guidance	Mark
11(a)	• Moment of a force (around a point) = force × perpendicular distance (to line of action of the force from the point) **Or** Moment of a force (around a point) = distance (to the point) × perpendicular component of force **(1)**	need to see "perpendicular" or equivalent	**1**
11(b)	• Takes one moment around pivot **(1)** • Equates a clockwise and anticlockwise moment **(1)** • Correct distance to gold or people **(1)** • $y = 1.2$ m **(1)** Alternative • Resolves vertical forces • Takes one moment around CoG • Equates a clockwise and anticlockwise moment • $y = 1.2$ m	<u>Example of calculation</u> $32000 \text{ N} \times y + 8700 \text{ N} \times (y + 4.5) = 31000 \text{ N} \times (4.0 - y)$ $71700\, y = 124000 - 39150 = 84850$ $y = 1.18$ m Alternative: $R = 31000 + 32000 + 8700 = 71700$ N Moments about CoG $71700 \text{ N} \times y + 8700 \text{ N} \times 4.5 = 31000 \text{ N} \times 4.0$ $y = 1.18$ m	**4**

(Total for Question 11 = 5 marks)

Question Number	Acceptable answers	Additional guidance	Mark
10(a)	• sum of moments (about any point) is zero **(1)** **Or** resultant moment is zero (about any point) • sum of the forces (in any direction) is zero **Or** resultant force is zero (in any direction) **(1)**		**2**
10(b)(i)	• shows clockwise moment = anticlockwise **(1)**	<u>Example of calculation</u> M.2 = 2M.1	**1**
10(b)(ii)	• Moment of 3M associated with 1 **(1)** • Takes moments around suspension **(1)** • crow at A and owl at B **(1)** Alternative scheme for MP2 and MP3: • Show that, without the extra birds, it balances **(1)**	<u>Example of calculation</u> 3M.1 + x.2 = M.3 + y.1 2x = y So y must be an owl and x the crow	**3**
	• So added birds must be crow at A and owl at B, as in part (i) **(1)**		

(Total for Question 10 = 6 marks)

Question Number	Acceptable Answer		Additional guidance	Mark
13(a)(i)	• Working leading to $W = 245$ (N)	**(1)**	Example of calculation $W = 25.0 \text{ kg} \times 9.81 \text{m s}^{-2} = 245 \text{ N}$	**1**
13(a)(ii)	• Use of moment of force = Fx • Use of the principle of moments • Support force = 170 N (ecf from (a)(i))	**(1)** **(1)** **(1)**	Example of calculation 245 N × 2.5 m = F × 3.6 m F = 170 N Show that value gives 174 N	**3**
13(b)	• When plank tips, support force at rock = 0 **Or** When plank tips, clockwise moment is greater than anticlockwise moment • Use of principle of moments • If person is at the end, clockwise moment = 770 N, anticlockwise moment due to weight is 270 Nm < 770 Nm so student is correct **Or** Starts to tip when person is 0.49 m to the right of the wall, 0.49 m < 1.4 m so student is correct	**(1)** **(1)** **(1)**	Example of calculation 245 N × (2.5 – 1.4) m = 550 N × x x = 0.49 m < 1.4 m so tips **Or** 245 N × (2.5 – 1.4) m = 270 Nm 550 N × 1.4 m = 770 Nm 770 Nm > 270 Nm so it tips	**3**

(Total for Question 13 = 7 marks)

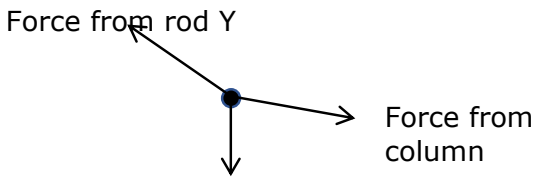
Question Number	Acceptable answers	Additional guidance	Mark
13(a)	• Use of moment = force × perpendicular distance **(1)** • Use of clockwise moments = anticlockwise moments **(1)** • Position of centre of gravity = 27 cm from base **(1)**	MP1 not awarded if cos θ not used or sin θ not used Example of calculation (18.5 kg × 9.81 N kg^{-1}) × x cos θ = 50 N × 0.97 m × cos θ x = 0.27 m	**3**
13(b)(i)	• Use of cos θ = vertical force ÷ applied force **(1)** • Answer 55 N **(1)**	Example of calculation cos θ = 50 N ÷ F F = 55.2 N	**2**
13(b)(ii)	• Correct use of trigonometrical function to determine force in direction of motion **(1)** • Use of $W = Fs$ **and** $P = W/t$ **Or** use of $v = s/t$ **and** $P = Fv$ **(1)** • P = 83 W **(1)**	MP3 allow ecf from (b)(i) Example of calculation F = 55.2 N × sin 25° = 23.3 N $P = \frac{23.3\text{ N} \times 15\text{ m}}{4.2\text{ s}}$ = 83.2 W	**3**

(Total for Question 13 = 8 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
12(a)	• Resultant force = 0 **(1)** • Resultant moment (about any point) = 0 **(1)**	Accept Clockwise moment = anticlockwise moment (about a point)	**2**
12(b)	• Use of Moment = $F.x$ around P **(1)** • Use of perpendicular component ie cos80 **(1)** • Use of clockwise moment = anticlockwise moment **(1)** • W = 3.3 N **(1)**	Accept: Use of Moment = $M.x$ around P Example of calculation Clockwise moment = 0.260 kg × 9.81 N kg^{-1} × 0.04 m = 0.102 N m Anticlockwise moment = W × 0.18 m × cos80 So 0.102 N m = W × 0.0313 W = 3.26 N	**4**
12(c)	• The whole lever-arm rotates through the same angle **(1)** • As the distance of pointer from the pivot is larger **Or** distance of the pan from pivot is smaller **(1)**	Accept as lever-arm radius is larger **Or** radius to pan is smaller	**2**

(Total for Question 12 = 8 marks)

Question Number	Acceptable answers	Additional guidance	Mark
13 (a)	• Take a correct moment about pivot P **(1)**	eg T.6.cos20 or sin70	**4**

Question Number	Acceptable answers		Additional guidance	Mark
14(a)(i)	• Attempt to take moments around right hand end of X • Use of $W = mg$ • Correct component of T or perpendicular distance to T • $T = 890$ N	(1) (1) (1) (1)	distance of 1.5 m used with 45 Or 1.3 m used with T Example of calculation $45\text{ kg} \times 9.81\text{ N kg}^{-1} \times 1.5\text{ m} = T \times 1.3\text{ m} \times \sin 35$ $T = 888$ N	4
14(a)(ii)	• (thrust) arrow approx 35° to horizontal to the upper left • arrow direction capable of balancing opposite pair	(1) (1)	Do not penalise whether force from column is above/below/on the horizontal 	2
14(b)	• Use of $E = \frac{\text{constant}}{r^2}$ • Calculates at least one value of the constant • Calculates a second value and states that the field is not inverse square law	(1) (1) (1)	eg writes $Q = 4\pi\varepsilon_0 Er^2$ Or $Q/4\pi\varepsilon_0 = Er^2$ Or $Er^2 = k$ Example of calculation $1200\text{ N C}^{-1} \times 3^2\text{ m}^2 = 10800\text{ V m}$ $100\text{ N C}^{-1} \times 25^2\text{ m}^2 = 62500\text{ V m}$ Or $1200\text{ N C}^{-1} \times 3^2\text{ m}^2 \times 4\pi\varepsilon_0 = 1.2 \times 10^{-6}\text{ C}$ $100\text{ N C}^{-1} \times 25^2\text{ m}^2 \times 4\pi\varepsilon_0 = 6.9 \times 10^{-6}\text{ C}$ Or $1200\text{ N C}^{-1} \times 3^2\text{ m}^2 = 10800\text{ V m}$ $\frac{10800\text{ V m}}{100\text{ N C}^{-1}} = 108\text{ m}^2$ and $\sqrt{108} = 10.4$ not 25	3

(Total for Question 14 = 9 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
3(a)(i)	An explanation that makes reference to the following points: • The prism and the centre of gravity are at different distances from the pivot **Or** The prism is not at the centre of gravity of the rule **(1)** • So for moments about the pivot to balance the force from the prism must be larger (than the weight of the rule) **(1)**	Allow an explanation based on use of equations. Allow "For the forces to be equal, they would have to be the same distance from the pivot to balance the moments"	**2**
3(a)(ii)	• Use of $F = mg$ **(1)** • Use of moment = Fx **(1)** • Application of principle of moments about the pivot **(1)** • $W = 0.84$ N **(1)**	Example of calculation Force at prism = F $F = (0.1802\text{ kg} - 0.0255\text{ kg}) \times 9.81\text{ N kg}^{-1} = 1.52$ N Taking moments about the pivot point $1.52\text{ N} \times (30.0 - 5.0)\text{ cm} = W \times (50.0 - 5.0)\text{ cm}$ $\therefore W = \frac{1.52\text{ N} \times 25.0\text{ cm}}{45.0\text{ cm}} = 0.84\text{ N}$	**4**
3(b)	• The distance to the pivot would increase **Or** Percentage uncertainty in distance decreases **(1)** • The force at the prism would decrease **Or** Percentage uncertainty in force/mass increases **(1)** • (As one increases and the other decreases) we cannot be sure how the percentage uncertainty would change **(1)**	Allow "reading on the balance decreases" Dependent upon MP1 and MP2	**3**

(Total for Question 3 = 9 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
11(a)	• Use of $W = mg$ • W = 868 (N)	**(1)** **(1)**	Example of calculation Mass of water = 85.0 litres × 1 kg = 85.0 kg Mass of base and water = 85.0 kg + 3.50 kg = 88.5 kg Weight of base = 88.5 kg × 9.81 N kg^{-1} = 868.2 N	**2**
11(b)	• See 868 N × 0.45 m × cos 15 (= 377.3 N m) • See 27 N ×2.0 m × cos 75 (= 13.98 N m) • See F_w ×2.4 m × cos 15 (= 2.31F_w) • Use of principle of moments e.g. substitution into: moment of weight of base = moment of weight of post arrangement + moment of wind • F_w = 157 or 158 N	**(1)** **(1)** **(1)** **(1)** **(1)**	MP1 accept sin75 for cos15 MP2 accept sin15 for cos75 MP3 accept sin75 for cos15 MP4, accept > correctly used in place of = to indicate the point at which it will tip and ecf for W from 11 (a) Example of calculation (using perpendicular forces) Moment of weight of base = 868 N × cos 15 × 0.45 m = 377.29 Nm Moment of the post arrangement = 27.0 N × cos 75 × (2.80 m – 0.80 m) = 13.98 N m Moment of the wind = F_w × cos 15 × 2.40 m = 2.31 F_w 377.29Nm = 13.98 Nm + 2.31 F_w F_w = 157.28 N Example of calculation (using perpendicular distances) (868 N × 0.45 m × cos 15) = (27 N ×2.0 m × cos 75) + (F_w ×2.4 m × cos 15) F_w = 156.72 N	**5**

11(c)	• F_w would increase **(1)** • The weight of the base would be heavier/increase **(1)** • This increases the clockwise moment **Or** this increases the moment of the (weight of the) base **(1)**			**3**

(Total for Question 11 = 10 marks)

Question Number	Acceptable answers	Additional guidance	Mark
13(a)(i)	**MAX 2** • Statement describing 740cos20 as the (perpendicular) component of weight of the hiker **and** Statement describing *W*cos20 as the (perpendicular) component of the weight of the bag **(1)** • 2R is the push of the ground on the hiker **(1)** • Use of $\Sigma F = 0$ with reference to hiker being stationary **(1)**	Accept reaction force	**2**

13(a)(ii)	• See 740 N × 0.25 m × cos 20 (= 173.8 N m) **(1)** • See W × 0.10 m × cos 20 (= 0.0940W N m) **(1)** • See R × 0.40 m (= 0.40N N m) **Or** 0.5(740cos20 + Wcos20) **(1)** • Use of principle of moments e.g. substitution into: moment of weight of man = moment of weight of bag + moment of R **(1)** • Use of equation of the resultant force with the equation obtained in MP4 **OR** Use of principle of moments about another point with the equation obtained in MP4 **(1)** • W = 120 N **(1)**	<u>Example of calculation</u> Moment of the weight of the man: 740 N × 0.25 m × cos 20 = 173.8 N m Moment of the weight of the bag: W × 0.10 m × cos 20 = 0.0940W N m Moment of R: R × 0.40 m = 0.40R N m 173.8 N m = 0.40R + 0.0940W N m Re-arranging to make R the subject of the equation: R = 435 N – 0.235W N Re-arranging the equation for the resultant force: R = 347.7 N + 0.470W 435 N – 0.235W N = 347.7 N + 0.470W 0.705W= 87.3 W = 124 N	**6**
13 (b)	• The position of the centre of gravity moves to the left/backwards **Or** the perpendicular distance (from O) would be greater **(1)** • The moment of the bag (about O) increases so the moment of R (and the size of R) decreases to preserve equilibrium **(1)**	MP1: accept lower for to the left	**2**

(Total for Question 13 = 10 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
12(a)	• Use of $W = mg$	**(1)**	Example of calculation $W = 25\ \text{kg} \times 9.81\ \text{m s}^{-2} = 245\ \text{N}$ Taking moments about A $245\ \text{N} \times 0.55\ \text{m} = F_B \times 1.50\ \text{m}$ $F_B = 90\ \text{N}$ $F_A = 245\ \text{N} - 90\ \text{N} = 155\ \text{N}$	**5**
	• Use of Moment of force = Fx	**(1)**		
	EITHER			
	• Application of the principle of moments about A	**(1)**		
	• $F_A + F_B = W$ **Or** Application of the principle of moments about B	**(1)**		
	• $F_A = 155\ \text{N}$ and $F_B = 90\ \text{N}$	**(1)**		
	OR			
	• Application of the principle of moments about B	**(1)**		
	• $F_A + F_B = W$ **Or** Application of the principle of moments about A	**(1)**		
	• $F_A = 155\ \text{N}$ and $F_B = 90\ \text{N}$	**(1)**		

12(b)	An explanation that makes reference to the following points: • Horizontal distance of weight (from A) increases **(1)** • Clockwise moment (about A) increases **Or** Moment of weight (about A) increases **(1)** • So anticlockwise moment (about A) increases **Or** moment of F_B (about A) increases **(1)** • And horizontal distance of F_B (from A) decreases **(1)** • So F_B increases and F_A decreases **(1)**		**5**

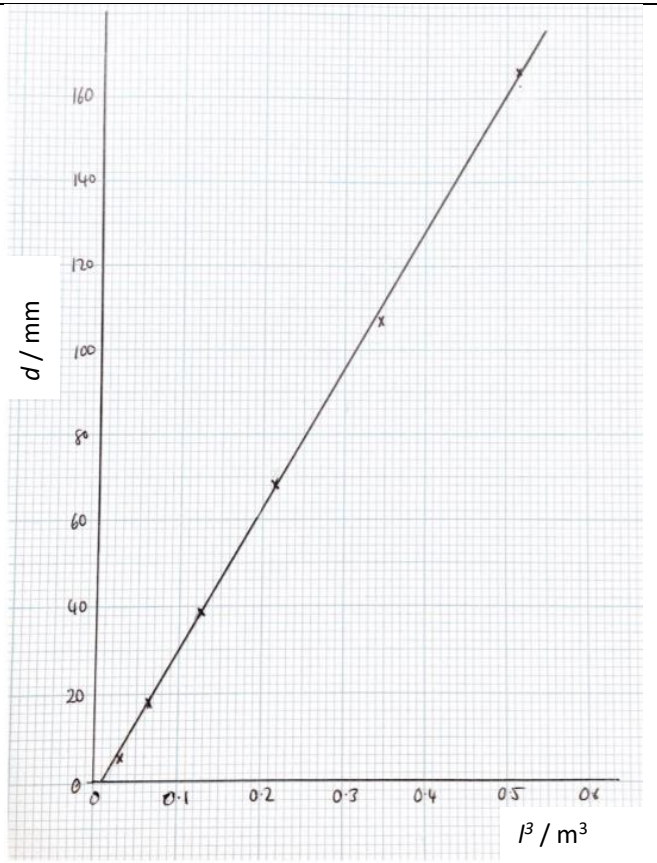
(Total for Question 12 = 10 marks)

Question Number	Acceptable answers		Additional guidance	Mark
17(a)	• Ensure the metre rule is vertical using a set square placed in contact with the floor. • Use set square held against metre rule to take the readings on the metre rule	**(1)** **(1)**	A labelled diagram can score full marks Accept references to reading at eye level for MP2.	**2**
17(b)(i)	• Use of half range **Or** Use of maximum deviation from the mean • 0.4 (%)	**(1)** **(1)**	<u>Example of Calculation.</u> ½ range = (6.29 mm - 6.24 mm) / 2 = 0.025 mm %U = (0.025 mm / 6.26 mm) x 100 %U = 0.40 %	**2**

17(b)(ii)

- Correct values for l^3 to 3 sf **(1)**
- Axes with labels & units **(1)**
- Scales **(1)**
- Plots **(1)**
- Line of best fit **(1)**

l/m	*d/mm*	l^3 / m^3
0.300	6	0.027(0)
0.400	18	0.064(0)
0.500	39	0.125
0.600	68	0.216
0.700	107	0.343
0.800	166	0.512



MP1: accept 2 or 3 sf's in table for first 2 values
MP3: scales only in 1,2,5 and must cover at least half of paper

MP4: a 1 mm square tolerance, check all points

5

17(b)(iii)	• Determine gradient **(1)** • Using a large triangle **(1)** • Use of gradient $= \frac{4W}{Ebt^3}$ **(1)** • $E = 9.2 \times 10^9$ (Pa) (in range $8.9 – 9.3 \times 10^9$ (Pa)) **(1)** • Identifies wood consistent with their value for E **(1)**	Example Calculation. $gradient = \frac{(160 \times 10^{-3}) - 0}{0.50 - 0.01}$ Gradient = 0.327 $0.327 = \frac{4 \times 5.6\ (\text{N})}{E\ x\ 0.0302\ (\text{m}) \times (6.26x10^{-3}\ (\text{m}))^3}$ $E = 9.2 \times 10^9$ Pa	**5**

(Total for Question 17 = 14 marks)

Question Number	Acceptable answers	Additional guidance	Mark
4	C	*mgh*	**1**
	A uses the distance AB rather than height B uses a component of height D uses a component of height		

6	C **190 kJ**	**1**
	Incorrect Answers: A – The velocity was not squared when using the formula $E_k = ½ mv^2$ e.g. ½ $(1.2 \times 10^3)(18) = 11$ kJ B – The velocity was not squared and the ½ was omitted when using the formula $E_k = ½ mv^2$ e.g. $(1.2 \times 10^3)(18) = 22$ kJ D – The ½ was omitted when using the formula $E_k = ½ mv^2$ e.g. $(1.2 \times 10^3)(18)^2 = 390$ kJ	

Question Number	Acceptable answers	Additional guidance	Mark
2	A		1

Question Number	Acceptable answers	Additional guidance	Mark
8	B		1

(Total for Multiple Choice Questions = 8 marks)

Question Number	Answer	Mark
2	**B -** mgy, $E_P = mg\Delta h$, correct distance (vertical)	**1**
	Incorrect Answers: **A** – incorrect distance (horizontal) **C** – incorrect distance (horizontal + vertical) **D** – incorrect distance (length of slope)	

Question Number	Answer	Additional Guidance	Mark
3	**A is the only correct answer**	B is incorrect because speed has been divided by 2 C is incorrect because $E_K = 0.5\ mv^2$ D is incorrect because $E_K = 0.5\ mv^2$	**1**

Question Number	Answer	Additional Guidance	Mark
4	**C is the only correct answer**	A is incorrect because the wrong trigonometric function has been used B is incorrect because the wrong trigonometric function has been used D is incorrect because the wrong algebraic equation has been used	**1**

Question Number	Answer	Additional Guidance	Mark
8	**A is the only correct answer**	B is incorrect because $P = mgh/t = mgv$ C is incorrect because $P = mgh/t = mgv$	**1**
		D is incorrect because $P = mgh/t = mgv$	

(Total for Multiple Choice Questions = 8 marks)

8	**D 1×10^{17} J**	**1**
	A – this answer is incorrect B – this answer is incorrect C – this answer is incorrect	

(Total for Multiple Choice Questions = 8 marks)

Question Number	Acceptable answers	Additional guidance	Mark
6	**The only correct answer is D** A is not the correct answer, as efficiency = useful output/input = 40/44		1
	B is not the correct answer, as efficiency = useful output/input = 40/44 C is not the correct answer, as efficiency = useful output/input = 40/44		

Question Number	Answer	Mark
6	**D** $\frac{mgh}{VIt}$ Incorrect Answers: A – this answer is incorrect B – this answer is incorrect C – this answer is incorrect	1

Question Number	Acceptable answers	Additional guidance	Mark
3	**The only correct answer is B** A is not the correct answer, as it equals (power of motor×time) −g.p.e. C is not the correct answer, as it equals (power of motor×time) −g.p.e. D is not the correct answer, as it equals (power of motor×time) −g.p.e.		1

Question Number	Acceptable Answer	Additional Guidance	Mark
9	• Use of $P = VI$ **Or** use of $\triangle E_{grav} = mg\triangle h$ **(1)** • Use of efficiency = $\frac{\text{useful power output}}{\text{total power input}}$ **(1)** • Efficiency = 0.75 to 0.78 (or 75 % to 78%) **(1)**	Accept use of efficiency = $\frac{\text{useful energy output}}{\text{total energy input}}$ with corresponding times <u>Example of calculation</u> $P_{motor} = (85 \times 10^{-3})$ A × 3.0 V = 0.255 W P_{block} = 0.05 kg × 9.81 N kg^{-1} × 0.40 m s^{-1} = 0.196 W Efficiency = $\frac{0.196\ \text{W}}{0.255\ \text{W}}$ = 0.77 (no unit)	**3**

(Total for Question 9 = 3 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
10(a)	• Use of horizontal component of force **(1)** • Use of $\Delta W = F\Delta s$ **(1)** • $\Delta W = 1.1 \times 10^4$ J **(1)**	Example of calculation Horizontal component of force = 35 N × cos50° = 22 N $\Delta W = 22$ N × 500 m = 1.1×10^4 J	**3**
10(b)	An explanation that makes reference to the following points: • Force is in the direction of motion **Or** Force is parallel to the direction of motion **Or** there is a greater proportion of the force in the direction of motion **(1)** • So lower applied force **Or** Force is now 22 N **(1)**		**2**

(Total for Question 10 = 5 marks)

Question Number	Acceptable answers		Additional guidance	Mark
11(a)	• Determines vertical height gained per second	(1)	Example of calculation $P = 18\ \text{N} \times 2.8\ \text{m} + 60\ \text{kg} \times 9.81\ \text{N kg}^{-1} \times 2.8\text{m} \times \sin 5.7$ $P = 50.4 + 163.7$ $P = 214\ \text{W}$ Alternative based on resolving forces $W\sin\theta = 60\ \text{kg} \times 9.81\ \text{Nkg}^{-1} \times \sin 5.7 = 58.5\ \text{N}$ Total force down slope = 58.5 N + 18 N = 76.5 N Power is work done per second = 76.5 N × 2.8 m s^{-1} = 214 W	4
	• Use of $\Delta E_{grav} = mg\Delta h$	(1)		
	• Use of $\Delta W = F \times \Delta s$ and $P = W/t$	(1)		
	• Power = 210 W	(1)		
	Alternative method based on resolving forces			
	• resolves weight along slope	(1)		
	• determines total force along the slope	(1)		
	• Use of $\Delta W = F \times \Delta s$ and $P = W/t$	(1)		
	• Power = 210 W	(1)		
11(b)	• Use of $P = I^2R$	(1)	Example of calculation $55\ \text{W} = 24^2\ \text{A}^2 \times R$ $I = 0.095\ \Omega$	2
	• resistance = 0.095 Ω	(1)		

(Total for Question 11 = 6 marks)

Question Number	Acceptable answers	Additional guidance	Mark
10(a)	**EITHER** • Use of $F=ma$ **(1)** • Use of $v^2 = u^2 + 2as$ **(1)** • u = 0.58 m s^{-1} **(1)** **OR** • Use of $\Delta W = F\Delta s$ **(1)** • Use of $E_k = \frac{1}{2}mv^2$ **(1)** • u = 0.58 m s^{-1} **(1)**	Example of Calculation -2.2×10^{-3} N $= 0.0085$ kg $\times a$ $a = -0.26$ m s^{-2} $0 = u^2 + (2 \times (-0.26)$ m s$^{-2} \times 0.65$ m) $u = 0.58$ m s^{-1}	**3**
10(b)	• Use of $s = ut + \frac{1}{2}at^2$ for vertical motion **(1)** • Use of $s = ut + \frac{1}{2}at^2$ for horizontal motion **(1)** • s = 0.20 m **(1)**	Example of Calculation $-1.20 \text{ m} = \frac{1}{2} \times (-9.81 \text{ m s}^{-2}) \times t^2$ $\therefore t = \sqrt{\frac{-1.20 \text{ m}}{0.5 \times (-9.81 \text{ m s}^{-2})}} = 0.495$ s $s = 0.40 \text{ m s}^{-1} \times 0.495 \text{ s} = 0.198$ m	**3**

(Total for Question 10 = 6 marks)

Question Number	Acceptable answers	Additional guidance	Mark
12(a)	• Use of efficiency = output energy / input energy **(1)** • With energy output = load × change in height **(1)** • Energy input = IVt **(1)**	May be answered in terms of power For MP1 & MP2 accept electrical energy for energy input and work done/GPE for energy output Answers can be in terms of headings from table or cell numbers or values Example of calculation ΔE_{grav} = 4.00 N × 0.825 m = 3.30 J W = 2.1 A × 4.3 V × 2.19 s = 19.8 J Efficiency = $\frac{3.30\text{ J}}{19.8\text{ J}}$ = 0.167	**3**
12(b)	**Max 5** • The time is too short to be measured by a stop watch **Or** there is reaction time. **(1)** • Another variable could have been controlled **(1)** • Repeats should have been taken and a mean calculated **(1)** • Identifies that there is an anomaly (at about 5 N) that has not been checked/repeated **(1)** • Smaller weight intervals (around 6 N) to identify the maximum **Or** plot/take more data points around 6 N. **(1)** • Don't know where the maximum is so can't make a judgement that there is a maximum efficiency at 6 N **(1)** • The conclusion ignores the decline after 6 N (so is incomplete) **(1)**	MP2 need to specify a variable e.g. current or p.d.	**5**

(Total for Question 12 = 8 marks)

Question Number	Acceptable Answers	Additional guidance	Mark
15(a)	• Energy absorbed in the impact is equal to the change in GPE (between start and end) (1) • $\Delta E = mg\Delta h$ and mg constant (so $E \propto \Delta h$) (1)		**2**
15(b)	• Equate $E = mg\Delta h$ and $E=\frac{1}{2}mv^2$ (1) • Use of $p=mv$ (1) • p = 50 kg m s^{-1} (1)	Do not accept $v^2 = u^2 + 2as$ (because the hammer does not move in a straight line with constant acceleration) Example of calculation $mg\Delta h = \frac{1}{2}mv^2$ 31 kg × 9.81 ms^{-2} × 0.13 m = $\frac{1}{2}$ × 31 kg × v^2 $v = \sqrt{(2 \times 9.81\ \text{ms}^{-1} \times 0.13\ \text{m})} = 1.6$ m s^{-1} p = 31 kg × 1.6 m s^{-1} = 49.6 kg m s^{-1}	**3**
15(c)	• Steel had a lower fracture toughness due to the low temperature (1) • at low temperatures less energy is absorbed before fracture (1) • the **(**absorbed) energy was sufficient to cause fracture (1)		**3**

(Total for Question 15 = 8 marks)

Question Number	Acceptable answers	Additional guidance	Mark
9(a)	• Use of $v^2 = u^2 + 2as$ **(1)** • With $v = 0$ and $a = -5.6$ **(1)** • $u = 9.2$ m s^{-1} **(1)** **Or** • Use of $a = \frac{F}{m}$ and $W = Fs$ **(1)** • Use of $E_K = \frac{1}{2}mv^2$ **(1)** • $u = 9.2$ m s^{-1} **(1)**	Example of calculation $0 = u^2 - 2 \times 5.6\ \text{ms}^{-2} \times 7.5\text{m}$ $u = 9.2$ m s^{-1}	**3**
9(b)	• use of mv **(1)** • applies momentum conservation **(1)** • $v = 17$ m s^{-1} **(1)**	Example of calculation 2700 kg × 9.2 m s^{-1} = 0 + 1500 kg × v 24840 kg m s^{-1} = 1500 kg × v v = 16.6 m s^{-1}	**3**
9(c)	• momentum not conserved as external force acts **(1)** • friction from the road **(1)**		**2**

(Total for Question 9 = 8 marks)

Question Number	Acceptable answers		Additional guidance	Mark
11(a)	• Use of $F = \frac{mv^2}{r}$ • States that $F = mg$ only as reaction force is zero	**(1)** **(1)**	Example of derivation: $mg = \frac{mv^2}{r}$ $v = \sqrt{gr}$	**(2)**
11(b)	• Use of energy conservation • Substitution of $v^2 = rg$ • V_{bottom} = 2.7 m s^{-1}	**(1)** **(1)** **(1)**	Example of calculation: $\frac{1}{2}mv^2_{top} + mgh = \frac{1}{2}mv^2_{bottom}$ $g(\text{ms}^{-2})r(\text{m}) + 2g(\text{ms}^{-2})0.30(\text{m}) = v^2(\text{ms}^{-1})^2$ $v^2 = 0.75g$ $v = 2.71\text{ms}^{-1}$	**(3)**
11(c)	• Use of $s = ut + \frac{1}{2}at^2$ • Recognise $u = 0$ • Use of $v = d/t$ in horizontal direction • Displacement = 1.1 m	**(1)** **(1)** **(1)** **(1)**	Example of calculation: $0.65\,\text{m} = \frac{1}{2}9.81\,\text{m}\,\text{s}^{-2}t^2$ $t = 0.364\,\text{s}$ $s = 3.0\,\text{m}\,\text{s}^{-1} \times 0.364\,\text{s}$ $s = 1.09\,\text{m}$	**(4)**

(Total for Question 11 = 9 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>12(a)</td><td>
• Speed of impact is the same for both spheres (1)
• mass of sphere ∝ (diameter)^3 (1)
• $E_k = \frac{1}{2}mv^2$ so factor = 8 (1)
OR
• Final $E_k = \Delta E_{grav}$ (1)
• mass of sphere ∝ (diameter)^3 (1)
• $\Delta E_{grav} = mg\Delta h$, so factor = 8 (1)
</td><td>
For MP2 accept radius instead of diameter

A bald correct answer scores MP3 only

Example of calculation:
$\frac{m_2}{m_1} = \left(\frac{4\text{ cm}}{2\text{ cm}}\right)^3 = 8$
$\frac{E_{k2}}{E_{k1}} = \frac{m_2}{m_1} = 8$
</td><td>3</td></tr>
<tr><td>*12(b)</td><td>
This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The table shows how the marks should be awarded for indicative content and lines of reasoning.
<table>
<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark available</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
<tr><td>4</td><td>3</td><td>1</td><td>4</td></tr>
<tr><td>3</td><td>2</td><td>1</td><td>3</td></tr>
<tr><td>2</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
</td><td>
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between its points and is unstructured</td><td>0</td></tr>
</table>
</td><td></td></tr>
</table>

	Indicative content: • The table shows that increasing the drop height does increase the crater diameter • Increasing the drop height increases the impact velocity/E_k • Because there is a greater acceleration time **Or** because there is a greater transfer of GPE to KE • The table does not show that increasing the sphere diameter (always) increases the crater diameter • For smaller spheres (from 2 to 4 cm), increasing sphere diameter does increase crater diameter **Or** for bigger spheres (from 4 to 6 cm), increasing the sphere diameter has little effect on crater diameter • More data is needed for firmer conclusions	For IC3 accept reference to an appropriate equation For IC5 accept "no effect" or "inconsistent effect" for "little effect"	**6**

(Total for Question 12 = 9 marks)

Question Number	Acceptable Answers	Additional guidance	Mark
17 (a)(i)	• Use of $v^2 = u^2 + 2as$ (1) • Use of $a = \frac{\Delta v}{\Delta t}$ (1) • Use of $F = R - mg = ma$ (1) • R = 360 N [accept total force = 721 N] (1)	Example of calculation $v^2 = 2 \times 9.81$ m s^{-1} × 1.6 m [v = 5.60 m s^{-1}] $a = \frac{5.60 \text{ m s}^{-1}}{0.9} = 6.23$m s^{-2} F = 45 kg × 6.23 m s^{-2} = 280 N R = 45 kg × 9.81 m s^{-2} + 280 N = 721 N	**4**
17(a)(ii)	• bending knees increases the time to come to rest (1) • decreasing rate of change of momentum **or** reducing the deceleration (1) • and (hence) force (1)	Accept converse argument	**3**
17(b)	**Max three** Elderly bone: • lower gradient showing the bone is under more strain for a given stress • graph ends at a lower stress showing it has a lower breaking stress (1) • Area under graph is smaller as less energy is absorbed before fracture (1) • Graph is shorter showing less plasticity (1) (1)	Accept answer with respect to healthy bone Accept more brittle	**3**

(Total for Question 17 = 10 marks)

Question Number	Acceptable Answers	Additional guidance	Mark
16(a)	• Use of $\Delta E_{grav} = mg\Delta h$ **and** $P = \frac{E}{t}$ (1) • Use of Efficiency $= \frac{\text{useful energy/power output}}{\text{total energy/power input}}$ (1) • $0.76\ \text{m s}^{-1}$ (1)	Example of calculation Useful energy output in 1 s = 15 MJ Total energy in 1 s $= \frac{1.5 \times 10^7}{0.8} = 1.875 \times 10^7$ J $mg\Delta h$ per second $= 1.875 \times 10^7$ J Δh per second $= v = \frac{1.875 \times 10^7 \text{ J}}{2500000 \text{ kg} \times 9.81 \text{ N kg}^{-1}}$ $v = 0.76\ \text{m s}^{-1}$	**3**
(b)	**Either** • A high power requires the mass to be lowered at a high speed (1) • But the length of time is limited by the depth of the mineshaft (1) **Or** • Total output energy is determined by the depth of the shaft (1) • $E=Pt$ so for a high power time must be small (since E is constant) (1)		**2**
(c)	• Use of $E = \frac{stress}{strain}$ **and** $stress = \frac{F}{A}$ (1) • $5.5 \times 10^{-2}\ \text{m}^2$ (1)	Example of calculation Stress $= 1.8 \times 10^{11} \times 0.005 = 9.0 \times 10^8\ \text{N m}^{-2}$ $A = \frac{5.0 \times 10^6 \text{kg} \times 9.81 \text{N kg}^{-1}}{9.0 \times 10^8\ \text{N m}^{-2}} = 5.45 \times 10^{-2}\ \text{m}^2$	**2**
(d)	• load needs to be accelerated upwards (1) • so greater force/stress/tension in cables (1) • a greater area decreases the stress (1)		**3**

(Total for Question 16 = 10 marks)

Question Number	Acceptable Answers	Additional guidance	Mark
17(a)	• Use of $s = ut + \frac{1}{2}at^2$ **(1)** • Acceleration = 9.61 m s^{-2} **(1)** • A sensible statement based on a comparison of the magnitude of their calculated value of acceleration with 9.81 m s^{-2} **(1)**	MP1 can be awarded if 66 m is used Accept: not weightlessness as this is less than 9.81 m s^{-2} **Or** nearly weightless as this is close to 9.81 m s^{-2} MP3 awarded following reasonable attempt at calculation Example of calculation $s = ut + \frac{1}{2}at^2$ ($u = 0$) $33\text{ m} = 0 + \frac{1}{2}a(2.62\text{ s})^2$ a = 9.61 m s^{-2}	**3**
17(b)	• use of $a = \frac{\Delta v}{\Delta t}$ **(1)** • a = 18 m s^{-2} **(1)** • conclusion that compares the magnitiude of their answer to 6g **(1)**	MP3 awarded following reasonable attempt at calculation Example of calculation $a = \frac{\left(\frac{130\text{ km h}^{-1} \times 1000}{(60 \times 60)\text{ s}}\right)}{2\text{ s}}$ a =18 m s^{-2} so within limit of 6g	**3**

17(c)	• Young modulus of steel > young modulus of wood **Or** steel is stiffer **Or** greater stress for a given strain **Or** less strain under the same stress **(1)** • So there are less changes in dimensions under a given force for steel **(1)** • Breaking stress of steel > breaking stress of wood **Or** steel is stronger **Or** steel withstands greater forces without breaking **(1)** • steel can withstand a larger force/weight than wood of the same (cross-sectional) area **Or** Under the same force/weight steel can have a smaller (cross-sectional) area than wood **(1)** • Steel coasters can be built that withstand the larger forces from faster cars **Or** (taller tracks can be built because) steel tracks can have smaller dimensions **(1)**	Answers must a comparison between steel and wood Accept deformation for changes in dimension MP3 accept UTS steel > UTS wood	**5**

(Total for Question 17 = 11 marks)

Question Number	Acceptable answers	Additional guidance	Mark
15(a)	• Use of $E_{grav} = mgh$ **(1)** • Use of $P = IV$ and $P = \frac{E}{t}$ **(1)** • Use of Efficiency $= \frac{\text{useful power output}}{\text{total power input}}$ **Or** • Use of Efficiency $= \frac{\text{useful energy output}}{\text{total energy input}}$ **(1)** • Efficiency = 0.74 **(1)**	Example of Calculation $E_P = 0.55\ kg \times 9.81\ ms^{-2} \times 0.20\ m$ $E_P = 1.08\ J$ Useful power $= \frac{1.08\ J}{15\ s} = 0.072\ W$ $P = 8.1 \times 10^{-3}\ A \times 12\ V$ Input power = 0.0972 W Input energy = 0.0972 × 15 = 1.46 J Efficiency $= \frac{1.08\ J}{1.46\ J} = 0.74$	**4**
15(b)	• There is now a (greater) current in the voltmeter **(1)** • The current in the battery/circuit increases **Or** Energy/power is dissipated in the voltmeter **(1)** • Power/energy output from the battery increases **(1)** • Efficiency of the motor circuit decreases **(1)** (MP4 dependent on MP3)	Accept reference to the resistance in the circuit decreasing for MP1. Accept power input to circuit for MP3.	**4**

15(c)	• Use of $p = mv$ **(1)** • Use of principle of conservation of momentum **(1)** • $v = 5.2$ ms^{-1} **(1)**	<u>Example of calculation.</u> 0.55 kg × 5.4 ms^{-1} = (0.55 kg × 2.1 ms^{-1}) + (0.35 kg × v) 2.97 = 1.16 + 0.35v v = 5.2 ms^{-1}	**3**

(Total for Question 15 = 11 marks)

Question Number	Acceptable answers	Additional guidance	Mark
13a	• Efficiency shouldn't have any units **Or** efficiency should be a ratio of energies **Or** efficiency should be a ratio of powers **Or** number < 1		**1**
13b	• Quote $P = E/t$ **(1)** • (k)W is unit of P and h unit of t so equivalent to E **(1)**		**2**
13c	• Use of Efficiency = useful energy output/energy input **(1)** • Uses Energy input is power (kW) × time (h) **(1)** • Efficiency = 0.87 **(1)**	<u>Example of calculation</u> $\text{Efficiency} = \frac{22\ \text{kWh}}{3.6\ \text{kW} \times 7\text{h}}$ Efficiency = 0.873	**3**

Question Number	Acceptable answers	Additional guidance	Mark
13d	• converts battery input to a cost **(1)** • comparison of petrol and electric cost for same range **Or** comparison of petrol and electric range for same cost **(1)**	Example of calculation Cost of charging the battery = 3.6 kW ×7 h× 13 p = £3.28 This is a cost per km of $\frac{3.28}{129}$ = 2.54 p **Or** use of website figures: 0.195 kW h x 13 p/kW h = 2.54 p. Petrol car: cost per km is $\frac{1.20}{21}$ = 5.71 p Alternative: to calculate cost for 129 km £3.276 for electric and £7.36 for petrol	**2**
13e	• no exhaust particulates **Or** no lead emission **Or** less carbon dioxide emission **Or** less greenhouse gases **Or** no polluting gases		**1**
13f	• use of $E_k = ½ mv^2$ **(1)** • use of $P = E/t$ **(1)** • power required is 51 kW, less than engine power so it does have enough power **(1)**	Example of calculation $E_k = \frac{1}{2}$1500 kg 28^2 (m s^{-1})^2 = 5.88×10^5 J P = 5.88×10^5 J / 11.5 s = 51.1 kW	**3**

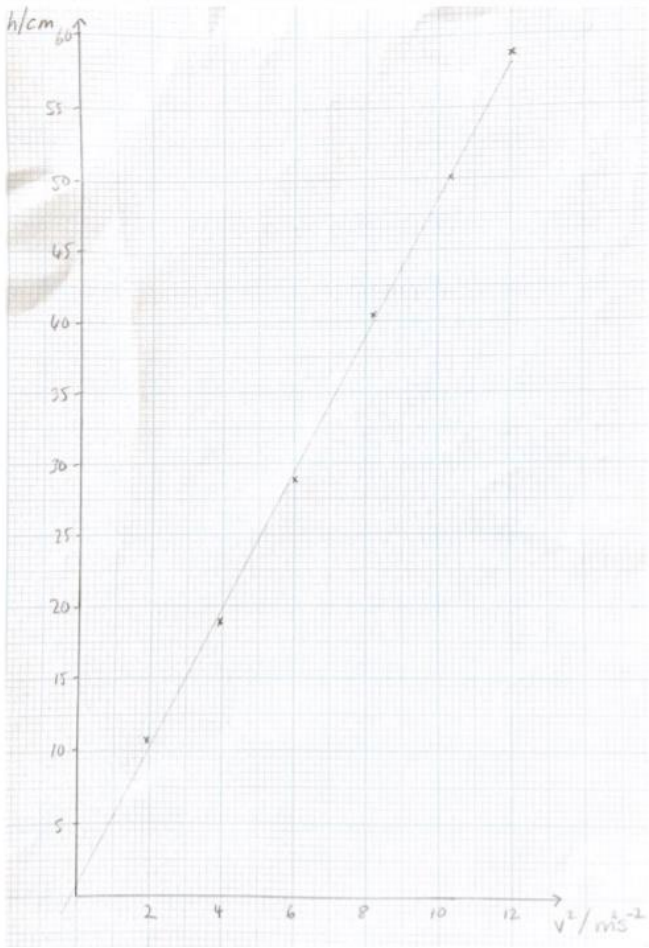
(Total for Question 13 = 12 marks)

Question Number	Acceptable answers	Additional guidance	Mark
16(a)	• Use of a metre rule **(1)** • Use of a set square to ensure the rule is vertical **Or** Use of plumbline to ensure that the rule is vertical **(1)**	Allow use of a spirit level for MP2	**2**
16(b)(i)	An explanation that makes reference to the following points: • Comparison of $h = \frac{v^2}{2g}$ with $y = mx + c$ **(1)** • Gradient = $\frac{1}{2g}$ which is constant **(1)**		**2**

16(b)(ii)

- Values of v^2 given to 3 s.f. **(1)**
- Axes with labels & units **(1)**
- Scales **(1)**
- Plots **(1)**
- Line of best fit **(1)**

h / cm	v^2/ m^2 s^{-2}
10.8	1.90
18.9	3.92
28.7	6.00
40.3	8.18
49.8	10.37
58.7	11.97

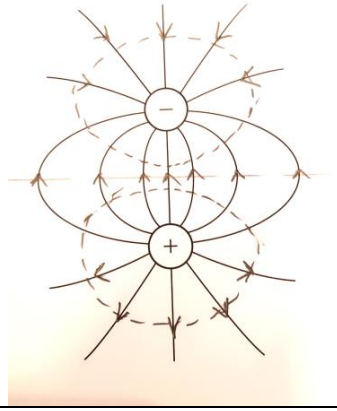


MP1 allow 4 s.f. for final two values in table
MP3: scales only in 1,2, or 5 and must cover at least half of paper

5

16(b)(iii)	• Use of large triangle **(1)** • Use of gradient = $\frac{1}{2g}$ **(1)** • g in range 10.0 – 10.9 (m s^{-2}) and relevant comment **(1)**	<u>Example of calculation</u> Gradient = (0.580 – 0.005) / 12.0 = 0.0479 g = 1 / (2 × 0.0479) = 10.4 m s^{-2}	**3**

(Total for Question 16 = 12 marks)

Question Number	Acceptable answers	Additional guidance	Mark
18(a)	• Replace Work W by force × distance **(1)** • Replace distance ÷ time by velocity v **(1)** • Use $v = r \times$ Angular velocity **(1)** • Recognise $F \times r$ is the moment of F **(1)**	Alternative method: Consider one revolution of axle , Load rises $2\pi r$ Work done = $2\pi rF$ Time taken = $2\pi \div \omega$ Power = Work ÷ time= $2\pi rF \div 2\pi/\omega$ to give reqd eq	**4**
18(b)(i)	• Arrow away from + charge **Or** arrow towards − charge **(1)** • At least 3 Equipotential lines, perpendicular to field lines **(1)** • Symmetrical about vertical/horizontal axis **and** not touching/crossing **(1)**	MP3 dependent on lines being perpendicular in MP2 	**3**

18(b)(ii)	• Use of $F = \frac{Q_1 Q_2}{4\pi\varepsilon_o r^2}$ **(1)** • F = 0.036 (N) **(1)**	Example of calculation: $F = 8.99\times10^{9}\,\text{Nm}^2\text{C}^{-2}\,\frac{(0.1\times10^{-6}\,\text{C})^2}{(0.05\text{m})^2}$ F = 0.036N	**2**
18(c)	• Use of moment = $F\,x$ **(1)** • Expression for correct moment **(1)** • Use of power = moment of force x angular velocity **(1)** • Only realistic possibility is pond pump and P = 0.6W (calculated answer could also be force and then comparison with b(i)) **(1)**	Show that value gives 3.2×10^{-3} Nm and 0.64 W Example of calculation: Moment $= 0.036\text{N}\times0.04\text{m}\times2 = 2.89\times10^{-3}\,\text{Nm}$ Power $= 2.89\times10^{-3}\,\text{N m}\times200\text{s}^{-1} = 0.58\text{W}$	**4**

(Total for Question 18 = 13 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
14(a)(i)	• Use of $\Delta E_{grav} = mg\Delta h$ and $P = \frac{E}{t}$ **(1)** • $P = 1.6 \times 10^5$ W **(1)**	Example of calculation E_{grav} per second = 130 kg × 9.81 m s^{-2} × 124 m $P = 1.6 \times 10^5$ W	**2**
14(a)(ii)	An explanation that makes reference to the following points: • Frictional forces between water and pipe **(1)** • Do work transferring energy to the surroundings **(1)**	Allow reference to process is less than 100% efficient for MP1	**2**
14(b)	**EITHER** • Use of $V = \frac{W}{Q}$ **(1)** • Use of $P = \frac{E}{t}$ **(1)** • t = 11 h **(1)** **OR** • Use of $P = VI$ **(1)** • Use of $I = Q/t$ or $W = VIt$ **(1)** • t = 11 h **(1)**	Example of calculation $Q = 4400 \times 3600 = 1.6 \times 10^7$ C $W = 1.6 \times 10^7$ C × 48 V = 7.6×10^8 J $t = 7.6 \times 10^8$ J / 20×10^3 W = 3.8×10^4 s $t = 3.8 \times 10^4$ s / 3600 = 10.6 h **Or** W = 4400 Ah × 48 V = 2.1×10^5 V A h $t = 2.1 \times 10^5$ V A h / 20×10^3 W = 10.6 h	**3**

14(c)(i)	• Use of $P = IV$ **(1)** • $I = 21.7$ (A) **(1)**	Example of calculation $I = 5 \times 10^3$ W / 230 V = 21.7 A	**2**

14(c)(ii)	• Use of $P = I^2R$ **(1)** • Use of $R = \frac{\rho l}{A}$ **(1)** • Use of $V = Al$ and the cost per m^3 **(1)** • Cost of copper per m = £12.54 **Or** Cost of aluminium per m = £1.56 **(1)** • The cost reduction is 88% which is close to 90% so the claim is correct (ecf from (c)(i)) **(1)** (Conclusion consistent with calculated percentage)	Example of calculation $R_{1\text{ m of cable}} = 0.05$ W / (22 A)$^2 = 1.03 \times 10^{-4}$ Ω For 1 m of copper cable $A = (1.68 \times 10^{-8}$ Ω m × 1) / 1.03×10^{-4} Ω = 1.63×10^{-4} m^2 $V = 1.63 \times 10^{-4}$ m^2 × 1 m = 1.63×10^{-4} m^3 Cost = 1.63×10^{-4} m^3 × £77 090 = £12.54 For 1 m of aluminium cable $A = (2.65 \times 10^{-8}$ Ω m × 1) / 1.03×10^{-4} Ω = 2.57×10^{-4} m^2 $V = 2.57 \times 10^{-4}$ m^2 × 1 m = 2.57×10^{-4} m^3 Cost = 2.57×10^{-4} m^3 × £6070 = £1.56 Cost reduction using Al = (£12.54 − £1.56) / £12.54 = 88%	**5**

(Total for Question 14 = 14 marks)

(Total for Section A = 57 marks)

Question Number	Acceptable Answers	Additional guidance	Mark
15(a)	• (High intensity of light means) <u>photons</u> strike the photocell at a greater rate (1) • One to one interaction between photons and electrons (1) • So Electrons released at a greater rate (1) • So greater current/charge/power in external circuit (1)		**4**
15(b)	• Use of $I = \frac{P}{A}$ (1) • Use of $P = \frac{E}{t}$ (1) • Multiply by 23% (1) • 1700 MJ (1)	<u>Example of Calculation</u> $E = 1300\ \text{Wm}^{-2} \times 200\ \text{m}^2 \times (8 \times 60 \times 60\ \text{s} \times 0.23)$ $E = 1700\ \text{MJ}$	**4**
15(c)	• Use of $E = Pt$ (1) • 430 MJ (1)	<u>Example of Calculation</u> $E = 4 \times 7500\ \text{W} \times (4 \times 60 \times 60)\text{s}$ E =432 MJ	**2**
15(d)	• Use of $E = mg\Delta h$ (1) • $E = 1.1 \times 10^8$ J (1)	<u>Example of Calculation</u> $E = mg\Delta h = 1600\ kg \times 9.81 ms^{-1} \times (8500 - 1500)m$ $E = 1.1 \times 10^8$ J	**2**
15(e)	• Drag increases as speed increases **Or** Drag increases as <u>density</u> of air increases (1) • Requiring a greater forward force (1) • So motors require more energy/power so plane should fly at a reduced speed (1)	Accept air resistance for drag	**3**
15(f)	**Max 1** (1) • Develops new technologies • Develops alternative energy sources • Raises public awareness • Secures funding for other projects		**1**
	Total for question 15		**16**

Question Number	Acceptable answers	Additional guidance	Mark
18(a)	• There is a (rate of) change of flux (linkage)/field with the (moving coil) **(1)** • Induces an emf (and current) **(1)** • To oppose the change that created (the induced current) **(1)** • Wheels will slow down/not turn as fast **(1)** MP4 dependent on MP3	Accept magnetic field (due to induced current) will oppose original field	4
18(b)(i)	• Converts speed to m s^{-1} **Or** converts time to hours **(1)** • Determines gradient of graph **Or** uses appropriate equation of motion **(1)** • Acceleration = 0.22 m s^{-2} **Or** 2800 km h^{-2} **(1)** range 2800-2900 km h^{-2}	Example of calculation 360 km/h = 360000 m / 3600 s = 100 m s^{-1} $a = \frac{100\ \text{m s}^{-1}}{450\ \text{s}} = 0.222\ \text{m s}^{-2}$	3
18(b)(ii)	• Determines area under graph for a time of 450 s. **Or** use of appropriate equation of motion **(1)** • Distance = 22.5 km **(1)** • 22.5 km is less than 40 km so meets specification **(1)** **Or** • Use of appropriate equation of motion to calculate v • velocity = 130 m s^{-1} • 130 m s^{-1} is more than 100 m s^{-1} so meets specification **Or** • Use of appropriate equation of motion to calculate a	Example of calculation $s = \frac{(0+100\ \text{m s}^{-1})}{2} \times 450\ \text{s} = 22.5\ \text{km}$ **Or** $v^2 = 2 \times 0.22\ \text{m s}^{-2} \times 40000\ \text{m}$ $v = 133\ \text{m s}^{-1}$ **Or** $(3600\ \text{km h}^{-1})^2 = 2 \times a \times 40\ \text{km}$ $a = 1620\ \text{km h}^{-2}$	3

	• a = 1620 km h^{-2} • 1620 km h^{-2} is less than 2800 km h^{-2} so meets specification		
18(c)(i)	• If the track is curved then a centripetal force is required **(1)** • This force provided by reaction force between wheel and rails **(1)** • The centripetal force is given by $F = mv^2/r$ **(1)** • There will be a maximum speed at which the train will leave the track (and the train must travel at less than this speed) as there is a maximum value of reaction/friction (between wheels and rails) **(1)**	Accept Force towards the centre Accept This force is provided by friction (between rail and wheels) Accept Train slips off track if centripetal force is larger than reaction/friction can provide	**4**
18(c)(ii)	• Use of constant = v^2/r **(1)** • r = 5800 m **(1)**	Example of calculation As v^2/r = constant (k) k = 200^2 (km h^{-1})^2/ 1800 m = 22.22 r = 360^2 (km h^{-1})^2 / 22.22 m (km h^{-1})$^{-2}$ r = 5840 m	**2**

(Total for Question 18 = 16 marks)