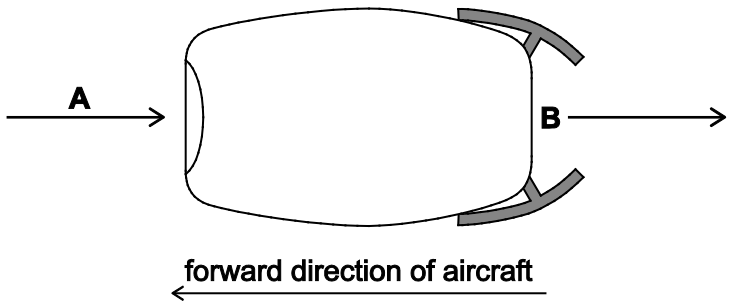
Answer **all** questions.

0 1 **Figure 1** shows a jet engine.

Figure 1



Air enters the engine at **A** and is heated before leaving **B** at a much higher speed.

0 1 . 1 State what happens to the momentum of the air as it passes through the engine.

[1 mark]

0 1 . 2 Explain, using appropriate laws of motion, why the air exerts a force on the engine in the forward direction.

[3 marks]

0 1 . 3 In one second a mass of $210\ \text{kg}$ of air enters at **A**. The speed of this mass of air increases by $570\ \text{m s}^{-1}$ as it passes through the engine.

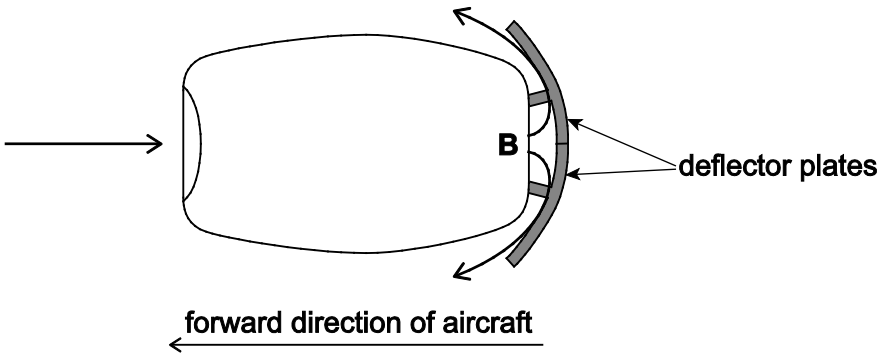
Calculate the force that the air exerts on the engine.

[1 mark]

force = _____ N

0 1 . 4 When an aircraft lands, its jet engines exert a decelerating force on the aircraft by making use of deflector plates. These cause the air leaving the engines to be deflected at an angle to the direction the aircraft is travelling as shown in **Figure 2**.

Figure 2



The speed of the air leaving **B** is the same as the speed of the deflected air.

Explain why the momentum of the air changes.

[2 marks]

0 1 . 5 The total horizontal decelerating force exerted on the deflector plates of the jet engines is $190\ \text{kN}$.

Calculate the deceleration of the aircraft when it has a mass of $7.0 \times 10^4\ \text{kg}$.

[1 mark]

deceleration = _____ m s^{-2}

0 1 . 6 The aircraft lands on the runway travelling at a speed of $68\ \text{m s}^{-1}$ with the deflector plates acting.

Calculate the distance the aircraft travels along the runway until it comes to rest. You may assume that the decelerating force acting on the jet engines remains constant.

[2 marks]

distance = _____ m

0 1 . 7 Suggest why in practice the decelerating force provided by the deflector plates may not remain constant.

[2 marks]

Question	Answer	Comments/ Guidance	Mark
01.1	(momentum of air) increases✓	words implying increase	1
01.2	(rate of change of momentum so) force acting on the air (Newton 2) ✓ it/air exerts force (on engine) of the same/equal magnitude/size✓ but opposite in direction (Newton 3) ✓	 allow backwards and forwards to indicate opposite	1 1 1
01.3	(*use of F = ⊿mv/t*) F = 210 × 570 = 120 000 (N) (119 700) ✓		1
01.4	momentum/velocity is a vector OR momentum/velocity has direction✓ there is a change(in the air's)direction✓		1 1
01.5	*(use of F = ma*) a = (-) 190 000/7.0 × 10^4 = 2.7 (2.71) (m s^{-2}) ✓		1
01.6	(use of $v^2 = u^2 + 2as$) $0 = 68^2 - 2 \times 2.7 \times s$✓ $s = 68^2/(2 \times 2.7)$= 860 (m) (856)	CE from 01.5 accept range 850 – 860 if forget to square *u* or double *a* score 1 mark accept alternatives using $s = ut + 1/2at^2$ OR average speed – first mark for time calculation AND correct substitution	1 1

01.7	rate of intake of air decreases (as plane slows) OR volume/mass/amount of air (passing through engine) per second decreases✓ (as) smaller rate of change of momentum OR momentum change ✓	allow argument in terms of (air) resistance (air) resistance decreases as speed of aircraft decreases for 1 mark NOT FRICTION	1 1

0 3 An electric wheelchair, powered by a battery, allows the user to move around independently.

One type of electric wheelchair has a mass of $55\ \text{kg}$. The maximum distance it can travel on level ground is $12\ \text{km}$ when carrying a user of mass $65\ \text{kg}$ and travelling at its maximum speed of $1.5\ \text{m s}^{-1}$.

The battery used has an emf of $12\ \text{V}$ and can deliver $7.2 \times 10^4\ \text{C}$ as it discharges fully.

0 3 . 1 Show that the average power output of the battery during the journey is about $100\ \text{W}$.

[3 marks]

0 3 . 2 During the journey, forces due to friction and air resistance act on the wheelchair and its user.

Assume that all the energy available in the battery is used to move the wheelchair and its user during the journey.

Calculate the total mean resistive force that acts on the wheelchair and its user.

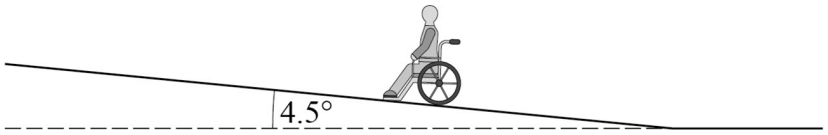
[2 marks]

total mean resistive force = _____ N

Question 3 continues on the next page

Figure 3 shows the wheelchair and its user travelling up a hill. The hill makes an angle of $4.5°$ to the horizontal.

Figure 3



0 3 . 3 Calculate the force that gravity exerts on the wheelchair and its user parallel to the slope.

[1 mark]

force parallel to the slope = _____ N

0 3 . 4 Calculate the maximum speed of the wheelchair and its user when travelling up this hill when the power output of the battery is 100 W.

Assume that the resistive forces due to friction and air resistance are the same as in question **03.2**.

[2 marks]

maximum speed = _____ m s^{-1}

0 3 . 5 Explain how and why the maximum range of the wheelchair on level ground is affected by

- the mass of the user
- the speed at which the wheelchair travels.

[4 marks]

Effect of mass _____

_____

_____

_____

_____

_____

Effect of speed _____

_____

_____

_____

_____

_____

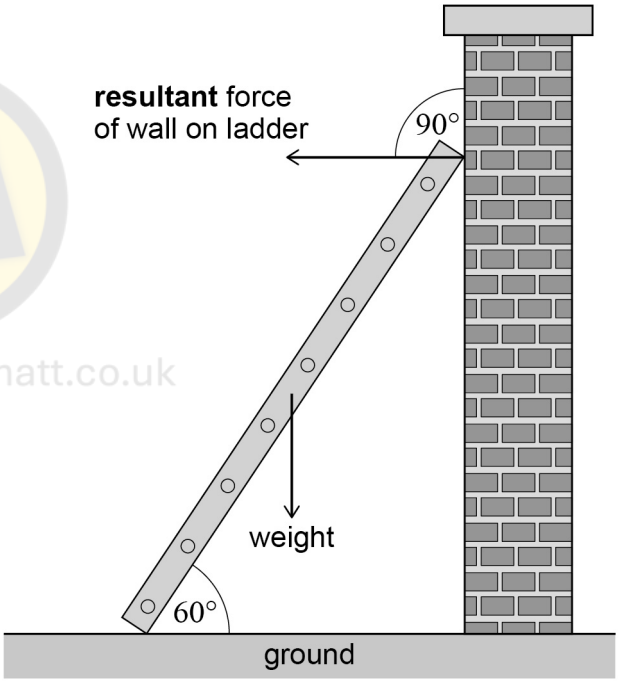
12

Question	Answer	Comments/ Guidance	Mark
03.1	Calculation of energy = $12 \times 7.2 \times 10^4 = 8.64 \times 10^5$ J Or time = $12000/1.5 = 8000$ s ✓ Calculation of other quantity and substitution in power = useful energy/time taken ✓ Power = 110 (108 W)✓ Or Time = 8000 s✓ Current = charge/time = 9 A✓ Power = VI = 108 (W) ✓	Allow ecf for current or time	3
03.2	Attempt to use Power/velocity✓ 73 N ✓ or work done = *F* x 12000 ✓ equates to 110×8000 so *F* = 73 N ✓	Allow use of 100W for P Ignore inclusion of KE in calculation If 108 used then answer is 72 N If 100 used then answer is 67 N allow ecf from 3.1	2
03.3	Force parallel to slope = $120 \times 9.81 \times \sin 4.5 = 92$ N ✓		1
03.4	Total resistive force = ans to **3.3** + ans to **03.2** (= 165 N) ✓ speed = $(\frac{100}{165} =)$ 0.61 m s^{-1} ✓	Allow ecf for incorrect F Allow 0.66/0.67 if 108 W or 110 W used	2

03.5	**Increasing the mass** Reduces the range ✓ increases the friction on the bearings/tyres OR More energy/power is used accelerating the user to the final speed OR user and wheelchair have higher KE/ more energy to move ✓ **Increasing the speed** Reduces the range ✓ Air resistance increases with speed ✓	Reward discussion of compression of tyres Treat as independent parts If not explicit about increasing/decreasing lose the first mark in each part Within each part, second mark is dependent on the first Allow opposite answers for decreasing mass/speed	4

0 5 **Figure 7** shows two of the forces acting on a uniform ladder resting against a vertical wall. The ladder is at an angle of $60°$ to the ground.

Figure 7



0 5 . 1 Explain how **Figure 7** shows that the friction between the ladder and the wall is negligible.

[1 mark]

0 5 . 2 The forces acting on the ladder are in equilibrium.

Draw an arrow on **Figure 7** to show the direction of the resultant force from the ground acting on the ladder. Label your arrow **G**.

[2 marks]

0 5 . 3 The ladder is 8.0 m long and weighs 390 N.

Calculate the magnitude of the resultant force from the wall on the ladder.

[2 marks]

resultant force = _____ N

0 5 . 4 Suggest the changes to the forces acting on the ladder that occur when someone climbs the ladder.

[3 marks]

_____

_____

_____

_____

_____

_____

_____

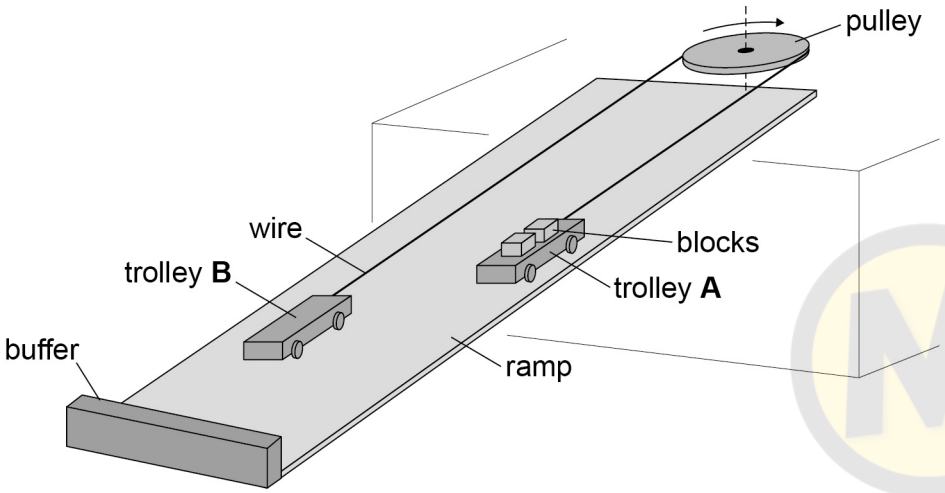
_____

8

Question	Answers	Additional Comments/Guidelines	Mark
05.1	force is at right angles/horizontal to wall (and so no component along the wall)✓		1
05.2	arrow drawn upwards from point of contact with ground✓ between ladder and vertical which when extended would pass through 'on ladder' part of label✓	Must be vertical or pointing to right for first mark	1 1
05.3	(*use of sum of clockwise moments = sum of anticlockwise moments*) EITHER $F \times 8.0 \sin 60$ OR $390 \times 4.0 \cos 60$ ✓ $F = 390 \times 4.0 \cos 60 / 8.0 \sin 60 = 110\ (113)$ N✓	Either moment correct gets first mark (does not have to be evaluated)	1 1
05.4	**ANY 3** (vertical reaction) force from ground increases✓ direction of arrow of resultant force from ground changes (as ladder is ascended)✓ friction force/horizontal component of G between ladder and ground would increase✓ the (reaction) force from the wall increases✓ weight (of system)/load on ladder increases✓ as person climbs they exert a force along the ladder✓		MAX 3
Total			**8**

0 6 **Figure 8** shows a model of a system being designed to move concrete building blocks from an upper to a lower level.

Figure 8

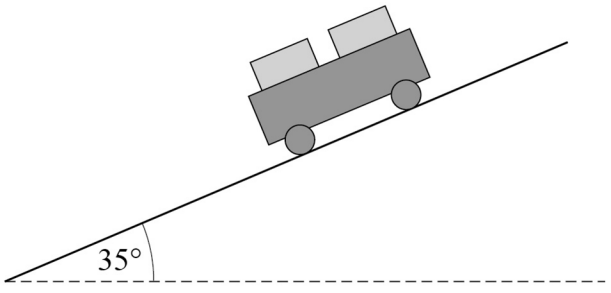


The model consists of two identical trolleys of mass M on a ramp which is at $35°$ to the horizontal. The trolleys are connected by a wire that passes around a pulley of negligible mass at the top of the ramp.

Two concrete blocks each of mass m are loaded onto trolley **A** at the top of the ramp. The trolley is released and accelerates to the bottom of the ramp where it is stopped by a flexible buffer. The blocks are unloaded from trolley **A** and two blocks are loaded onto trolley **B** that is now at the top of the ramp. The trolleys are released and the process is repeated.

Figure 9 shows the side view of trolley **A** when it is moving **down** the ramp.

Figure 9



0 6 . 1 The tension in the wire when the trolleys are moving is T.

Draw and label arrows on **Figure 9** to represent the magnitudes and directions of any forces and components of forces that act on trolley **A** parallel to the ramp as it travels down the ramp.

[1 mark]

0 6 . 2 Assume that no friction acts at the axle of the pulley or at the axles of the trolleys and that air resistance is negligible.

Show that the acceleration a of trolley **B** along the ramp is given by

$$a = \frac{mg \sin 35^\circ}{M + m}$$

[2 marks]

0 6 . 3 Compare the momentum of loaded trolley **A** as it moves downwards with the momentum of loaded trolley **B**.

[2 marks]

Question 6 continues on the next page

0 6 . 4 In practice, for safety reasons there is a friction brake in the pulley that provides a resistive force to reduce the acceleration to 25% of the maximum possible acceleration.

The distance travelled for each journey down the ramp is 9.0 m.

The following data apply to the arrangement.

Mass of a trolley M = 95 kg
Mass of a concrete block m = 30 kg

Calculate the time taken for a loaded trolley to travel down the ramp.

[3 marks]

time = _____ s

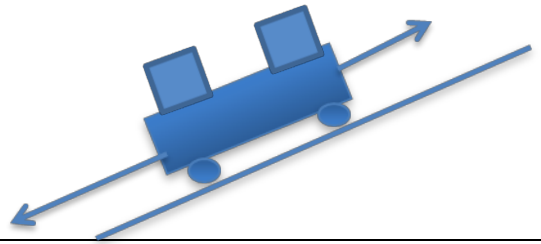
0 6 . 5 It takes 12 s to remove the blocks from the lower trolley and reload the upper trolley.

Calculate the number of blocks that can be transferred to the lower level in 30 minutes.

[2 marks]

number = _____

10

Question	Answers	Additional Comments/Guidelines	Mark
06.1	arrow parallel to slope labelled (M+2m)gsin35 and label parallel to slope labelled tension OR T✓ 	Ignore arrows not parallel to ground e.g. weight Ignore friction W not acceptable for (M +2m)g	1
06.2	T – Mgsin35 = Ma AND (M+2m)gsin35 – T = (M+2m)a ✓ add two equations (M + 2m)gsin35 – Mg sin35 = Ma + (M +2m)a ✓ HENCE (a= mgsin35/(M+m)) OR (M +2m)gsin35 – Mgsin35✓ (= (2M+2m)a) a = 2mgsin35 /(2M +2m) ✓ HENCE (a= mgsin35/(M+m))		1 1
06.3	SECOND MARK CONDITIONAL ON FIRST mass/impulse/acceleration (of trollies) is the same✓	SECOND MARK CONDITIONAL ON FIRST both have same <u>speed / magnitude of velocity</u> but different	1

	momenta (trolley A and B) the same	masses✓ (hence)momentum of A is greater/momenta in opposite directions✓	1

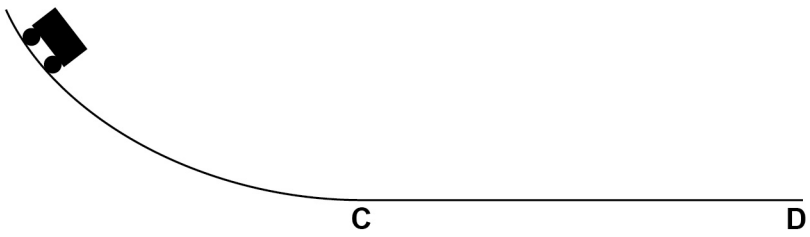
06.4	acceleration = $\frac{1}{4} \times \frac{30 \times 9.81 \times \sin 35^\circ}{(30+95)} = 0.338$ ✓ (use of $v^2 = 2as$) $v = \sqrt{(2 \times 0.338 \times 9.0)} = 2.47$ ✓ $t = \frac{2.47}{0.338} = 7.3$ s ✓ OR (use of $s = 1/2at^2$) $9 = ½ \times 0.338 \times t^2$ ✓ $t = 7.3$ s ✓	CE from acceleration calculation If used g for acceleration then no marks awarded	1 1 1

06.5	number of journeys = $(1800/(12 + 7.3) = 93$ or 94✓ number of blocks = $2 \times 93 = 186$ or $2 \times 94 = 188$✓	Allow CE from 06.4 Allow between 93 to 94 Allow CE from incorrect number of journeys Allow 186 to 188	1 1

Total			**10**

0 2 . 2 **Figure 2** shows the truck moving down a ramp with a varying slope.

Figure 2



The truck starts from rest and moves freely down the ramp. It reaches point **C** and then moves along the horizontal runway to **D**. Friction and air resistance are negligible.

Discuss how the acceleration of the truck in **Figure 2** differs from the acceleration of the truck in **Figure 1**.

[3 marks]

Question 2 continues on the next page

0 2 . 3 The total vertical displacement of the centre of mass of the truck in **Figure 2** is also $8.0\ \text{m}$

The speed of the truck when it reaches the horizontal runway is the same as the speed of the truck in **Figure 1** when it reaches point **A**.

Explain why.

[1 mark]

0 2 . 4 The horizontal runway in **Figure 2** has negligible friction and air resistance. As the truck moves along the runway, it starts to rain. The rain falls vertically and water collects in the truck.

Discuss whether there are any changes in the momentum of the truck and collected water.

[3 marks]

9

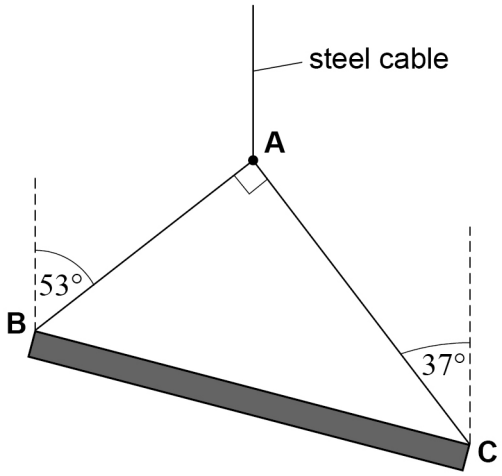
Question	Answers	Additional Comments/Guidelines	Mark
02.1	*(use of gain in E_k = loss in E_p)* $1/2mv^2 = mgh$ $1/2v^2 = 9.81 \times 8.0$✓ $(v = \sqrt{(2 \times 9.81 \times 8.0)}) = 13\ (12.5)\ (m\ s^{-1})$ ✓	Bald correct answer scores 1 mark If use $v^2 = u^2 + 2as$ then zero Unless resolved g along slope If use 10 for g (-1) Gets second mark if answer rounds to 13	 1 1
02.2	THREE FROM: acceleration of truck in Fig.1 is constant✓ In Fig.2 acceleration is greater/greatest at start/top✓ acceleration decreases✓ reference to zero acceleration/uniform velocity between C and D✓ because the component of weight/acceleration parallel to the slope changes✓		 1 1 1 (3 MAX)
02.3	the loss of (gravitational) potential energy is the same hence gain in kinetic energy is the same✓		1
02.4	THREE FROM: rain has no (initial) <u>horizontal</u> momentum ✓ <u>vertical</u> momentum of rainwater decreases ✓ there is no external (horizontal) impulse/force on the truck (and water system) ✓ mass (of truck) increases but speed/velocity decreases✓ <u>horizontal</u> momentum of water increases (but horizontal momentum of	If say: 'vertical momentum/velocity of rain drops/water changes to horizontal (momentum/velocity)' score 2 marks	 1 1 1 (3 MAX)

	truck decreases by same amount) ✓		
	(so) no change in (horizontal) momentum of truck and collected water/total momentum ✓	Cannot score last mark if stated that speed/velocity of truck does not change	

Total			**9**

0 4 **Figure 4** shows a uniform beam supported by two light cables, **AB** and **AC**, which are attached to a single steel cable from a crane. The beam is stationary and in equilibrium.

Figure 4



0 4 . 1 State **two** necessary conditions for the beam to be in equilibrium.

[2 marks]

Condition 1 _____

_____

_____

Condition 2 _____

_____

_____

0 4 . 2 State what is meant by the centre of mass.

[1 mark]

_____

_____

0 4 . 3 Explain why the centre of mass of the beam in **Figure 4** must be vertically below **A**.

[2 marks]

0 4 . 4 The weight of the beam is $12\,000$ N

Calculate the tension T_1 in cable **AB** and the tension T_2 in cable **AC**.

[4 marks]

T_1 = _____ N

T_2 = _____ N

Question 4 continues on the next page

0 4 . 5 The steel cable from the crane has a circular cross-section of diameter $1.5 \times 10^{-2}\,\text{m}$
The cable is $12\,\text{m}$ long.

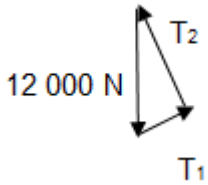
Calculate the extension of the cable caused by the weight of the beam. You can assume that the weights of **all cables** are negligible.

Young modulus of steel = $2.0 \times 10^{11}\,\text{Pa}$

[3 marks]

extension = _____ m

12

Question	Answers	Additional Comments/Guidelines	Mark
04.1	resultant/overall/sum of force = 0 OR forces up equal forces down AND forces left equal forces right✓ (sum of) anticlockwise moments (about any point) = (sum of) clockwise moments/zero resultant moment/torque✓		1 1
04.2	EITHER the point through which (the line of action of) a force has no turning effect/causes no rotation/ no torque✓ OR where the mass of the body can be considered to be concentrated OR where the weight can be considered to act✓	NOT where mass can be considered to act Ignore reference to force of gravity	1
04.3	so there is not a resultant moment/turningeffect / turning forceOR moments do not balance OR (beam) does not rotate/oscilate/swing ✓ about A/ because A is pivot ✓	Allow moments balanced for no resultant moment	1 1
04.4	 T_1 = 12 000 cos 53✓ T_1 = 7200 (7221) (N)✓ T_2 = 12 000 sin53✓ T_2 = 9600 (9583) (N)✓ OR	If T_1 and T2 are the wrong way round get 3 out of 4 If scale drawing 2 max +/- 300(N) If values out by a factor of 10 then -1 (i.e. confusion over g)	1 1 1 1

	$T_1 \cos 53 + T_2 \cos 37 = 12\,000$✓ $T_1 \sin 53 = T_2 \sin 37$✓ $T_2 = T_1 \sin 53/\sin 37$ hence $T_1 \cos 53 + T1 \sin 53 \cos 37/\sin 37 = 12\,000$ $T_1 = 7200$ (7221) (N)✓ $T_2 = 7221 \sin 53/\sin 37 = 9600$ (9583) (N)✓		

Question	Answers	Additional Comments/Guidelines	Mark
04.5	(use of $\Delta l = Fl/AE$) $A = \pi \times (0.75 \times 10^{-2})^2$✓ (= 1.767×10^{-4}) $\Delta l = 12\,000 \times 12/(1.767 \times 10^{-4} \times 200 \times 10^9)$✓ $\Delta l = 4.1 \times 10^{-3}$ (m)✓	No attempt to calculate area scores zero wrong area (e.g. d^2 or $2\pi r$ or $2\pi rl$) maximum 1 mark unless diameter used for radius in πr^2 then maximum 2 mark accept 4.0×10^{-3} If 4×10^{-3} then -1 as 1 sig. fig.	1 1 1
Total			**12**

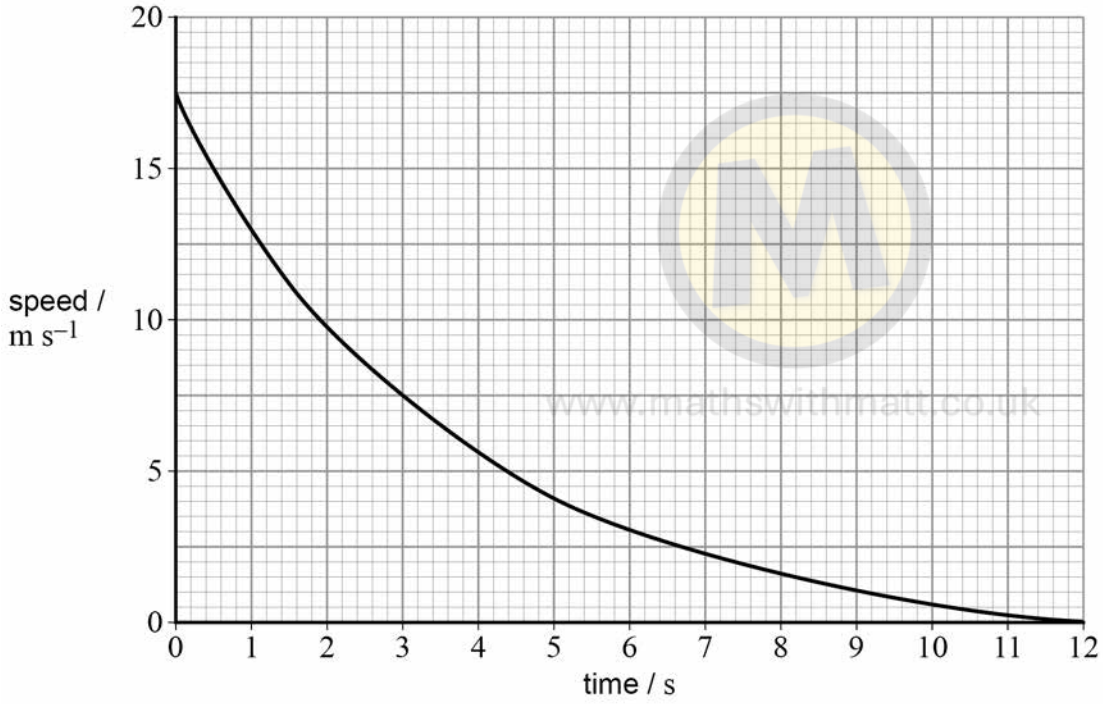
Section A

Answer **all** questions in this section.

0 1 Horizontal escape lanes made of loose gravel have been constructed at the side of some roads on steep hills so that vehicles can stop safely when their brakes fail.

Figure 1 shows an engineer's prediction of how the speed of an unpowered vehicle of mass 1.8×10^4 kg will vary with time as the vehicle comes to rest in an escape lane.

Figure 1



0 1 . 1 Determine the force decelerating the vehicle 2.0 s after entering the escape lane.

[3 marks]

force decelerating the vehicle = _____ N

0 1 . 2 Deduce whether a lane of length $85\ \text{m}$ is long enough to stop the vehicle, assuming that the engineer's graph is correct.

[3 marks]

0 1 . 3 Discuss the energy transfers that take place when a vehicle is decelerated in an escape lane.

[2 marks]

Question 1 continues on the next page

0 1 . 4 An alternative to an escape lane containing gravel is an escape lane that consists of a ramp. An escape ramp is a straight road with a concrete surface that has a constant upward gradient.

One escape ramp makes an angle of $25°$ to the horizontal and is 85 m long.

Deduce whether this escape ramp is sufficient to stop the vehicle.

Assume that any frictional forces and air resistance that decelerate the vehicle are negligible.

[3 marks]

0 1 . 5 Discuss whether an escape lane containing gravel or an escape ramp would provide the safer experience for the driver of the vehicle as it comes to rest.

[1 mark]

12

Question	Answers	Additional Comments/Guidelines	Mark
01.1	Tangent drawn at $t = 2.0 \pm 1$ s ✓	Use of *suvat* loses first 2 marks Guidance- take tangent point to be half-way between where the line clearly leaves the curve	1
	Mean deceleration from use of tangent using correct coordinates (correct Δv and Δt) and answer in range (-)2.5 to (-)2.9 (m s^{-2}) ✓	Ignore minus sign $=15/5.5 = 2.7(3)$ m s^{-2} Allow if answer rounds to these values	1 1
	Use of $F = ma$ using their a with answer i.e Force =1. 8 x 10^4 x their a from an attempt at a tangent or trying to use *suvat* equation✓	answers from best attempts at tangent in range 4.7 to 4.9 x 10^4 N	
01.2	Attempt to estimate area under the graph. ✓	Use of *suvat* equation = 0	1
	Correct square count 21 to 23 10 mm squares (525-575 small squares) **OR** distance per square = 2.5 m or 0.1 m✓	For attempt to find area using trapezium rule expect use of 1 s intervals for this mark.	1 1
	Value in range 50 m to 60 m **and conclusion** that escape lane would be long enough✓		

01.3	KE of lorry : to KE of gravel (as it is pushed aside/moved)✓ OR PE of gravel (as it may be ejected upwards)✓ transfer to thermal energy /internal energy/heating of gravel /ground/lorry **OR** work done on the gravel/vehicle increasing internal energy/raising temperature✓	Ignore losses due to friction Not KE of the ground Must refer to what is heated	Max 2 1 1

1.4	Appreciates that KE converted into PE or May be stated or by attempt to use of $mgh = ½ mv^2$ or Calculates initial KE of lorry $\frac{1}{2}1.8 \times 10^4 \times 17.5^2 = 2.76 \times 10^6$ (J) ✓ Height needed in escape lane $= 2.76 \times 10^6/(1.8 \times 10^4 \times 9.81) = 15.6$ m or Length of lane required $=15.6/\sin 25 = 37$ m **(**compare with 85 m) or vertical height of ramp $= 35.9$ m (compare with height needed 15.6 m) or maximum change in PE possible = 85 sin 25 x 9.81 x 1,8 x 10^4= 6.3 x 10^6 (J) (compare with initial KE) ✓ **Comparison and conclusion** that escape lane would be long enough.This must follow from correct working✓ …… Deceleration produced by slope = 9.8(1) sin 25 or 4.15 (4.1 or 4.2) m s^{-2} seen✓ Distance to stop from $v^2 = 2as$ give s = 37 m (compare with 85 m)✓ Or Minimum deceleration needed = $17.5^2/2$ x 85 = 1.8 m s^{-2} (compare with 4.15 m s^{-2})	Allow max 2 if height = 85 tan 25 or length of lane = 15.6/tan 25 i.e allow these incorrect values when drawing conclusion Arriving at 37 m gets first two marks	1 1 1

	Comparison and conclusion that escape lane would be long enough This must follow from correct working✓		

01.5	The straight road of uniform gradient because: The deceleration (condone acceleration) is uniform ✓ with the gravel the initial deceleration is larger/may vary ✓ Travelling through gravel could make the vehicle unstable/bounce erratically(owtte) ✓ Gravel because: On the ramp the lorry would roll backwards after stopping (as it has no brakes)	Do not allow deceleration less when on gravel(It is greater initially) Do not allow answers that (average) force using gravel lane is less than decelerating force on the ramp (due to increased stopping distance or stopping time) Or because stopping time is longer	Max 1

Total			**12**

0 5 **Figure 8** shows a side view of an act performed by two acrobats. **Figure 9** shows the view from above.

Figure 8

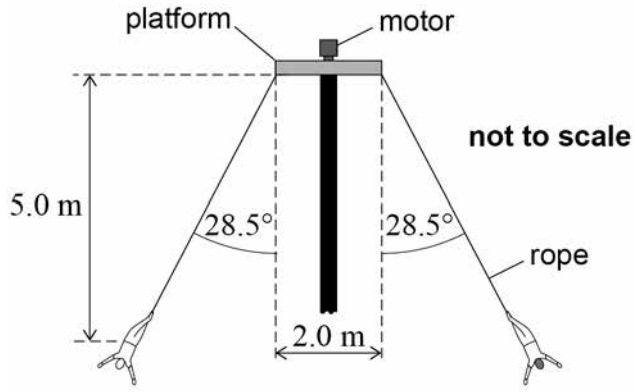
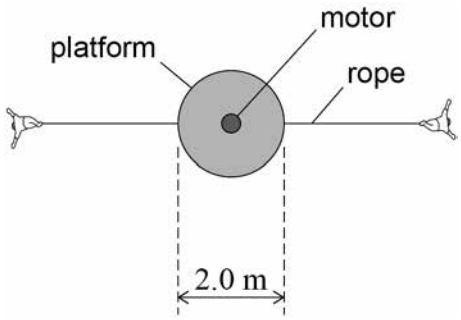


Figure 9



The acrobats, each of mass $85\ \text{kg}$, are suspended from ropes attached to opposite edges of a circular platform that is at the top of a vertical pole. The platform has a diameter of $2.0\ \text{m}$
A motor rotates the platform so that the acrobats move at a constant speed in a horizontal circle, on opposite sides of the pole.

When the period of rotation of the platform is $5.2\ \text{s}$, the centre of mass of each acrobat is $5.0\ \text{m}$ below the platform and the ropes are at an angle of $28.5°$ to the vertical as shown in **Figure 8**.

0 5 . 1 Show that the linear speed of the acrobats is about $4.5\ \text{m s}^{-1}$

[2 marks]

0 5 . 2 Determine the tension in each rope that supports the acrobats.

[3 marks]

tension = _____ N

0 5 . 3 Discuss the consequences for the forces acting on the pole when one acrobat has a much greater mass than the other.

[3 marks]

8

05.1	Radius of orbit = 5 tan 28.5 + 1 = 3.71 m ✓ Speed = 2 × 3.14 × 3.71/5.2 = 4.49 () ✓	For second mark only allow Use of sin 28.5 gives orbit radius 3.39 m and speed = 4.1 m s^{-1} Or Forgets to add 1 giving radius 2.71 and speed 3.27 m s^{-1}	1 1

05.2	Centripetal force = $85 \times 4.49^2/3.71 = 460$ N ✓ Centripetal force = $T \sin 28.5$✓ T = 950 - 970 N✓ **OR** Weight = 85 x 9.8(1) 0r 834 N seen✓ Weight = $T \cos 28.5$ ✓ T = 950 (949) (N) ✓ **OR** Centripetal force = 85 x $4.5^2/3.71$ = 464 N✓ Weight = 834 N✓ $T = \sqrt{464^2 + 834^2}$ = 950 - 970 N✓ Allow ecf for incorrect weight or centripetal force	470 N if using 4.5 m s^{-1} leads to 1000 N **Allow the following as ecf:** forgetting to add the 1 m (using r = 2.71 m) leads to centripetal force = 630 N T = 1300 N) Using r =3.39 m as ecf from 5.1 which leads to Centripetal force = 510 N giving T = 1070 N **Allow the following as ecf:** forgetting to add the 1 m (using r = 2.71 m) leads to centripetal force = 630 N, T = 1050 N using r =3.39 m leads to Centripetal force = 510 N giving T = 980N	1 1 1

05.3	Vertical (compressive) force **on the pole** increases✓ Increases mass <u>increases weight</u> and hence tension in the rope(for the same angle) ✓ <u>Centripetal Force</u> on the acrobats/masses would be different/not equal Or would be greater <u>on the more massive acrobat</u>(travelling at the same speed/same angle to vertical) ✓ Unbalanced (horizontal) forces/resultant force exists (on the pole) ✓ **or** Unbalanced moments acting (on pole)/resultant torque acting (on pole)✓ Causing the pole to sway/bend/move/ or tilt/topple the platform <u>toward more massive acrobat</u>✓		Max 3 1 1 1
Total			**8**

0 6 **Figure 10** shows two railway trucks **A** and **B** travelling towards each other on the same railway line which is straight and horizontal.

Figure 10

The trucks are involved in an inelastic collision. They join when they collide and then move together.

The trucks move a distance of $15\ \text{m}$ before coming to rest.

Truck **A** has a total mass of $16\ 000\ \text{kg}$ and truck **B** has a total mass of $12\ 000\ \text{kg}$

Just before the collision, truck **A** was moving at a speed of $2.8\ \text{m s}^{-1}$ and truck **B** was moving at a speed of $3.1\ \text{m s}^{-1}$

0 6 . 1 State the quantity that is **not** conserved in an inelastic collision.

[1 mark]

0 6 . 2 Show that the speed of the joined trucks immediately after the collision is about $0.3\ \text{m s}^{-1}$

[3 marks]

0 6 . 3 Calculate the impulse that acts on each truck during the collision.
Give an appropriate unit for your answer.

[2 marks]

impulse = _____ unit _____

0 6 . 4 Explain, without doing a calculation, how the motion of the trucks immediately after the collision would be different for a collision that is perfectly elastic.

[2 marks]

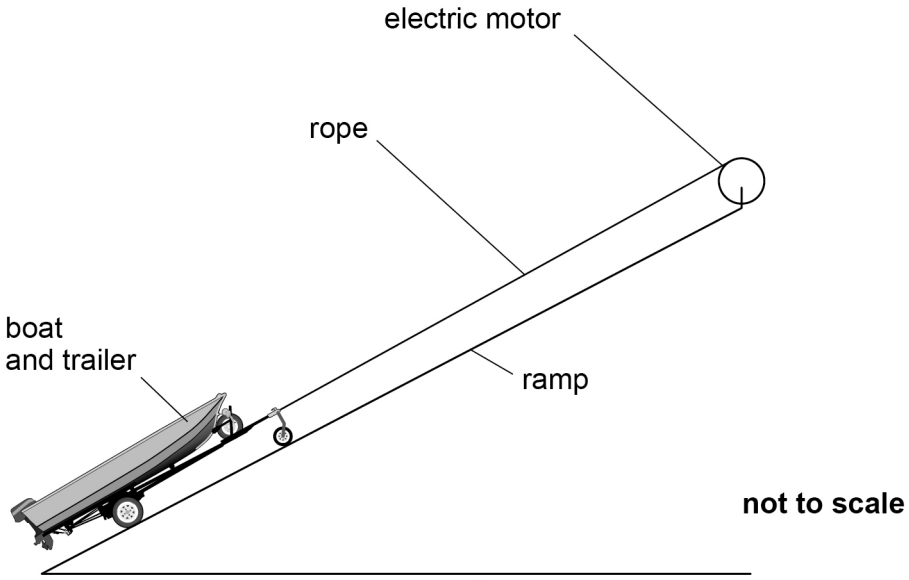
8

06.	(Total) kinetic energy ✓		1
06.2	Attempt to apply conservation of momentum ✓ $16\,000 \times 2.8 - 12\,000 \times 3.1 = 28\,000\,v$ ✓ $v = 0.27(1)$ (m s^{-1}) ✓	NB This is a 'show that' so all stages must be seen Must see substitution Correct equation (watch signs) gets first and second marks	1 1 1
06.3	Impulse = $16\,000(2.8 - 0.271)$ or $12\,000(3.1 + 0.271) = 4.0(5) \times 10^4$ ✓ N s or kg m s^{-1} ✓	If 0.3 m s^{-1} used then impulse will be 4.0×10^4 or $4.08(4.1) \times 10^4$	1 1
06.4	Trucks move in opposite directions/rebound ✓ velocity of **B** is greater than that of **A** because total momentum is to the right OR **B** has lower mass ✓ or Momentum of **B** after collision is same as that of **A** before the collision (and vice versa)		1 1
Total			**8**

Do not write outside the box

0 4 This question is about the initial motion of a boat and trailer when pulled up a ramp as shown in **Figure 8**.

Figure 8

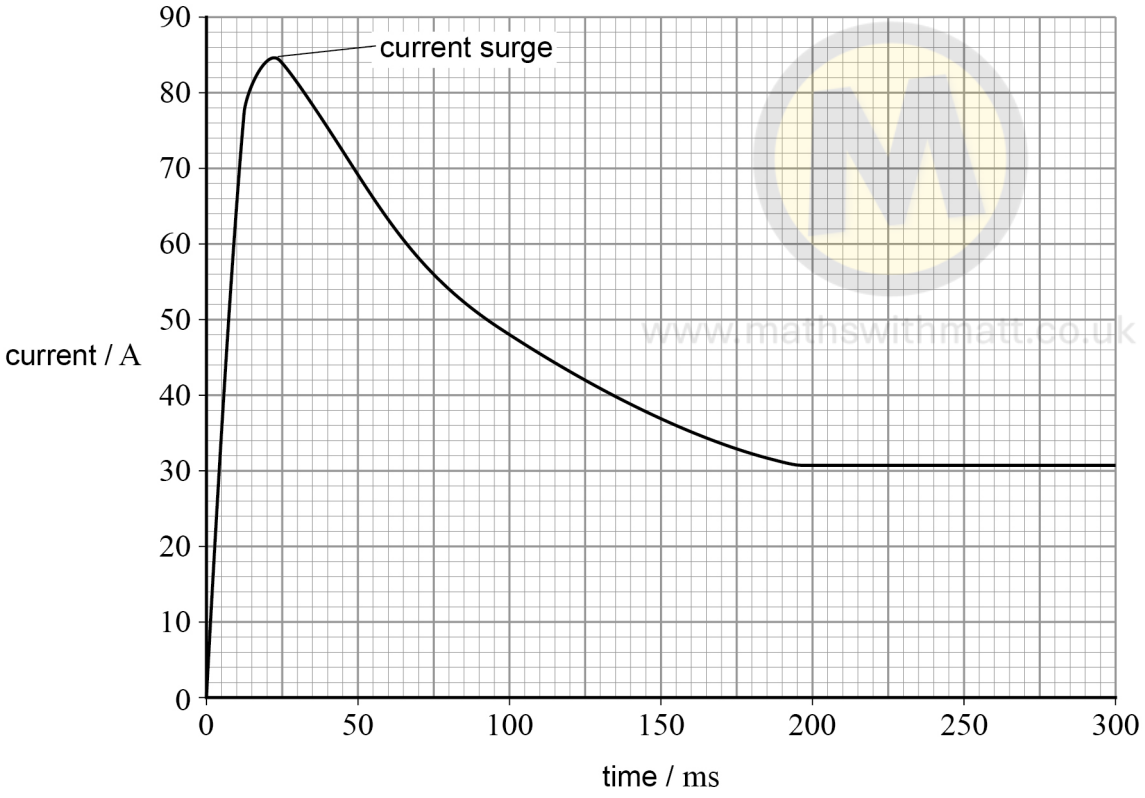


The boat and trailer are pulled by a motor which is connected to a 24 V battery of negligible internal resistance.

Do not write outside the box

The motor is switched on at time $t = 0$
Figure 9 shows how the current in the motor's circuit varies with time.

Figure 9



0 4 . 1 Determine the total energy input by the 24 V battery to the motor in the first 200 ms.
[3 marks]

total energy input = _____ J

Question 4 continues on the next page

Do not write outside the box

0 4 . 2 The boat and trailer are initially at rest. In the first $200\ \text{ms}$ the boat and trailer are raised through a vertical height of $3.3 \times 10^{-2}\ \text{m}$ and the speed increases to $0.85\ \text{m s}^{-1}$.

Assume that all the useful energy output by the motor is transferred into kinetic energy and gravitational potential energy of the boat and trailer.
The boat and trailer have a total mass of $180\ \text{kg}$.

Determine the average efficiency of the motor during these first $200\ \text{ms}$.

[3 marks]

average efficiency = _____

Do not write outside the box

0 4 . 3 Either of the circuits shown in **Figure 10a** and **Figure 10b** could be used to reduce the initial current surge.

Figure 10a

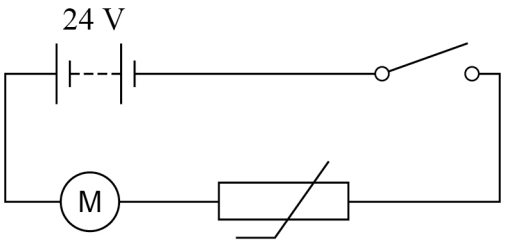
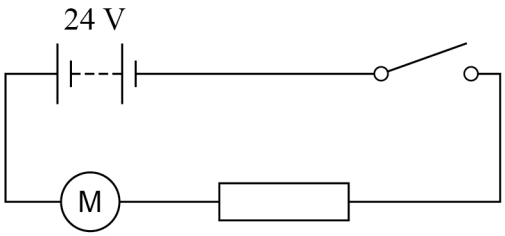


Figure 10b



The thermistor and the fixed resistor have the same resistance when they are at the temperature of the surroundings.
When the surge has ended, the boat and trailer continue to move at a constant speed to the top of the ramp.

Explain, with reference to the properties of the thermistor and the fixed resistor, why using the thermistor is preferable to using the fixed resistor.

[3 marks]

9

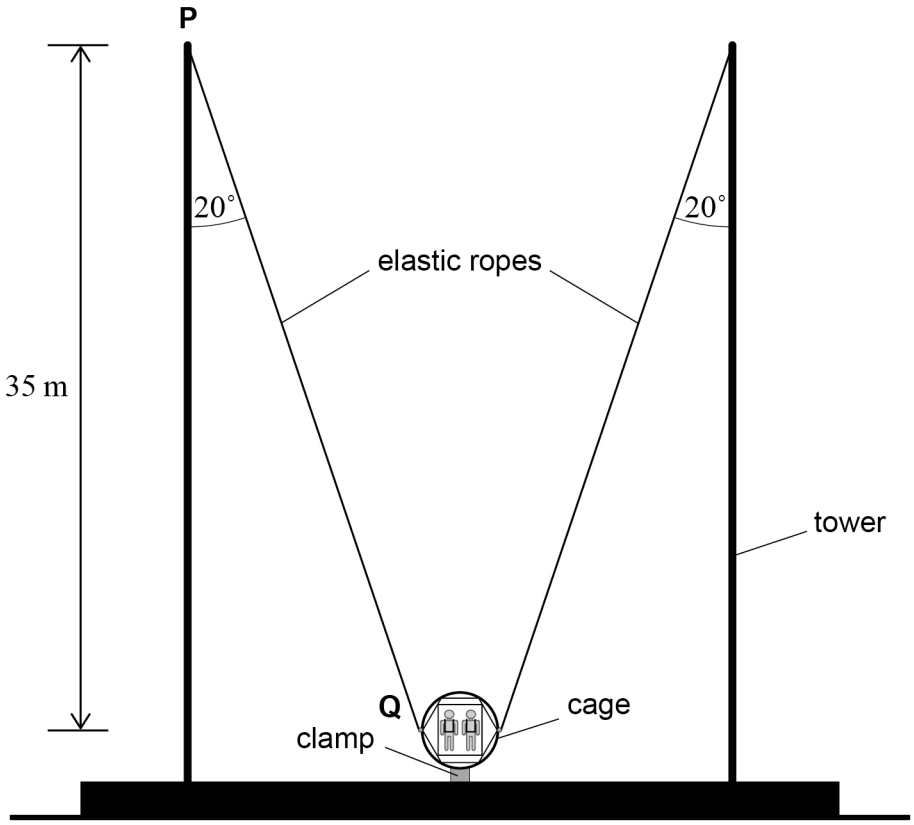
Question	Answers	Additional Comments/Guidelines	Mark
04.1	**Method 1:** Attempts to determine area under curve / by counting squares $_1$✓ Multiplies their (total) area (or charge) by 24 (V) $_2$✓ 240 (J) $_3$✓ **Method 2:** Attempt to determine average current (over first 200 ms in range 45 A to 55 A) $_1$✓ Use of $E = I \times V \times t$ $_2$✓ 240 (J) $_3$✓	Allow POT error on area of square in $_1$✓ and $_2$✓ Evidence seen by calculations **or** from counting squares **or** from division of area into **at least two** recognisable geometrical shapes (triangles, rectangles, trapezia) answer in range 220 J to 264 J Substitutes current value (or Δ current) with t = 200 ms and V = 24 V. Condone POT Allow as two stage $Q=It$ and $E=QV$ Or $P= VI$ **and** $E=Pt$ answer in range 220 J to 264 J	3

04.2	(KE gained) =) $65(.0)$ (J) **or** (PE gained) =) $58(.3)$ (J) $_1$✓ Use of efficiency = $\frac{\text{an output energy}}{\text{ans from part 04.1}}$ **or** (total output = 65 + 58 =) 123 (J) $_2$✓ (Efficiency =) 0.51 or 51% $_3$✓	Allow output energy = 65 /58/ 120 /123 or candidate ke + pe Allow ecf from 4.1 for all 3 marks. Answer to at least 2 sf. Range is 0.467 to 0.56 (46.7 % to 56 %)	3
04.3	Heating occurs / temperature increases when there is a <u>current</u> (in the thermistor) (due to I^2R) $_1$✓ (When the temperature increases) the resistance of thermistor decreases (whereas fixed resistor remains high) $_2$✓ (Lower resistance from thermistor means) less wasted power $_3$✓ OR (Lower resistance from thermistor means) more pd dropped across the motor (less wasted voltage) $_3$✓	Alternatively: (Lower resistance from the thermistor means) less voltage drop across thermistor $_3$✓	3
Total			**9**

Do not write outside the box

0 3 **Figure 3** shows a fairground ride called a 'reverse bungee'.

Figure 3



Two identical stretched elastic ropes are fixed to a cage with passengers inside. The loaded cage is held in place by a clamp. When the clamp is released the elastic ropes accelerate the loaded cage vertically into the air.

P is the point where the rope attaches to the top of the vertical tower.
Q is the point where the rope attaches to the cage. **Q** is level with the centre of mass of the loaded cage.

Before release, the tension T in each elastic rope is 3.7×10^4 N and each rope makes an angle of $20°$ with the vertical tower.

The total mass M of the loaded cage is 1.2×10^3 kg and the mass of the elastic ropes is negligible.

Do not write outside the box

0 3 . 1 Show that the downward force F exerted by the clamp on the loaded cage is about 6×10^4 N.

[4 marks]

0 3 . 2 Calculate the initial acceleration of the loaded cage when the clamp is released.

[2 marks]

acceleration = _____ m s^{-2}

Question 3 continues on the next page

Do not write outside the box

0 3 . 3 The unstretched length of each elastic rope is $24\ \text{m}$. The ropes obey Hooke's Law for all extensions used in the ride.
The **vertical** distance between points **P** and **Q** on **Figure 3** is $35\ \text{m}$.

Show that the total elastic potential energy stored in both ropes before the loaded cage is released is about $5 \times 10^5\ \text{J}$.

[4 marks]

0 3 . 4 The designers of the ride claim that the loaded cage will reach a height of $50\ \text{m}$ above **Q**.

Deduce whether this claim is justified.

[3 marks]

Do not write outside the box

0 3 . 5 The designers also claim that the loaded cage reaches a maximum speed of at least $90\ \text{km h}^{-1}$.

Calculate, in J, the kinetic energy of the loaded cage when it travels at $90\ \text{km h}^{-1}$.

[3 marks]

kinetic energy = _____ J

0 3 . 6 Deduce without further calculation whether the maximum speed claim is justified.

[1 mark]

_____

_____

_____

_____

_____

_____

17

Question	Answers	Additional Comments/Guidance	Mark	ID details
03.1	Attempt to calculate weight of cage eg $1.2 \times 10^3 \times 9.81$ or 1.18×10^4 seen ✓ Attempt to find vertical component of tension T_V in one rope eg $3.7 \times 10^4 \cos 20$ or 3.5×10^4 seen ✓ Uses F = twice their tension – their weight ✓ 5.8×10^4 (N) ✓	If weight not calculated, allow MP3 for doubling their tension or their resolved component	4	AO2.1b
03.2	Use of $F = ma$ with 6×10^4 N or their 03.1 ✓ 50 (m s^{-2}) ✓	Allow 48 (m s^{-2}).	2	AO2.1f
03.3	Calculation of length of rope eg $35/\cos 20$ or 37.2 seen ✓ Calculation of extension of one rope or calculation of total extension of both ropes eg their length–24 or 13.2 or 26.4 seen ✓ Use of $E = ½ F\Delta L$ e.g. ½ × $3.7 \times 10^4 \times 13.2 = 2.44 \times 10^5$ (J) ✓ 4.9×10^5 (J) ✓	Allow methods using $F=k\Delta L$ and $E = ½ k\Delta L^2$	4	AO2.1b

03.6	If their $E_k > 5 \times 10^5$, claim is unjustified **OR** If their $E_k < 5 \times 10^5$, claim may be justified depending on gain in E_p or losses due to resistive forces ✓		1	AO3.1b

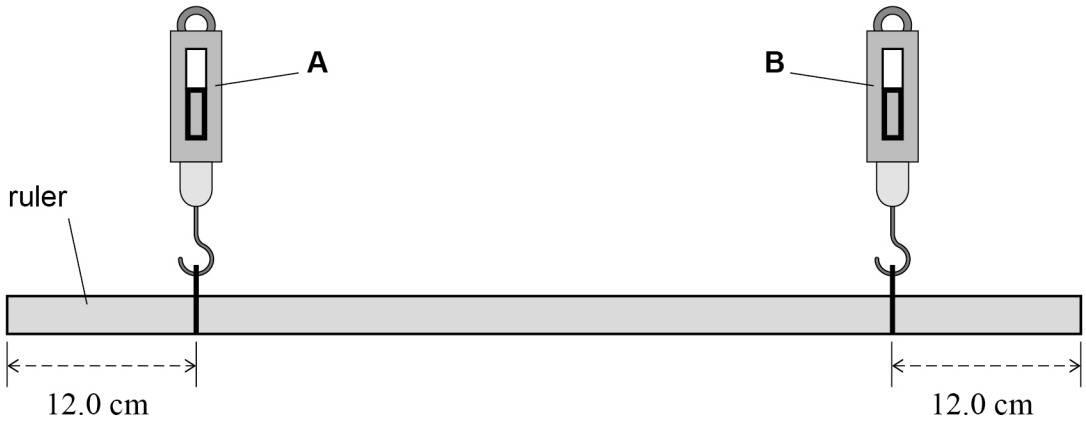
Total			**17**

Do not write outside the box

0 5 A student investigates moments by suspending a 100 cm ruler from two force meters, **A** and **B**. **A** and **B** are attached to the ruler 12.0 cm from each end. Their supports are adjusted to make **A** and **B** vertical and the ruler horizontal.

Figure 8 is a simplified diagram of the experiment.

Figure 8



0 5 . 1 The ruler is uniform and weighs 1.12 N.

Determine the reading on **A**.

[1 mark]

reading = _____ N

0 5 . 2 The student suggests that the forces exerted on the ruler by **A** and **B** act as a couple.

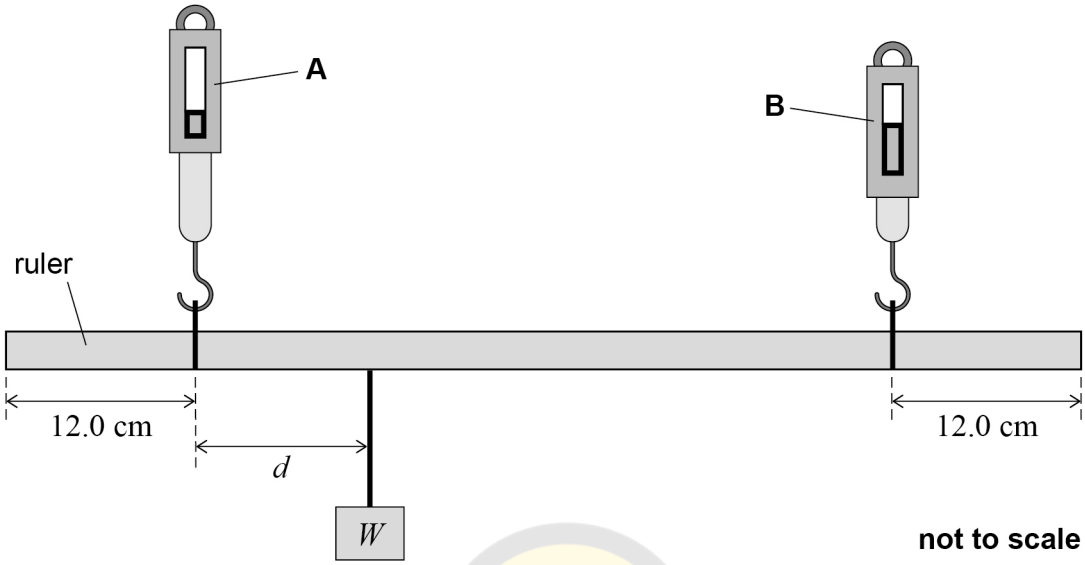
Discuss whether his suggestion is correct.

[2 marks]

Do not write outside the box

0 5 . 3 The student hangs a mass of weight W on the ruler between **A** and **B**, as shown in **Figure 9**.
He adjusts the supports so that **A** and **B** are again vertical and the ruler is horizontal.
The mass hangs at a distance d from **A**.

Figure 9



not to scale

The reading on **A** is 0.82 N and the reading on **B** is 0.62 N.

Determine
- W
- d.

[4 marks]

$W =$ _____ N

$d =$ _____ m

Question 5 continues on the next page

Do not write outside the box

0 5 . 4 A second student sets up the same apparatus as shown in **Figure 9**.
She suspends the mass in the same position on the ruler as in question **05.3**.
She moves the supports to make **A** and **B** vertical but does not make the ruler horizontal.

Discuss whether the readings on **A** and **B** taken by this student are different to those in question **05.3**.

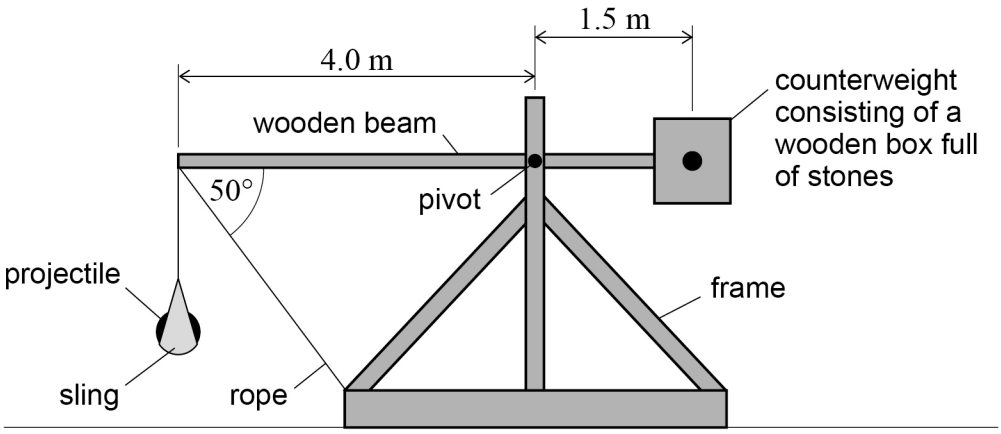
[2 marks]

9

Question	Answers	Additional Comments/Guidance	Mark	ID details
05.1	0.56 (N) ✓		1	AO2.1h
05.2	Definition of couple as two <u>equal</u> forces acting in opposite directions ✓ Forces (are equal but) don't act in opposite directions, therefore it is not correct ✓	Moment of a couple is independent of the point about which moments are taken ✓ Combined moment of the two forces depends on the point about which moments are taken, therefore not correct. ✓	2	AO2.1c
05.3	Use of total upward force = total downward force eg $0.87 + 0.62 = 1.12 + W$ ✓ 0.32 (N) ✓ Attempt to use Principle of Moments ✓ 0.14 (m) ✓	1 mark for any attempt to equate upward and downward forces. Response may be on diagram. Allow MP4 if (their W) × (their d) = 0.0448	4	AO2.1d
05.4	Readings (on A and B) would be the same/1.44 (N) ✓ (Because) total downwards force/weight is same **OR** All (perpendicular) distances affected by the same factor (cos θ) ✓		2	AO3.1b
Total			**9**	

0 4 **Figure 5** shows a simplified catapult used to hurl projectiles a long way.

Figure 5



The counterweight is a wooden box full of stones attached to one end of the beam.
The projectile, usually a large rock, is in a sling hanging vertically from the other end of the beam. The weight of the sling is negligible.
The beam is held horizontal by a rope attached to the frame.

0 4 . 1 The catapult is designed so that the weight of the beam and the weight of the **empty** wooden box have no effect on the tension in the rope.

Suggest how the pivot position achieves this.

[2 marks]

Question 4 continues on the next page

Do not write outside the box

0 4 . 2 The stones in the counterweight have a total mass of $610\ \text{kg}$ and the projectile weighs $250\ \text{N}$.

Calculate the tension in the rope.

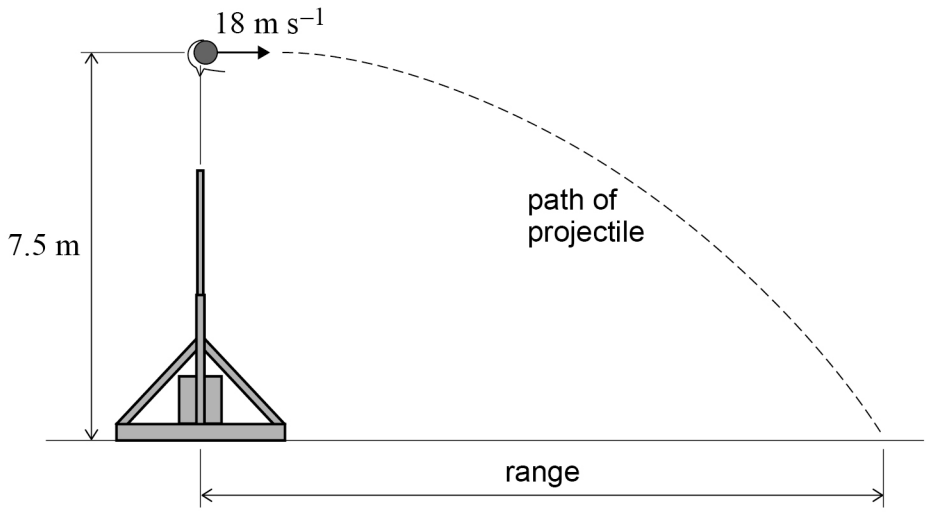
[5 marks]

tension = _____ N

0 4 . 3 When the rope is cut, the counterweight rotates clockwise. When the beam is vertical it is prevented from rotating further. The projectile is then released horizontally with a velocity of $18\ \text{m s}^{-1}$, as shown in **Figure 6**.

The projectile is released at a height of $7.5\ \text{m}$ above ground level.

Figure 6



Do not write outside the box

The range of the catapult is the horizontal distance between the point where the projectile is released to the point where it lands.

Calculate the range.
Ignore air resistance.

[2 marks]

range = _____ m

0 4 . 4 In another release, the sling is adjusted so that a projectile of the same mass is released just before the wooden beam is vertical. The projectile is not released horizontally.

Discuss the effect this change has on the range of the catapult.

[3 marks]

12

Question	Answers	Additional Comments/Guidelines	Mark
04.1	The centre of mass of the beam and box is at the pivot ✓ Idea that moments balance / sum of the moments is zero at this position ✓ **OR** The anticlockwise moment (of weight of the beam) = clockwise moment (of weight of the box) ✓ Links pivot position to a consideration of moments ✓	Accept one route or the other, do not accept points from both. Allow max 1 for "the pivot is to the right of the centre (of mass) of the beam" 'pivot' on its own does not get the first mark Award 2 for 1.25 x weight of beam = 1.5 x weight of empty box Confusion of moments with eg work done/forces = max 1	2
04.2	Clockwise moment = $610 \times 9.81 \times 1.5$ (= 8976 N m) ✓ Anticlockwise moment = $250 \times 4 + T \sin 50 \times 4.0$ (N m)✓ Use of clockwise = anticlockwise✓ Use of $T \sin 50^{o}$ seen / relates vertical component to tension✓ T (= 1994/sin 50^{o}) = 2600 (N)✓	Credit any evidence to work out a moment with one mark Condone cos 50 in MP2. Allow ecf for clockwise moment Allow ecf for anticlockwise moment Use of g = 10 N kg^{-1} gives 2990 N Omission of 4.0 m (g = 9.8) gives 10410 N. Use of cos 50 (g = 9.8) gives 3100 N	5

04.3	$7.5 = ½\ g\ t^2$ ✓ (t = 1.2 s) (calculate distance) s (= ut = 18 × 1.2) = 22 (m)✓	Allow ecf from incorrect t for MP2	2

04.4	**(Range will be greater:)** component of velocity upwards ✓ rock will spend longer in the air ✓ greater *t* ✓ ***therefore*** the range is greater ✓ **OR** **(Range will be smaller)** Counterweight will fall less far before projectile released ✓ Less energy transferred to rock ✓ Initial speed of rock less/horizontal velocity reduced ✓ ***therefore*** the range is smaller ✓ **OR** (balanced arguments) ***therefore*** the range is unchanged / answer is indeterminate✓	Candidates can argue from both lists to reach a balanced view suggesting that there is no change. Full credit can be obtained from 2 deductions from one list ✓✓+ consistent conclusion✓ 1 deduction from each list ✓✓+ consistent conclusion ✓ Do not allow an unsupported conclusion. Conclusion must be consistent with **correct** statements. Treat incorrect statements as neutral. Do not reward arguments based on a longer time of flight.	Max 3
Total			12

Do not write outside the box

0 5 Safety barriers are used on UK motorways to prevent vehicles crossing from one carriageway to the other carriageway. The barriers also absorb some of the kinetic energy of a vehicle and deflect vehicles along the barrier.

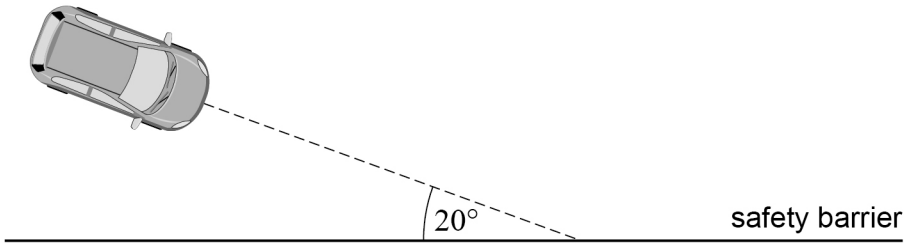
The standard test of a safety barrier uses a vehicle that contains dummies. The total mass of the vehicle and its contents is 1.5×10^3 kg and its initial speed is 110 km h^{-1}.

0 5 . 1 Show that the initial kinetic energy of the test vehicle is 700 kJ.

[2 marks]

0 5 . 2 The test vehicle hits a steel safety barrier at an angle of $20°$, as shown in **Figure 7**.

Figure 7



Calculate the component of the momentum of the test vehicle in a direction along the line of the safety barrier.
Give an appropriate unit for your answer.

[3 marks]

momentum = _____ unit _____

Do not write outside the box

0 5 . 3 Immediately after the collision, the test vehicle moves along the safety barrier with no change in its momentum in this direction.

Show that the kinetic energy lost in the collision is about $80\ \text{kJ}$.

[3 marks]

0 5 . 4 The steel safety barrier deforms during the collision. For the barrier to pass the test, the test vehicle should not move more than $1.5\ \text{m}$ towards the other carriageway.

The barrier can apply an average force of $60\ \text{kN}$ at right angles to the carriageway.

Deduce whether the safety barrier will pass the test.

[3 marks]

Question 5 continues on the next page

Do not write outside the box

0 5 . 5 A different safety barrier uses a solid concrete wall which does not deform. The same standard test is carried out on a concrete wall.

Discuss which type of barrier would cause less damage to the dummies in the test.

[2 marks]

13

Question	Answers	Additional Comments/Guidelines	Mark
05.1	Conversion of $110\ \text{km h}^{-1}$ to $31\ \text{m s}^{-1}$ ✓ = ½ × 1.5×10^3 × *their conversion*^{2} with a consistent answer✓ (= $7(.2) \times 10^5$)	Allow ecf for incorrect or failure to carry out speed conversion Expect answer to be calculated correctly and to 2+ sf. Accept 700 kJ as 2 sf	2
05.2	Component of velocity = $31 \times \cos(20)$ **OR** evidence of using momentum = mass × velocity (eg 1.5×10^3 x a velocity) ✓ = 4.4×10^4 ✓ For unit <u>only</u> accept kg m s^{-1} **OR** N s ✓	Allow ecf for speed from 05.1 Accept 4.65×10^4 kg m s^{-1} for max 2 Use of 30.6 m s^{-1} gives 43 kN s	3
05.3	(KE before collision = 700 kJ) Speed (parallel to barrier) after (= $31 \times \cos 20$) = $28.7\ \text{m s}^{-1}$ ✓ KE after(= ½ × $1.5 \times 10^3 \times 28.7^2$) = 618 kJ ✓ Change = 700 – 618 ✓ (= 82 kJ) **OR**	Allow ecf for speed from 05.1 Use of KE = $p^2/2m$ can gain full credit. Allow ecf for momentum in 05.2 Final answer depends on extent to which candidate has rounded in earlier parts. Allow correctly evaluated solutions for full credit.	3

05.4	Evidence of work done = force × distance Eg Force = 82 000 / 1.5 **OR** *their value for 05.3*÷1.5✓ = 5.5×10^4 N✓ This is less than braking force – so yes. ✓ **OR** energy approach • work done by barrier = 60 kN x 1.5 m✓ • 90 kJ ✓ • which is > E_k of vehicle, so yes ✓ **OR** impulse argument • evaluate time taken to stop, 0.26 s ✓ • impulse value leading to distance or force✓ • conclusion consistent with correct method of calculation ✓ **OR** use of *F=ma* and *suvat* : • F= ma leading to *a* = (-)40 m s^{-2}✓ • *suvat* leads to 1.37 m✓ • which is <1.5 m, so yes ✓	Allow 80 kJ for energy General scheme for alternatives and reverse arguments is: • first step calculation • subsequent calculation(s) leading to comparative value. Allow ecf for error in first step. • conclusion consistent with correct method of calculation Alternative suvat method: • uses suvat to get a = 36.5 m s^{-2} • uses F=ma • which is <60 kN, so yes	3

05.5	~~(Steel barrier is better because)~~ Increase time of contact as material deforms ✓ Reference to impulse (= change in momentum = Ft) implies smaller force (on dummy) ✓ **OR** Increasing stopping distance as material deforms ✓ Reference to work done (= Fs) implies smaller force (on dummy) ✓	Allow correct discussion leading to concrete barrier is worse. Alternative second mark for either alternative can be awarded for correct reference to F=ma	2

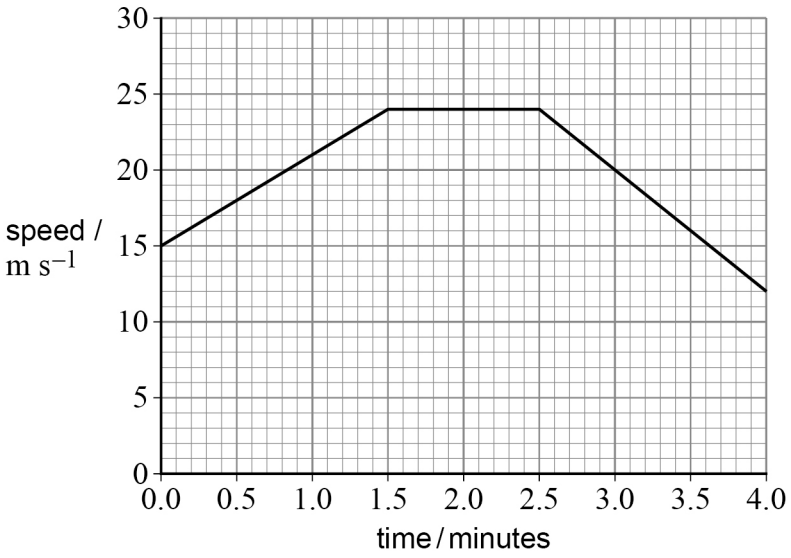
Total			**13**

Do not write outside the box

0 4 A pair of cameras is used on a motorway to help determine the average speed of vehicles travelling between the two cameras.

Figure 5 shows the speed–time graph for a car moving between the two cameras.

Figure 5



0 4 . 1 The speed limit for the motorway between the two cameras is $22\ \text{m s}^{-1}$.

Determine whether the average speed of the car exceeded this speed limit.

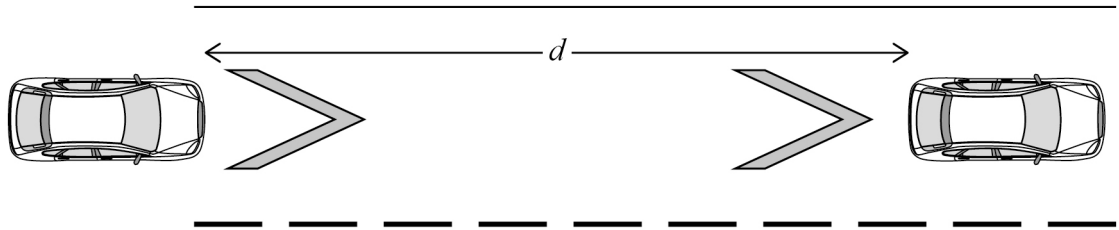
[3 marks]

Question 4 continues on the next page

0 4 . 2 Markings called chevrons are used on motorways.

The chevron separation is designed to give a driver time to respond to any change in speed of the car in front. The driver is advised to keep a minimum distance d behind the car in front, as shown in **Figure 6**.

Figure 6



not to scale

Government research suggests that the typical time for a driver to respond is between 1.6 s and 2.0 s.

Suggest a value for d where the speed limit is 31 m s^{-1}.

[2 marks]

$d =$ _____ m

Do not write outside the box

0 4 . 3 The chevron separation is based on the response time, not on the time taken for a car to stop.

The brakes of a car are applied when its speed is $31\ \text{m s}^{-1}$ and the car comes to rest. The total mass of the car is $1200\ \text{kg}$.

The average braking force acting on the car is $6.8\ \text{kN}$.

Calculate the time taken for the braking force to stop the car **and** the distance travelled by the car in this time.

[4 marks]

time = _____ s

distance = _____ m

0 4 . 4 Suggest why the chevron separation on motorways does not take into account the distance travelled as a car comes to rest after the brakes are applied.

[1 mark]

_____

_____

_____

_____

Question 4 continues on the next page

0 4 . 5 At bends on motorways the road is sloped so that a car is less likely to slide out of its lane when travelling at a high speed.

Figure 7 shows a car of mass $1200\ \text{kg}$ travelling around a curve of radius $200\ \text{m}$. The motorway is sloped at an angle of $5.0°$.

Figure 8 shows the weight W and reaction force N acting on the car. The advisory speed for the bend is chosen so that the friction force down the slope is zero.

Figure 7

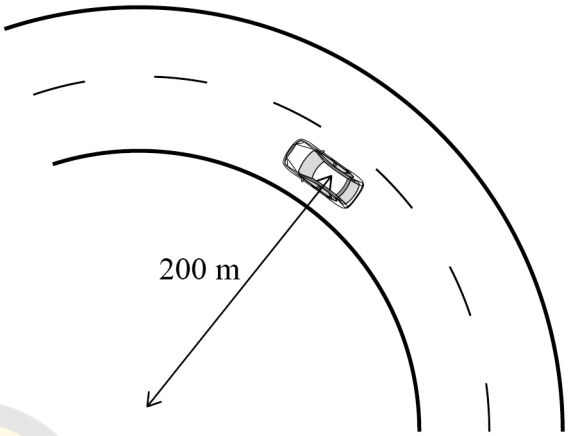
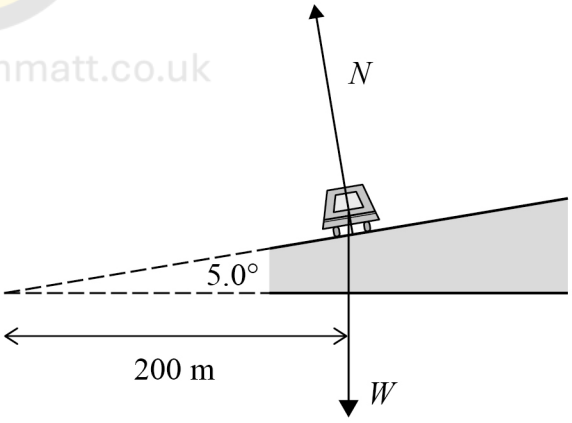


Figure 8



Do not write outside the box

Suggest an appropriate advisory speed for this section of the motorway.

[4 marks]

advisory speed = _____ $m\ s^{-1}$

14

Question	Answers	Additional comments/Guidelines	Mark	ID details
04.1	Evidence of distance travelled = area under graph $= 1755 + 1440 + 1620 = 4815$✓ Average speed = total distance/time taken = $4815/240$ = $20.1\ \text{m s}^{-1}$✓ (at least 3sf) Which is less than (speed) limit, (and therefore the answer is No). ✓ Alternative for MP2 and MP3 Calculation of distance travelled at speed limit = $5280\ \text{m}$✓ Which is greater than distance travelled (so no). ✓	Full marks can be credited for use of suvat. Allow ecf for distance in MP2 Only award MP3 for incorrect speed if attempt made to calculate distance correctly e.g. area under graph OR a.e. in distance or speed Alternative for MP1 and MP2: Total area = $80.25\ \text{m s}^{-1}\ \text{min}$✓ Time = $4\ \text{min}$ Average = $20.1\ \text{m s}^{-1}$✓	3	AO3.1a AO2.1f AO3.1a
04.2	Using reaction time of $2.0\ \text{s}$ ✓ Use of distance = speed × time = $62\ \text{m}$. $62\ \text{m}$ (would be appropriate). ✓	Award MP2 if $1.6\ \text{s}$ (to give 50 m) or 1.8 s (to give 56 m) or 1.7 s (to give 53 m) or average of two distances used Allow $60\ \text{m}$.	1 1	AO3.1a AO1a

04.3	Use of F = ma to calculate acceleration. a = 6800/1200✓ = 5.7 m s^{-2} evidence of use of suvat to calculate s or t, ✓ to give t = 5.5 s ✓ s = 85 m. ✓	If no other mark given, allow 1 mark for mv = 1200 x 31 (= 37200) Alternative for MP1 and MP2 $t = \frac{mv-mu}{F}$ Allow ce for a. Allow ce for either incorrect s or t.	4	AO2.1b

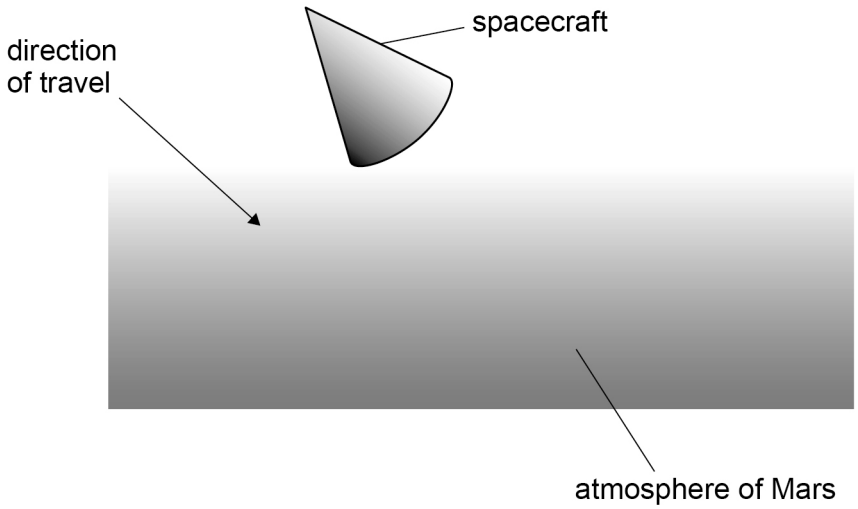
Question	Answers	Additional comments/Guidelines	Mark	ID details
04.4	(It is assumed that) the car in front would take the same time/travel the same distance as the car behind when braking/ only difference is reaction time of the driver of car behind.✓ Or Car in front cannot stop instantaneously (so car behind will have time/distance to bring car to rest).or words to that effect	Alternative: suggestion that total stopping distance is too large (drivers would ignore it/inefficient use of motorway)	1	AO3

Question	Answers	Additional comments/Guidelines	Mark	ID details
04.5	Correct use of cos (5) ✓ E.g. $mg = N \cos(5)$ Correct use of sin (5) ✓ E.g. $N \sin(5)$ (= mv^2/r) So mv^2/r seen✓ And $v = (rg \tan(5))^{½}$ Gives $v = (200 \times 9.81 \times \tan(5))^{½} = 13$ So speed limit = $13\ \text{m s}^{-1}$✓	May see cos (85) for sin (5) Alternative for MP1 and MP2: Evidence of $mg \tan(5)$ fourth mark is for answer and suggesting this as the speed limit. Max 3 if mg = N used	4	AO3.1a
Total			**14**	

Do not write outside the box

0 2 A spacecraft entering the atmosphere of Mars must decelerate to land undamaged on the surface.

Figure 1



0 2 . 1 **Figure 1** shows the spacecraft of total mass $610\ \text{kg}$ entering the atmosphere at a speed of $5.5\ \text{km s}^{-1}$.

Calculate the kinetic energy of the spacecraft as it enters the atmosphere.
Give your answer to an appropriate number of significant figures.

[3 marks]

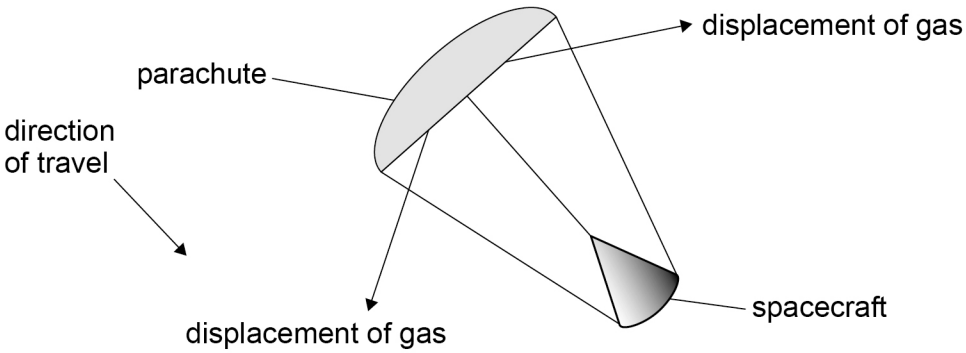
kinetic energy = _____ J

Do not write outside the box

0 2 . 2 A parachute opens during the spacecraft's descent through the atmosphere.

Figure 2 shows the parachute–spacecraft system, with the open parachute displacing the atmospheric gas. This causes the system to decelerate.

Figure 2



Explain, with reference to Newton's laws of motion, why displacing the atmospheric gas causes a force on the system **and** why this force causes the system to decelerate.

[4 marks]

Question 2 continues on the next page

Do not write outside the box

0 2 . 3 As the parachute–spacecraft system decelerates, it falls through a vertical distance of $49\ \text{m}$ and loses $2.2 \times 10^5\ \text{J}$ of kinetic energy.
During this time, $3.3 \times 10^5\ \text{J}$ of energy is transferred from the system to the atmosphere.
The total mass of the system is $610\ \text{kg}$.

Calculate the acceleration due to gravity as it falls through this distance.

[3 marks]

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

0 2 . 4 Dust from the surface of Mars can enter the atmosphere. This increases the density of the atmosphere significantly.

Deduce how an increase in dust content will affect the deceleration of the system.

[3 marks]

13

Total			10	
Question	**Answers**	**Additional Comments/Guidance**	**Mark**	**ID details**
02.1	Use of $E_k = ½ mv^2$ ✓ (Kinetic energy =) 9.2×10^9 (J)✓ An answer to 2 significant figures (with some working)✓	Condone POT error on 1st MP Allow use where v where has been converted from 5.5 km h^{-1} Significant figure mark requires evidence of some relevant working.	3	AO1.1a AO2.1b AO1.1b

02.2	**Why force on the gas:** The gas's momentum is changing✓ This require a force according to **Newton's 2nd law** ✓ Or The gas is being accelerated✓ This require a force according to **Newton's 2nd law** ✓ **Why (resistive) force on system:** The gas exerts a force on the parachute (with an equal magnitude and opposite direction force) / there is air resistance (on the system) / there is drag (on the system) / there is a resistive force (on the system)✓ (because) the Parachute exerts a force on the gas according to **Newton's 3rd law** ✓ **Why system decelerates:** The resistive force is greater than the weight so there is a resultant force **Or** The **resultant** force is acting in the opposite direction (to its motion). ✓ acceleration in same direction as resultant force according to **Newton's 2nd law** ✓	**Max 3** for **why there is a force on the gas** and **why there is a resistive force on the system** Must have **why the system decelerates** to obtain all **4 marks**. The reason why the resultant force causes the deceleration rather than the acceleration. Allow statement that is equivalent to N1 / N2 / N3. Allow: air resistance (or drag) increases. Allow: there is an upward force must have a clear action-reaction pair for this **N3** mark. allow the **resultant** force is vertically upwards **Or** **Links** to violation for conditions of Newton's 1st law and therefore cannot continue at constant velocity.	4	AO2.1a AO2.1e AO2.1a AO2.1e

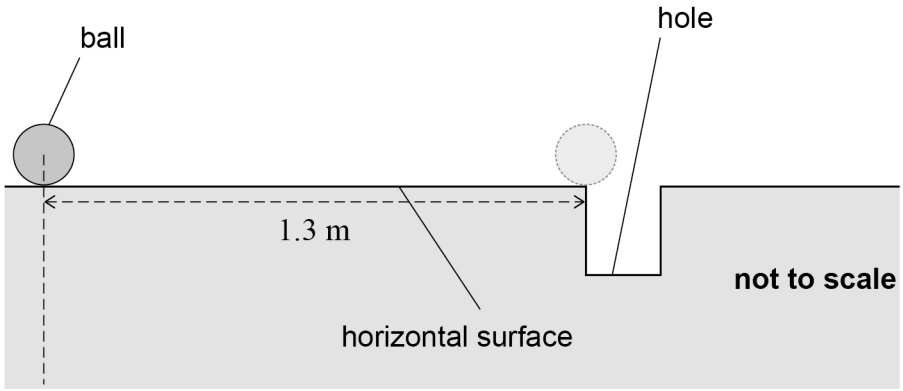
Question	Answers	Additional Comments/Guidance	Mark	ID details
02.3	Attempt at determining difference = $3.3\ (\times 10^5) - 2.2\ (\times 10^5)$ or difference = $1.1\ (\times 10^5)$✓ Use of $E_p = mgh$✓ $(g =)\ 3.7\ (m\ s^{-2})$ ✓	1st mark: Credit an application of conservation of energy (allow written statement, or equation without substitution) Ignore signs on difference and answer. MP2 allow their energy in a substitution that is, otherwise correct. Condone an answer = 18.4 ($m\ s^{-2}$) is worth 2 marks. Condone mgh = ½ mv^2 where rearranged to make g subject. Condone 610 x g x 49 = t**heir energy** Alternative: • Attempt to use appropriate equations of motion to determine acceleration $v^2=u^2+2as$ rearranged to make a the subject (condone use of their values for v and u and / or g = a) • Attempt to use W=Fs to determine the air resistance F_D (or F_D= 6734(.7) (N) seen) • Attempt to determine g from the deceleration of the system $g = \frac{F_D - ma}{m}$	3	AO2.1f AO1.1a AO2.1b

02.4	More mass to **displace** / more particles to **collide with** / more gas / dust to displace ✓ (at any given speed) Greater (rate of) change of momentum / More work done (per unit distance) / Greater (resistive) force / more kinetic energy transferred (per unit distance) ✓ Greater **resultant** force **on** the system (therefore greater deceleration) / greater loss of velocity per second (therefore greater deceleration) ✓	Must have some interaction with parachute-spacecraft. N/E to say there are more particles / gas / dust /mass 3rd MP for greater resultant force: allow the idea that the difference between the drag and weight has increased 3rd MP Allow clear statement that links: • rate of change of momentum of gas / dust to rate of change of momentum of system • rate of work done on gas / dust to rate of work done by system	3	AO3.1b AO3.1b AO3.1b

Do not write outside the box

0 3 . 1 **Figure 3** shows a golf ball at rest on a horizontal surface $1.3\ \text{m}$ from a hole.

Figure 3



A golfer hits the ball so that it moves horizontally with an initial velocity of $1.8\ \text{m s}^{-1}$.
The ball experiences a constant deceleration of $1.2\ \text{m s}^{-2}$ as it travels to the hole.

Calculate the velocity of the ball when it reaches the edge of the hole.

[2 marks]

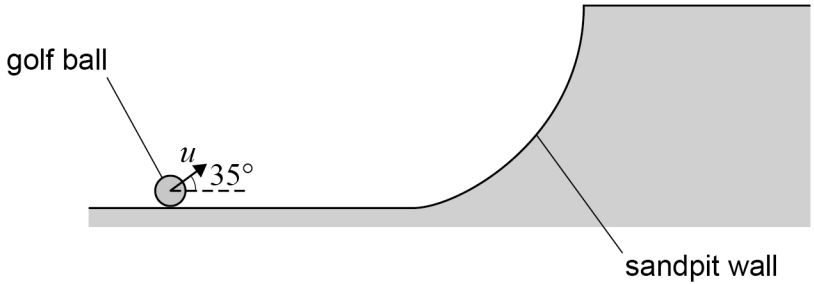
velocity = _____ m s^{-1}

Question 3 continues on the next page

Do not write outside the box

0 3 . 2 Later, the golf ball lands in a sandpit. The golfer hits the ball, giving it an initial velocity u at $35°$ to the horizontal, as shown in **Figure 4**. The horizontal component of u is $8.8\ \text{m s}^{-1}$.

Figure 4



not to scale

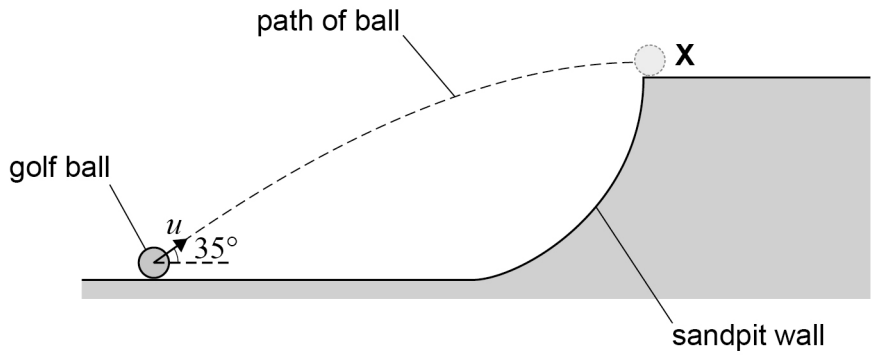
Show that the vertical component of u is approximately $6\ \text{m s}^{-1}$.

[1 mark]

Do not write outside the box

0 3 . 3 The ball is travelling horizontally as it reaches **X**, as shown in **Figure 5**.

Figure 5



not to scale

Assume that weight is the only force acting on the ball when it is in the air.

Calculate the time for the ball to travel to **X**.

[2 marks]

time = _____ s

0 3 . 4 Calculate the vertical distance of **X** above the initial position of the ball.

[2 marks]

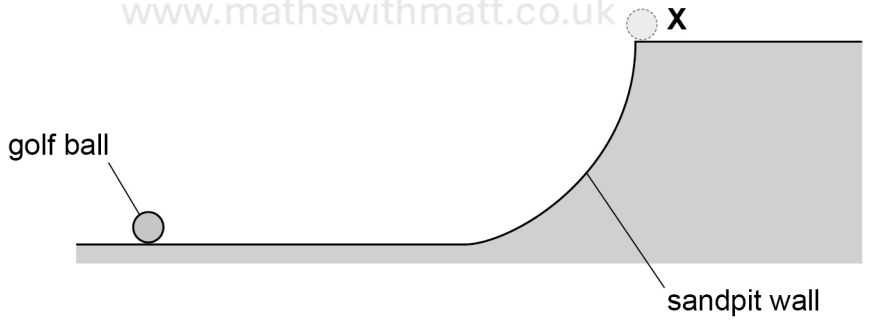
vertical distance = _____ m

Question 3 continues on the next page

Do not write outside the box

The golfer returns the ball to its original position in the sandpit. He wants the ball to land at **X** but this time with a **smaller** horizontal velocity than in **Figure 5**.

Figure 6



not to scale

0 3 . 5 Sketch on **Figure 6** a possible trajectory for the ball.

[1 mark]

0 3 . 6 Explain your reason for selecting this trajectory.

[2 marks]

10

Total			**13**

Question	Answers	Additional Comments/Guidance	Mark	ID details
03.1	Use of an appropriate equation of motion✓ (v =) 0.35 (ms^{-1}) ✓	Where $v^2 = u^2 + 2as$ is correctly stated, condone one error in substitution e.g. sign of a Where other equations are used it must be clear that v can be determined. Must see v as subject and an attempt to determine t. Allow more than 2 sf where correct.	2	AO1.1a AO2.1b
03.2	Use of tan 35 = u_v / 8.8 Or Use of u cos 35 = 8.8 and u_v = u sin 35 and 6.2 or 6.16 with supporting a calculation✓	Alternative: credit use of sine rule Must see answer to at least two significant figures	1	AO2.1b

03.3	Use of an appropriate equation of motion✓ ECF (t=) 0.63 (s) ✓ ECF		Condone their incorrect value of u in this substitution. Condone errors in signs in substitution Where other equations are used it must be clear how t can be determined. Must see t as subject and an attempt to determine s. 0.61 (s) for use of $u = 6\ \text{m s}^{-1}$ For MP2, where their value of u is used, the answer must be consistent with this value. **Only** allow this use where their value of u, to 1 significant figure, = (5<u<7) m s^{-1} Condone 1 significant figure answer where U is 1 sig fig.	2	AO1.1a AO2.1b

Question	Answers	Additional Comments/Guidance	Mark	ID details
03.4	Use of an appropriate equation of motion ✓ ECF (h =) 1.9 (m) ✓ ECF	Where equation is correctly stated, condone one error in substitution e.g. **one error on sign** of a substituted value **or** one incorrect value substituted (of course, ecf is acceptable) h = 1.83 m for use of u = 6 m s^{-1} allow ecf on t (check 3.3) For MP2, where their value of u is used, the answer must be consistent with this value. **Only** allow this use where their value of u, to 1 significant figure, = (5<u<7) m s^{-1} allow reverse calculation where u=0 and v = 6 m s^{-1}	2	AO1.1a AO2.1b

03.5	Smooth curve with maximum turning point seen, curve starts at the ball and finishes at **X**✓	Curve should be approximately parabolic in shape. Curve must start below the label 'golf ball' and ends within 5mm of the ball or the label **X**. Curve must have a maximum turning point.	1	AO3.1b

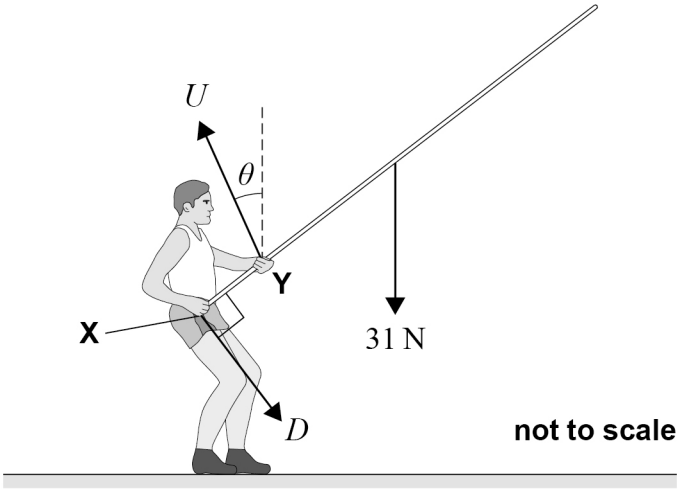
03.6	(Increase the angle to horizontal so) the ball must go higher (and increases its time in the air) **Or** (Increase the angle to horizontal so) the ball must have a greater (initial) vertical velocity ✓ (Covers the same horizontal distance over) a longer time in the air (so has a smaller horizontal velocity)✓ Alternative: Increased angle (to horizontal of projection) so smaller horizontal velocity✓ must be falling towards ground to land at **X**✓	(Increase the angle to horizontal so that) the vertical velocity greater than the horizontal / increase the vertical decreases the horizontal	2	AO3.1b AO3.1b

Total			**10**

Do not write outside the box

0 4 **Figure 7** shows an athlete holding a vaulting pole at an angle of $40°$ to the horizontal.

Figure 7

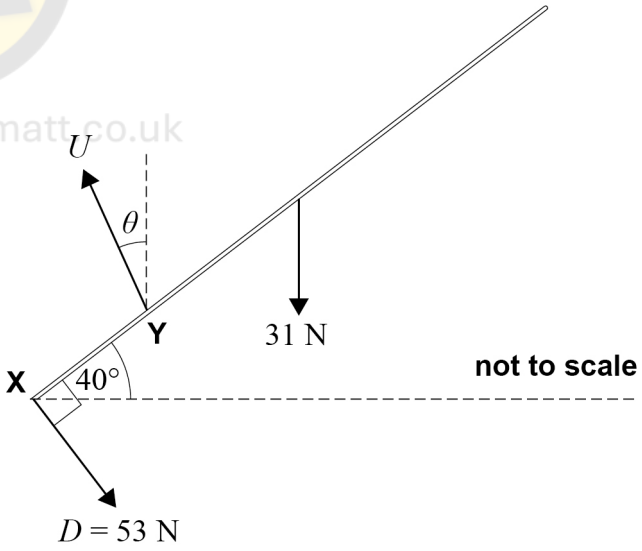


Forces D and U are exerted on the pole by the athlete's right and left hands respectively.
U is applied at point **Y** at an angle θ to the vertical.
The magnitude of D is 53 N and is applied at $90°$ to the pole at **X**.

The uniform pole is in equilibrium. It has a weight of 31 N.

Figure 8 shows the forces acting on the pole.

Figure 8



Do not write outside the box

0 4 . 1 Determine, using a scale diagram, θ and the magnitude of U.

[4 marks]

$\theta =$ _____ °

magnitude of $U =$ _____ N

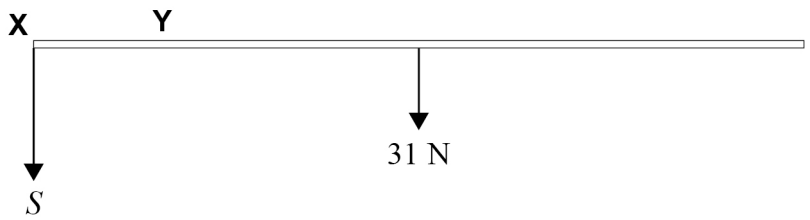
Question 4 continues on the next page

Do not write outside the box

0 4 . 2 The athlete now moves the pole to a horizontal position. The pole is held stationary in this position.
The athlete's right hand applies a force S vertically downwards at **X** as shown in **Figure 9**. The athlete's left hand applies a force V at **Y**.

Figure 9

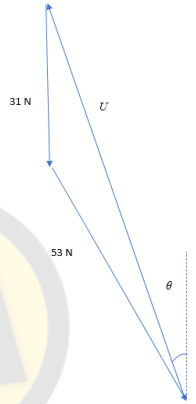
not to scale



Discuss the differences between the magnitudes and directions of force U in **Figure 7** and force V applied at **Y** in **Figure 9**.

[3 marks]

7

Question	Answers	Additional Comments/Guidance	Mark	AO
04.1	Closed triangle of forces drawn ✓ Appropriate scale ✓ $\theta = 23$ to 27 (°) ✓ $U = 77$ to 81 (N) ✓	Accept scale where 10 N is represented by at least 1 cm.  Treat each marking point independently. Do not accept answers for U and θ without a scale diagram. Maximum of 3 marks for a free-body diagram where forces have been drawn to scale. (Check figure 8)	4	AO1.1a AO1.1b AO1.1b AO1.1b

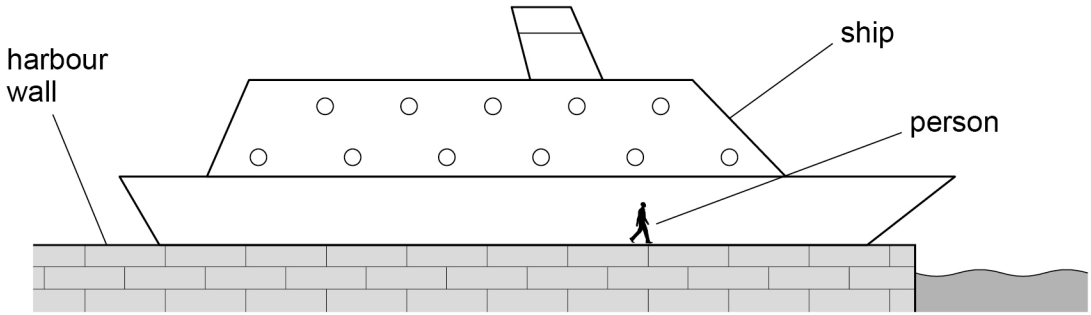
Question	Answers	Additional Comments/Guidance	Mark	AO
04.2	V is vertical / Force at **Y** is now vertical / V does not have a horizontal component / $V = S + 31$ / V is perpendicular to the pole / V is of greater magnitude than U / Force at **Y** has increased in magnitude✓ (Because) S and weight (or mg) are both vertical (in **Fig 9**)✓ (Because) greater moment of weight (about **Y**) in **Fig 9** / smaller moment of weight (about **Y**) in **Fig 7** / (Because) S is larger in magnitude than D (to produce a greater moment (about **Y** because they are equal distances from Y)✓		3	AO3.1a AO3.1a AO3.1a

Total			7

Do not write outside the box

0 5 . 1 **Figure 10** shows a ship leaving a harbour at a constant velocity.
The ship moves at the same velocity as a person walking on the harbour wall alongside the ship.

Figure 10



The momentum of the ship is approximately 1×10^7 N s.

Estimate the mass of the ship.

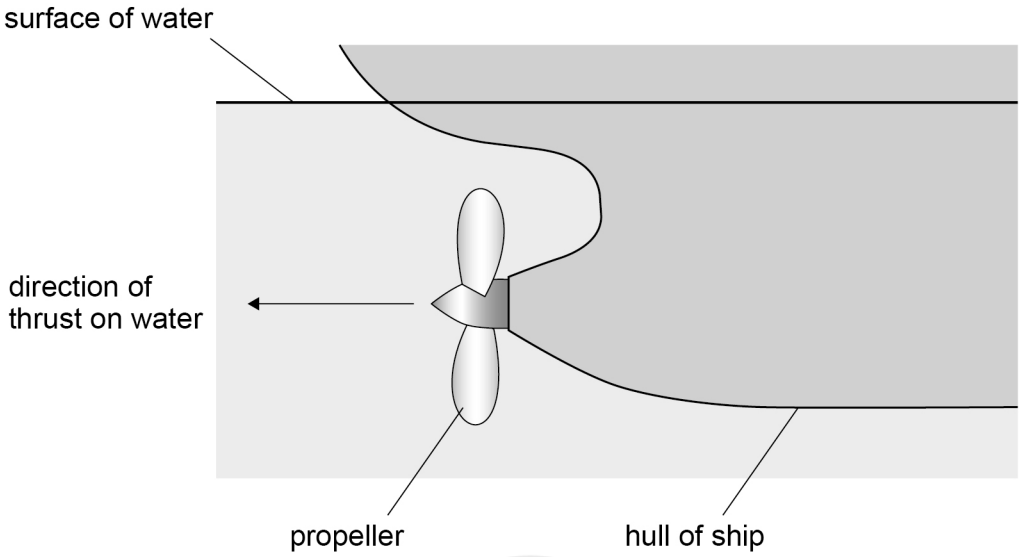
[2 marks]

mass of ship = _____ kg

Do not write outside the box

0 5 . 2 **Figure 11** shows the direction of the thrust exerted by the ship's propeller as the propeller rotates. The ship's engine makes the propeller rotate. When more water is accelerated, more work is done by the engine.

Figure 11



Explain, using Newton's laws of motion, how the thrust of the propeller on the water enables the ship to maintain a constant momentum.

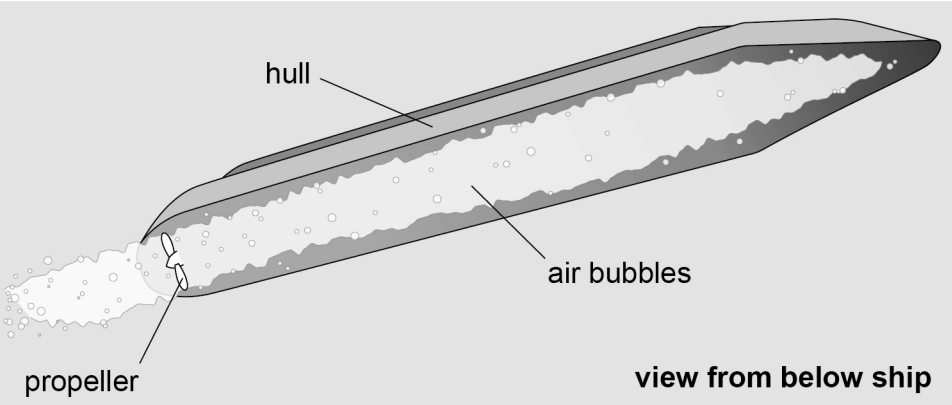
[4 marks]

Do not write outside the box

0 5 . 3 **Figure 12** shows the bottom of the hull with a drag reduction system in operation. Air bubbles are introduced into the water below the hull. This reduces the work done per second against the drag on the hull at any given speed.

However, when the air bubbles reach the propeller they decrease the mass of water being accelerated by the propeller every second. This decreases the thrust produced by the propeller at a given speed of rotation.

Figure 12



The system enables the ship to save fuel while maintaining the same momentum.

Explain why the system delivers this fuel saving.
In your answer, consider the effects of the introduction of the system on

- the thrust
- the drag on the hull.

[3 marks]

9

Question	Answers	Additional Comments/Guidance	Mark	AO
05.1	Use of $p = mv$ **or** estimates walking speed = 1 or 2 m/s✓ Accept any answer in range 2×10^6 to 10×10^6 (kg) ✓	Allow use of where m has been made the subject and p has been substituted. Range on answer: (Using speeds in range 0.5 ms^{-1} to 2.5 ms^{-1}) Accept 1 significant figure answer	2	AO1.1a AO2.1a

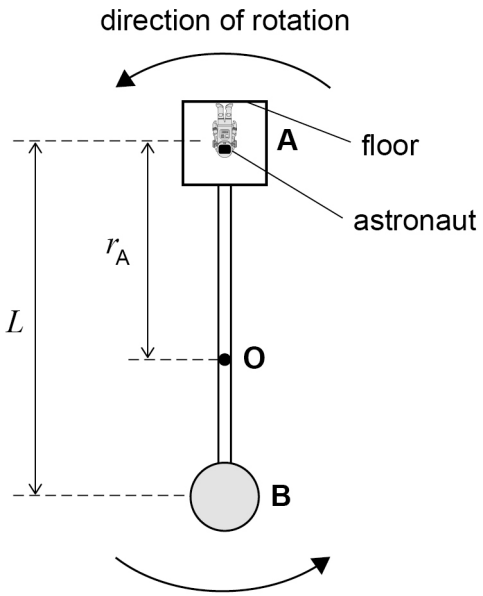
Question	Answers	Additional Comments/Guidance	Mark	AO
05.2	**Max 4** There is a force on the water (from the propeller) and this produces an equal force on the propeller (from the water in the opposite direction) ✓ Correctly links to Newton's 3rd law ✓ This force on the ship equals the drag force on the ship✓ Correctly links to Newton's 1st law✓ Force is needed to change the water's momentum✓ Correctly links to Newton's 2nd law✓	Must link correct law to at least one correct statement for all 4 marks	4	AO2.1a

Question	Answers	Additional Comments/Guidance	Mark	AO
05.3	(When system is enabled,) drag decreases by more than thrust **Or** (When system is enabled,) decrease in work done (per second) against drag (at any speed) is greater than the decrease in the work done by the propeller (at any rotational speed)✓ To maintain constant momentum then drag must equal thrust✓ Propeller can operate at lower rotational speed so that thrust again equals drag **Or** Engine does less work (and less fuel needs burnt) ✓	Work done (per second) by drag decreases and work done (per second) by propeller decreases (at any rotational speed) ✓ 3rd MP: Accept answer in terms of power $= Fv$	3	AO3.1b AO3.1b AO3.1b
Total			**9**	

Do not write outside the box

0 4 **Figure 6** shows a rotating spacecraft that is proposed to carry astronauts to Mars.

Figure 6



The spacecraft consists of two parts **A** and **B** connected by a rigid cylindrical rod. When the spacecraft is travelling, **A** and **B** rotate at a constant angular speed about their common centre of mass **O**.

L is the distance between the centre of mass of **A** and the centre of mass of **B**.
r_A is the distance from **O** to the centre of mass of **A**.

0 4 . 1 As the spacecraft rotates, a force that imitates the effect of gravity acts on an astronaut who is in contact with the floor.

Explain why.

[2 marks]

Do not write outside the box

0 4 . 2 The forces exerted on **A** and **B** by the connecting rod have the same magnitude.

m_A is the mass of **A**
m_B is the mass of **B**

Show, by considering the centripetal forces acting on **A** and **B**, that r_A is given by

$$r_A = \frac{m_B L}{m_A + m_B}$$

[2 marks]

0 4 . 3 In this spacecraft $m_A < m_B$.

Deduce whether the centre of mass of **A** or the centre of mass of **B** rotates with a greater linear speed.

[2 marks]

Question 4 continues on the next page

Do not write outside the box

The astronauts live in **A** and the cargo is stored in **B**.

When loaded,

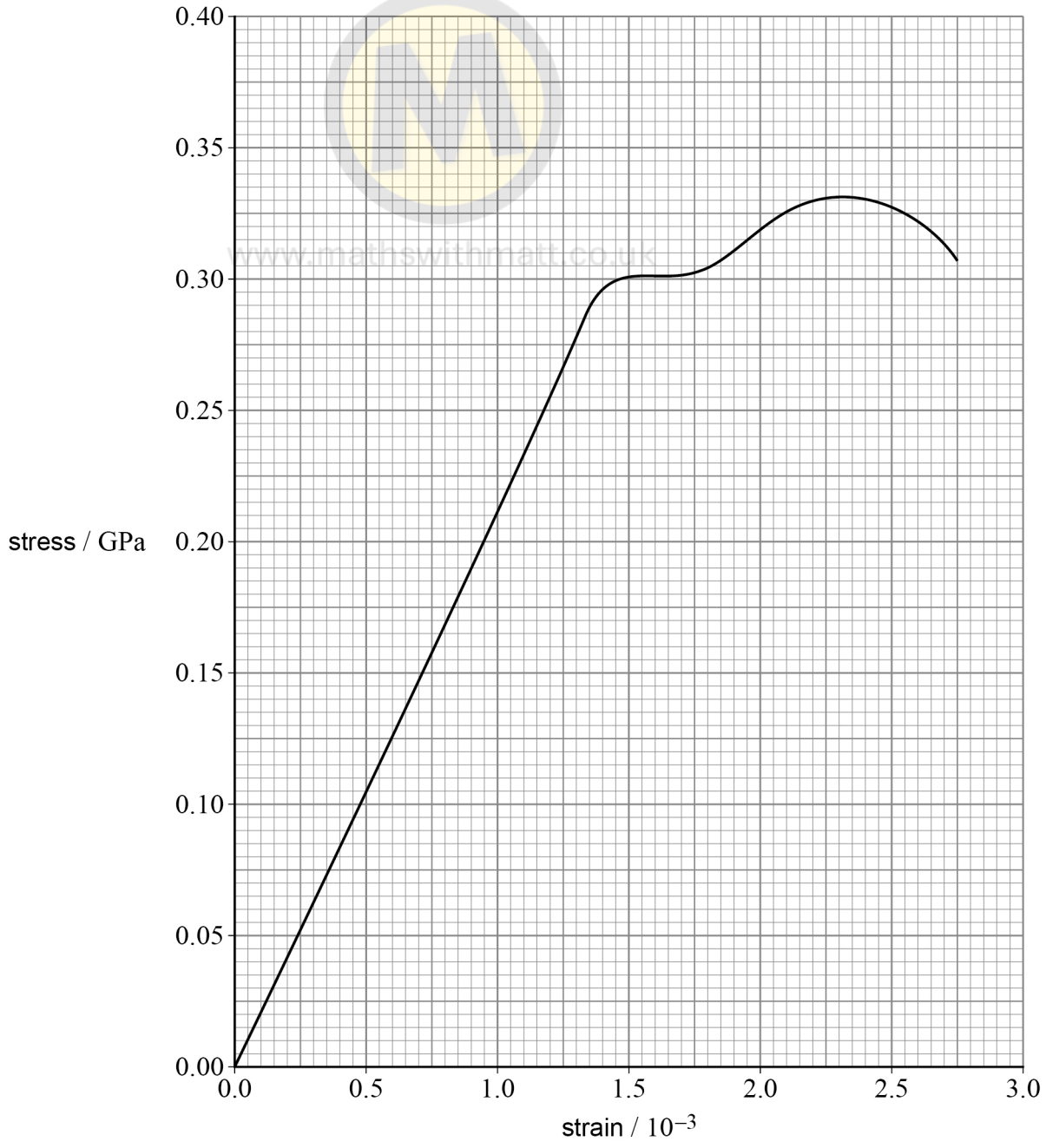
$m_A = 1.32 \times 10^6$ kg

$m_B = 3.30 \times 10^6$ kg.

The spacecraft imitates the gravity of Mars where $g = 3.7$ m s^{-2}.

Figure 7 shows a stress–strain curve for the metal used for the rigid rod.

Figure 7



Do not write outside the box

0 4 . 4 Suggest a suitable diameter for the rod.
Justify your answer.

[5 marks]

diameter = _____ m

11

Question	Answers	Additional comments/Guidelines	Mark	AO
04.1	Centripetal force acts inwards / towards the centre of rotation ✓ Links reaction force to centripetal force ✓		2	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
04.2	Equates forces AND states **either** centripetal force with correct symbols✓ cancelling ω✓ $m_A r\cancel{\omega^2} = m_B(L-r)\cancel{\omega^2}$ $r = \dfrac{m_B L}{m_A + m_B}$	E.g. $F = m_A r\omega^2$ $F = m_B(L-r)\omega^2$ In MP1 condone: equations containing v; use of ω_A and ω_B for the angular velocities. In MP2 it must be clear that the angular velocity and not the velocity.	2	AO2 L2 Maths 2

Question	Answers	Additional comments/Guidelines	Mark	AO
04.3	The angular speed is the same for A & B or Rotational radius for B less than that for A ✓ Both of these points AND $v = r\omega$ so velocity of A is greater.✓	Alternative for MP2: Both of points in MP1 AND A travels greater distance in the same time.	2	AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
04.4	Use of safety factor e.g. maximum stress << 0.300 GPa ✓ $F = ma = 1.32 \times 10^6 \times 3.7$✓ $(= 4.9 \times 10^6$ N) $A = \frac{F}{\sigma}$ valid substitution ✓ $d = \sqrt{\frac{4A}{\pi}}$ ✓ (expect > 0.144 m) Valid justification for selection of maximum stress used e.g. using a stress that is from the linear / elastic section of the graph or reference to either safety factor or trying to limit weight of cable. ✓	Alternative for MP1: they can work through for a stress of 0.3 GPa and then increase the diameter, if justified as a safety factor. Do not allow use of stress ≈0.3 GPa for full marks. Allow ecf for stress and force	5	AO3 L2 Maths 2
Total			**11**	

0 5 **Figure 8** shows the H-shaped posts used in a game of rugby.

Figure 8

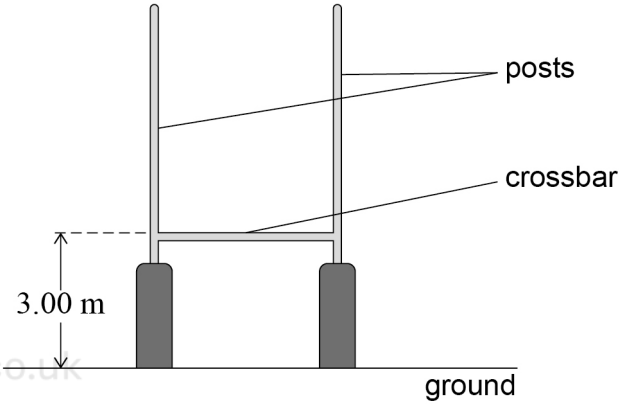
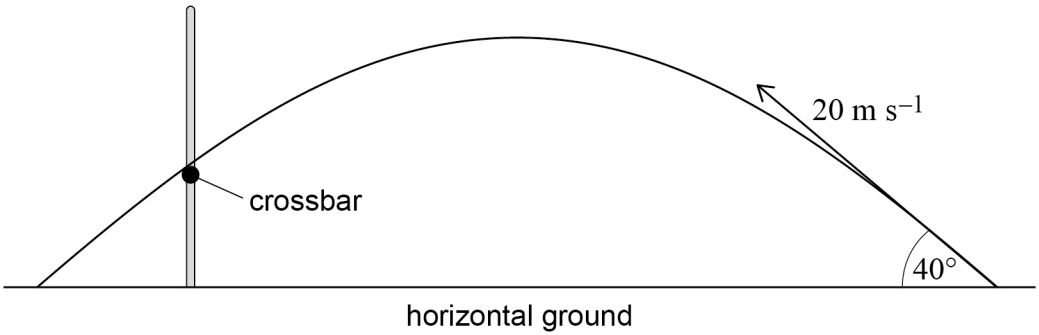


Figure 9 shows the path of a ball that is kicked and just passes over the crossbar. The initial velocity of the ball is $20.0\ \text{m s}^{-1}$ at an angle of $40.0°$ to the ground.

You should consider air resistance to be negligible and treat the ball as a simple projectile.

Figure 9



The top of the crossbar is $3.00\ \text{m}$ above the horizontal ground.

0 5 . 1 Show that the minimum speed of the ball in flight is about $15\ \text{m s}^{-1}$.

Explain your answer.

[2 marks]

0 5 . 2 The ball just passes over the crossbar at a time t after it is kicked.

Show that t must satisfy the following equation:

$$4.91t^2 - 12.9t + 3.00 = 0$$

[2 marks]

Do not write outside the box

0 5 . 3 There are two solutions to the equation

$$4.91t^2 - 12.9t + 3.00 = 0$$

Discuss which of the two solutions is the time taken for the ball to pass over the crossbar from when it is kicked.

In your answer you should

- state the value for t given by each solution
- explain the physical significance of the other solution.

[4 marks]

solution 1 = _____ s

solution 2 = _____ s

0 5 . 4 Another attempt is made to kick the ball over the crossbar. The initial velocity of the ball is the same as in the first attempt.
This kick is made from a horizontal distance of $38\ \text{m}$ from the posts.

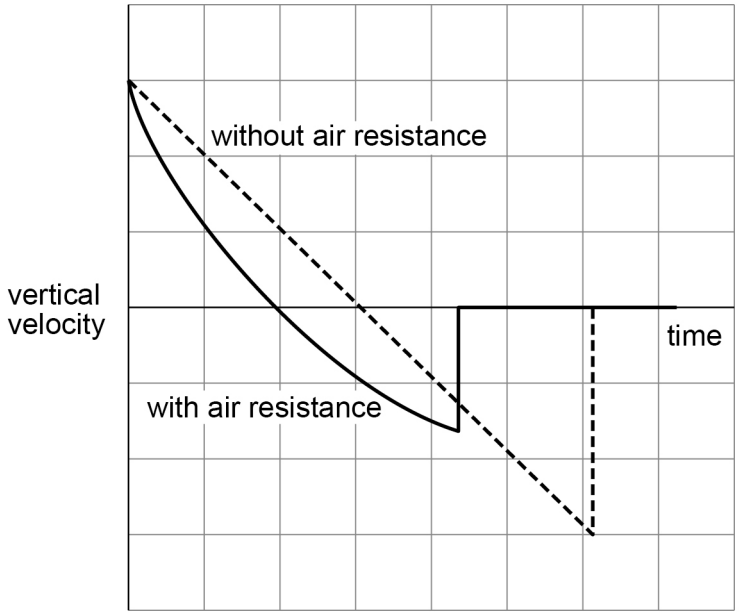
Deduce whether the ball can pass over the crossbar.

[1 mark]

Do not write outside the box

0 5 . 5 **Figure 10** shows the variations with time of the vertical velocity of a ball with and without air resistance.

Figure 10



Discuss the features of the motion of the ball shown by the two graphs.

In your answer you should refer to

- the gradients of the graphs
- the area between each line and the time axis.

[5 marks]

Question	Answers	Additional comments/Guidelines	Mark	AO
05.1	horizontal velocity $= 20\cos 40° = 15.3$ ✓(m s^{-1}) horizontal velocity (is constant) / minimum when vertical velocity $= 0$ ✓	Needs minimum 3 sf For MP1 it must be clear that the horizontal velocity has been determined.	2	AO2 L2 Maths 1

Question	Answers	Additional comments/Guidelines	Mark	AO
05.2	(vertical velocity) $v = 20\sin 40°$ $(= 12.9)$ ✓ (m s^{-1}) $s = ut + \frac{1}{2}at^2$ $-3 = -12.9t + \frac{1}{2} \times 9.81t^2$ or $3 = 12.9t - \frac{1}{2} \times 9.81t^2$✓ $(4.91t^2 - 12.9t + 3.00 = 0)$	For second mark both suvat equation and substitution must be shown. Equation may be rearranged before substitution	2	AO1 AO2 L2 Maths 2

Question	Answers	Additional comments/Guidelines	Mark	AO
05.3	Use of quadratic formulae with $+$, $-$ or $\pm$ ✓ 0.258 s and 2.37 s✓ Time to reach 3 m once on the way up and once on the way down (OWTTE)✓ Larger value ✓	eg $t = \frac{12.9 \pm \sqrt{(-12.9)^2 - 4 \times 4.91 \times 3.00}}{2 \times 4.91}$ Two correct answers alone scores first 2 marks. ecf available for last 2 marks	4	AO1 AO1 L2 Maths 2 AO2 AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
05.4	$s = vt = 20 \cos 40° \times 2.37 = 36.3$ m so no✓	ecf from **05.3** Calculation must be seen	1	AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
05.5	Gradient is the acceleration **AND** area under graph = <u>vertical</u> distance travelled✓$_1$ Without air resistance: comment about gradient✓$_2$ comment about area✓$_3$ With air resistance comment about gradient✓$_4$ comment about area✓$_5$	For each comment on the graph a reason must be given not just a description. e.g for ✓$_2$ • constant gradient = g or $9.81\ \text{m s}^{-1}$ e.g. for ✓$_4$ • initially steeper gradient since air resistance in same direction as weight (so $a > g$) • when line crosses time axis, gradient = g /9.81 / gradient without air resistance as air resistance = 0 when $v = 0$ / • After crossing time axis, gradient decreases as air resistance increases with speed E.g. for ✓$_3$ or ✓$_5$ • total area under graph = 0 since ball starts and finishes on ground • area between graph and axis is max height/**vertical** distance • without air resistance reaches a higher height as area greater statement referring to area under both graphs gains ✓$_3$ and ✓$_5$	5	AO1 AO2 AO2 AO3 AO3
Total			**14**	

Section B

Answer **all** questions in this section.

0 4 **Figure 10** shows a conveyor used to raise concrete blocks on a building site. The blocks do not slip on the belt at any time.

Figure 10

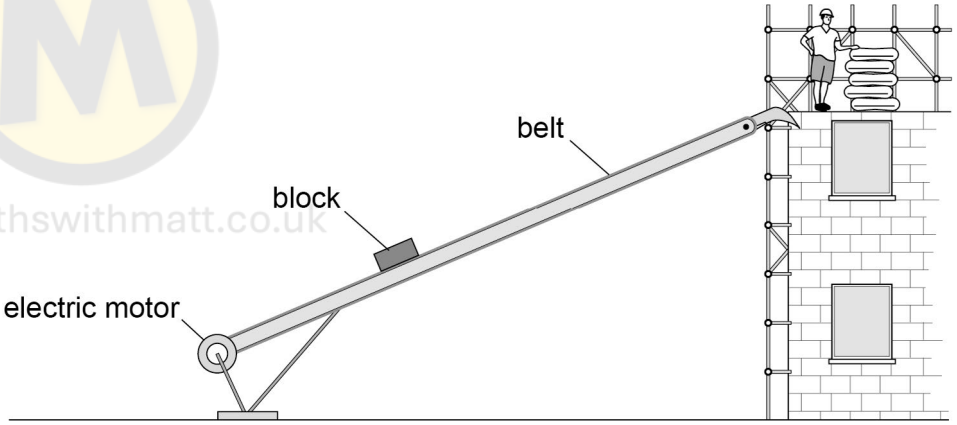
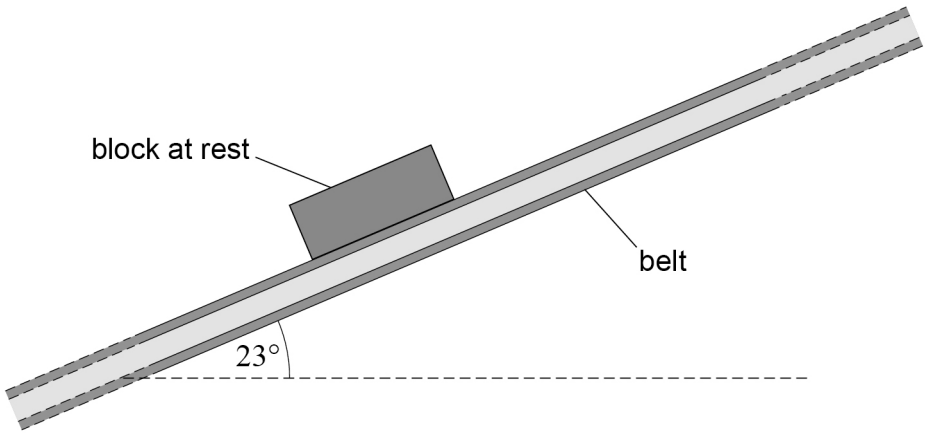


Figure 11 shows an enlarged view of one block on the belt. The belt is inclined at $23°$ to the horizontal. The mass of the block is $19\ \text{kg}$.

Figure 11



The belt exerts a frictional force F on the block when the block is at rest.

0 4 . 1 Draw an arrow on **Figure 11** to show the line of action of F.

[1 mark]

Do not write outside the box

0 4 . 2 Show that the magnitude of F is approximately $70\ \text{N}$.

[1 mark]

0 4 . 3 The belt is driven by an electric motor. When the motor is switched on, the belt and the block accelerate uniformly from rest to a speed of $0.32\ \text{m s}^{-1}$ in a time of $0.50\ \text{s}$.

Calculate the magnitude of the frictional force of the belt on the block during this acceleration.

[3 marks]

frictional force = _____ N

Question 4 continues on the next page

Do not write outside the box

0 4 . 4 The motor is connected to a $110\ \text{V}$ dc supply that has negligible internal resistance. The maximum operating current in the motor is $5.0\ \text{A}$.

The efficiency of the motor and drive system of the conveyor is 28%. The belt travels at $0.32\ \text{m s}^{-1}$ and is $8.0\ \text{m}$ long.

Deduce the maximum number of blocks that can be moved on the belt at one time.

[4 marks]

maximum number of blocks = _____

9

Question	Answers	Additional Comments/Guidance	Mark	AO
04.1	arrow between block and belt pointing upwards along the belt ✓		1	AO1.1-a

Question	Answers	Additional Comments/Guidance	Mark	AO
04.2	$(F =)\ 19g\sin 23°$ to give 72.8 (N) ✓	Allow 2 sf answer.	1	AO2.1-f

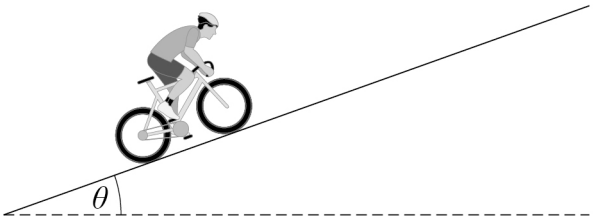
Question	Answers	Additional Comments/Guidance	Mark	AO
04.3	uses $F = \frac{\Delta(mv)}{\Delta t}$ ✓ $F = 12$ (N) ✓ their **04.2** + 12 (N) ✓	Allow for MP1 use of appropriate kinematic equation for a **AND** use of $F=ma$ Expect 82 or 85 (N)	3	AO2.1-b

Question	Answers	Additional Comments/Guidance	Mark	AO
04.4	uses V and I to get total input power or energy ✓	P_{input} of motor $= 110 \times 5.0 = 550$ W $E_{input} = 550 \times \frac{8.0}{0.32} = 13\,750$ J	4	AO3.1-a
	uses efficiency equation ✓	P_{useful} to belt $= 550 \times 0.28 = 150$ W $E_{useful} = 3850$ J, from $154 \times \frac{8.0}{0.32}$, or $13\,750 \times 0.28$		
	determines power or energy to move one block ✓	$P_{block} = 22$ or 23 W $E_{block} = 560$ or 580 J		
	divides (total) useful power or energy by individual power or energy to give answer of 6 blocks ✓	Allow ecf for MP4 only for their **04.3**		
Total			**9**	

Do not write outside the box

0 7 . 1 **Figure 8** shows a cyclist going up a hill.

Figure 8



not to scale

The angle θ of the slope of the hill is constant.
The total mass m of the cyclist and bicycle is $65\ \text{kg}$.

Write an expression for the component of the total weight parallel to the slope.

[1 mark]

0 7 . 2 The useful power output of the cyclist is $310\ \text{W}$.
The cyclist has a steady speed of $1.63\ \text{m s}^{-1}$.

Assume that air resistance is negligible at this speed.

Calculate θ.

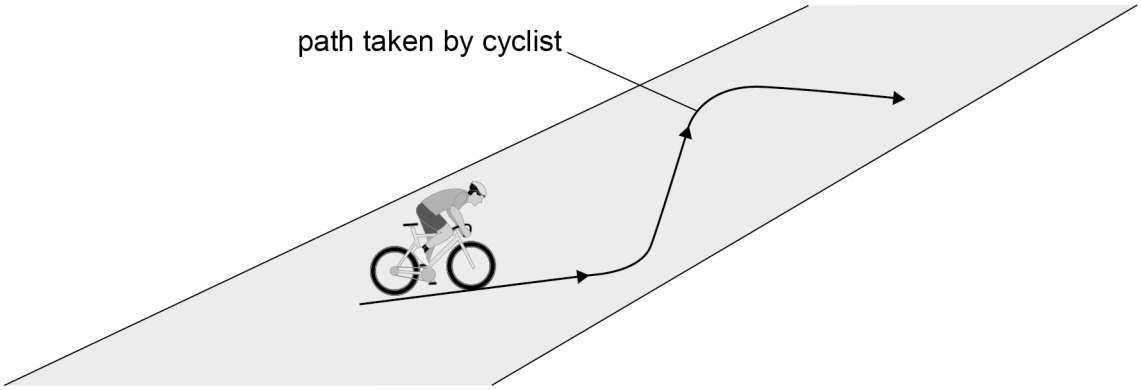
[2 marks]

$\theta =$ _____ °

Do not write outside the box

Figure 9 shows an alternative 'zig-zag' path taken by the cyclist up the same hill. She maintains a steady speed of $1.63\ \text{m s}^{-1}$.

Figure 9



0 7 . 3 Discuss how her useful power output when taking the path in **Figure 9** compares with her useful power output in Question **07.2**.

[3 marks]

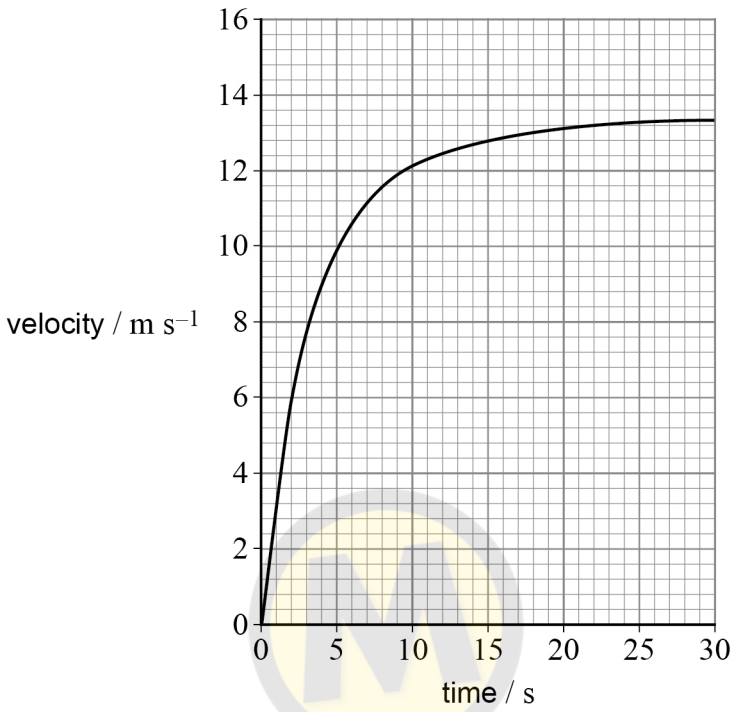
Question 7 continues on the next page

Do not write outside the box

The cyclist reaches the top of the hill. She then travels back down the hill in a straight line. The bicycle rolls freely without the cyclist pushing the pedals or applying the brakes.

Figure 10 shows the variation of her velocity with time as she goes down the hill.

Figure 10



0 7 . 4 Determine the acceleration of the cyclist 10.0 s after she begins to go down the hill.

[3 marks]

acceleration = _____ m s^{-2}

Do not write outside the box

0 7 . 5 Energy transfers occur as the cyclist travels down the hill.

Outline how these energy transfers explain the shape of the graph in **Figure 10**.

[4 marks]

13

Question	Answers	Additional Comments/Guidance	Mark	AO
07.1	(Component of total weight parallel to slope =) $640 \sin \theta$ ✓	Allow $mg \sin \theta$ or $65g \sin \theta$ *or* $638 \sin \theta$ *or* $637.7 \sin \theta$ *or* $637.65 \sin \theta$ Condone labelling this component as W in statements such as $W = 640 \sin \theta$ Do not accept $W \sin \theta$ unless W *is defined as* mg	1	AO2

Question	Answers	Additional Comments/Guidance	Mark	AO
07.2	use of $P = Fv$ ✓ $(\theta =)$ 17(.4) (°) ✓	Ecf from **07.1** for MP1 and MP2 Use of $P = Fv$ by substitution and rearrangement to make F the subject. Expect to see $(F =)$ 190(.184) (N) Accept a correctly rounded answer to 2 or more significant figure. (Calculator displays: 17.35298907 for mg sin θ *and* 65g sin θ *and 637.65* sin θ*)* As an alternative to 17.35298907 may see Calculator display or answer of: • 17.34316751 for 638 sin $\theta = 17(.3)$ • 17.3515853 for 637.7 sin $\theta = 17(.4)$ • 17.28726034 for 640 sin $\theta = 17(.3)$ Common ecf: $(65g\cos\theta = 190)$ = 72.6 (°) or 73(°) scores MP1 and MP2 $(65 \tan\theta = 190)$ = 71.1 (°) or 71(°) scores MP1 and MP2 Use of $W = Fs\cos\theta$ is only acceptable as an ecf where $F = 65g$ and component of weight is given as $65g\cos\theta$ (or equivalent) in **07.1** Alternative MP1: height gain per second = 0.486 m **and** distance along the slope per second = 1.63 m **OR** Use of $\sin\theta = \dfrac{\text{height gained per second}}{\text{distance travelled per second}}$	2	1 x AO1 1 x AO2

Question	Answers	Additional Comments/Guidance	Mark	AO
07.3	Less (useful) power output ✓ Same gain in (gravitational) potential energy (in climbing hill) / same amount of work done (in climbing hill) / gains same height (in climbing hill) ✓ Gains less (gravitational) potential energy every second ✓ **OR** (component of weight doing work against) Less (useful) power output ✓ Effective θ has decreased / $mg \sin \theta$ has decreased / component of the weight parallel to the slope has decreased ✓ Smaller force does less work per second✓ **OR** (component of vertical velocity) Less (useful) power output ✓ The vertical component of the velocity has decreased / height gained per second decreases ✓ $(P =)\ mg\ v \sin \theta$ has decreased / P = $\frac{\Delta W}{\Delta t}$ has decreased / less work done (against the weight) per second / Less gain in (gravitational) potential energy per second✓ **OR** (distance travelled) Less (useful) power output ✓ Less force is exerted over greater distance (for same change in height) ✓ Smaller force does less work per second✓	General marking principle: MP1 less (useful) power output MP2 basic point MP3 explains consequences of basic point in terms of power (MP3 is an extension of MP2, quoting P = $\frac{\Delta W}{\Delta t}$ without linking to an appropriate explanation is insufficient). Loses MP1: where conflicting statements made about (useful) power output / states more power output / total power output is same Loses MP3 for conflicting statements made in support of explanation. Accept θ as the effective angle to the slope. Condone P= $\frac{E}{t}$ has decreased as MP3 Treat 'inputs more energy' or 'does more work' as neutral	3	3 x AO3

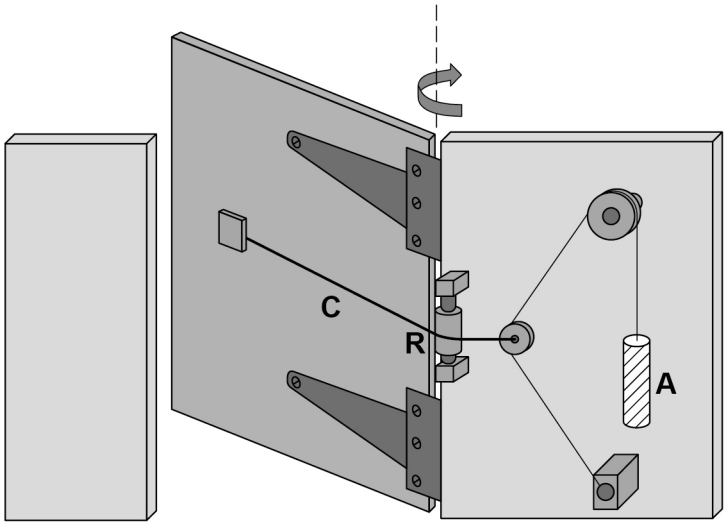
Question	Answers	Additional Comments/Guidance	Mark	AO
07.4	Draws tangent which touches curve between 9 and 11 s ✓ Determine gradient of a tangent drawn at 5s / Determines gradient of tangent drawn at 10s✓ (acceleration =) 0.21 ($m\ s^{-2}$) ✓	Must see an attempt to draw a tangent to curve to score any marks. Read-offs must be within ½ square of accuracy Condone one read-off error. For tangent at t =5s, expect to see an answer of 0.61 to 0.71 ($m\ s^{-2}$). MAX 2 marks for this. Accept answers in range 0.15 to 0.27 ($m\ s^{-2}$) Accept 2 or 3 significant figures only. **MAX 1 mark** Condone a correctly determined gradient for a tangent to the curve at **any other** point **between** 5 and 11 seconds.	3	1 x AO1 1 x AO2 1 x AO3

Question	Answers	Additional Comments/Guidance	Mark	AO
07.5	Air resistance increases (with speed) / resistive forces increase (with speed) / Energy is transferred from the cyclist (due to work done) by resistive forces ✓ **MAX 3** from: Initially, any of the gravitational potential energy that is transferred is transferred to kinetic energy of cyclist ✓ As speed increases, less of the gravitational potential energy transferred per second is transferred to kinetic energy of cyclist✓ As speed increases, energy transferred per second to the air increases / as the speed increases, the energy transferred per second from the cyclist increases✓ At top speed, the gravitational potential energy that is transferred (per second) is transferred to the air / the gravitational potential energy (transferred per second) is being transferred (from the cyclist) due to work done by resistive forces ✓	Condone 'frictional forces increase with speed' Treat kinetic energy is transferred from the cyclist as neutral. The answer must be written in terms of energy transfers	4	1 x AO1 3 x AO2
Total			**13**	

Do not write outside the box

0 3 **Figure 3** shows a garden gate with a pulley system designed to close the gate.

Figure 3



The pulley system raises weight **A** when the gate is opened. When the gate is released, **A** falls. The horizontal cable **C** passes over pulley **R**. The tension in cable **C** causes the gate to close.

Weight **A** is a solid cylinder with the following properties:

diameter = 4.8×10^{-2} m
length = 0.23 m
weight = 35 N

Table 2 gives the density of three available materials.

Table 2

Material	Density / kg m^{-3}
concrete	2.4×10^3
iron	7.8×10^3
brass	8.6×10^3

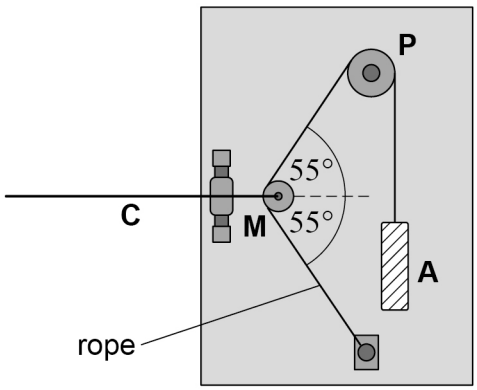
0 3 . 1 Deduce which **one** of the three materials is used for **A**.

[3 marks]

Do not write outside the box

Figure 4 shows the pulley arrangement when the gate is closed.

Figure 4



Pulleys **P** and **M** are frictionless so that the tension in the rope attached to **A** is equal to the weight of **A**.
A weighs 35 N and the weight of moveable pulley **M** is negligible.

0 3 . 2 Calculate the tension in the horizontal cable **C** when the gate is closed.

[2 marks]

tension = _____ N

0 3 . 3 Pulley **M** is pulled to the left as the gate is opened.

Explain why this increases the tension in the horizontal cable **C**.

[2 marks]

_____

_____

_____

_____

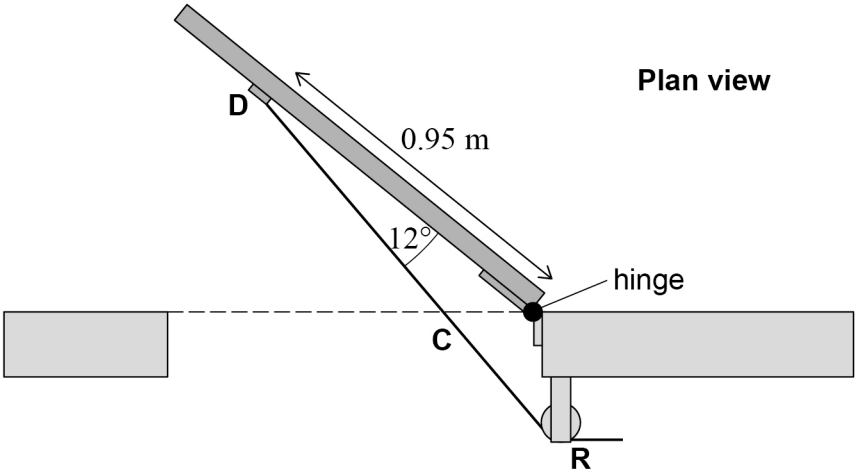
_____

Do not write outside the box

0 3 . 4 **Figure 5** shows a plan view with the gate open. The horizontal cable **C** passes over pulley **R** and is attached to the door at **D**.
The angle between the door and the horizontal cable **C** is $12°$.

The horizontal distance between the hinge and **D** is 0.95 m.

Figure 5



The tension in the horizontal cable **C** is now 41 N.

Calculate the moment of the tension about the hinge.

[2 marks]

moment = _____ N m

Do not write outside the box

0 3 . 5 The same system is attached to an identical gate with stiffer hinges. Now the system does not supply a sufficiently large moment to close the gate.

Discuss **two** independent changes to the design to increase the moment about the hinges due to horizontal cable **C**.

[4 marks]

1

2

13

Question	Answers	Additional comments/Guidelines	Mark	AO
03.1	Volume of A = area × length = 4.16×10^{-4} m^3 OR Mass of A = W/g = 3.6 kg ✓ Use density equation ✓ Compares a calculated property of brass (e.g. weight, length or diameter) with A OR the calculated density of A with density of brass OR the calculated mass of A with the calculated mass of brass and therefore brass ✓ Example: Volume of A = area × length = 4.16×10^{-4} m^3✓ Mass if brass = density × volume = 3.58 kg✓ Weight = $3.58 \times 9.81 = 35$ N (which is weight of A) and therefore brass is correct. ✓	Condone POT error in MP1 Do not allow use of weight in density equation Do not accept 8.3 x 10^3 for density of A . Award zero marks for an unsupported answer “Brass” Only award MP3 if answer “brass” given.	3	3 x AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
03.2	Use of $T = (35) \cos 55$ ✓ 2 x their T (= 40 N) ✓		2	2 x AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
03.3	Angle (to horizontal) decreases ✓ (Weight/tension in rope remains constant at 35 N) So horizontal components (from tension in rope) increase ✓ (Therefore tension in cable must increase)	Do not award MP2 if answer suggests that tension in rope increases. Do not allow "tension increases" for credit.	2	2 x AO2

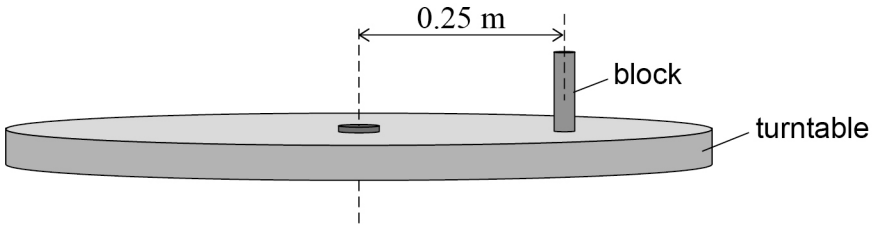
Question	Answers	Additional comments/Guidelines	Mark	AO
03.4	Component of the force at right angle to door = 41 cos (90−12) / 41 sin (12) = 8.5 N ✓ Moment = 8.5 × 0.95 = 8.1 (N m) ✓ Allow ecf from their value of weight component .	Alternative: Perpendicular distance = 0.95 sin (12) = 0.198 m ✓ Moment = 41 × 0.198 = 8.1 ✓ Allow ecf from their value of perpendicular distance. (Calculator value is 8.098 160 3) Award zero marks for simply multiplying 41 N × 0.95 m.	2	2 x AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
03.5	ALTERNATIVE 1 Increase weight / density / mass / volume of **A** ✓ Increases tension (and therefore moment) ✓ ALTERNATIVE 2 Position pulley **R** further (out) from gate hinges / increase diameter of pulley **R** ✓ Increases angle and therefore bigger perpendicular component (and therefore moment). ✓ ALTERNATIVE 3 Decrease angle of rope eg by putting P and fixed point closer together / further to right ✓ Increases tension (and therefore moment) ✓ ALTERNATIVE 4 Move **D** further from hinge/**R** OR make **C** longer ✓ Increases perpendicular distance (and therefore moment) ✓	Any 2 alternatives If more than two answers given, mark first two. Ignore the 1 and 2 in answer lines.	4	4 x AO3
Total			**13**	

Do not write outside the box

0 5 A teacher sets up a demonstration to show the relationship between circular motion and simple harmonic motion (SHM).
She places a block on a turntable at a point $0.25\ \text{m}$ from its centre, as shown in **Figure 9**.

Figure 9



The turntable rotates with an angular speed of $1.8\ \text{rad s}^{-1}$ and the block does not slip.

0 5 . 1 Calculate the time taken for the turntable to complete one revolution.

[2 marks]

time = _____ s

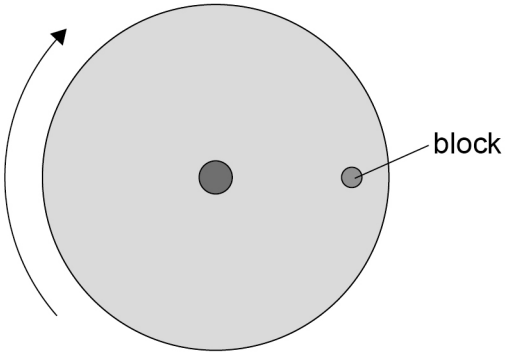
Do not write outside the box

0 5 . 2 **Figure 10** shows a plan view of the turntable and block.
The turntable rotates in a clockwise direction.

Draw an arrow on **Figure 10** to show the direction of the resultant force on the block.

[1 mark]

Figure 10



0 5 . 3 The mass of the block is $0.12\ \text{kg}$.

Calculate the magnitude of the resultant force on the block.

[2 marks]

magnitude of force = _____ N

Do not write outside the box

0 5 . 4 Describe, with reference to one of Newton's laws of motion, the evidence that a resultant force is acting on the block.

[2 marks]

0 5 . 5 The teacher adjusts the angular speed of the turntable so that the block completes one rotation every 2.50 s.
She sets up a simple pendulum above the centre of the turntable so that it swings in phase with the movement of the block.

Calculate the length of the simple pendulum.

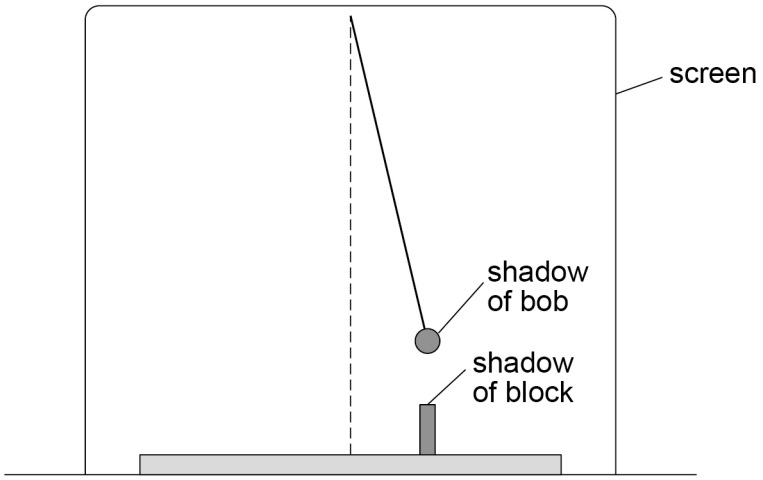
[2 marks]

length = _____ m

Do not write outside the box

0 5 . 6 A lamp is used to project shadow images of the block and pendulum bob on a screen. Both shadows appear to move with SHM across the screen.
Figure 11 shows the images on the screen at one instant.

Figure 11



Initially the shadows move in phase with the same amplitude.

Air resistance affects the motion of the pendulum.

Suggest the effect this has on the amplitude relationship and the phase relationship between the moving shadows.

[2 marks]

amplitude _____

_____

_____

phase _____

_____

_____

11

Question	Answers	Additional comments/Guidelines	Mark	AO
05.1	Use of time = angle ÷ angular speed ✓ To get 3.5 (s) ✓	Alternative for MP1: Accept distance÷speed when circumference has been calculated. Accept answers that round to 3.49	2	2 x AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
05.2	Arrow towards centre of turntable . ✓		1	AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
05.3	Use of $F = mrw^2$ OR determination of centripetal acceleration and then *F=ma* ✓ To give 0.097 N ✓	Shown by substitution. Condone use of diameter or radius halved in MP1. Accept negative answer. Calculator value: 0.0972	2	2 x AO2

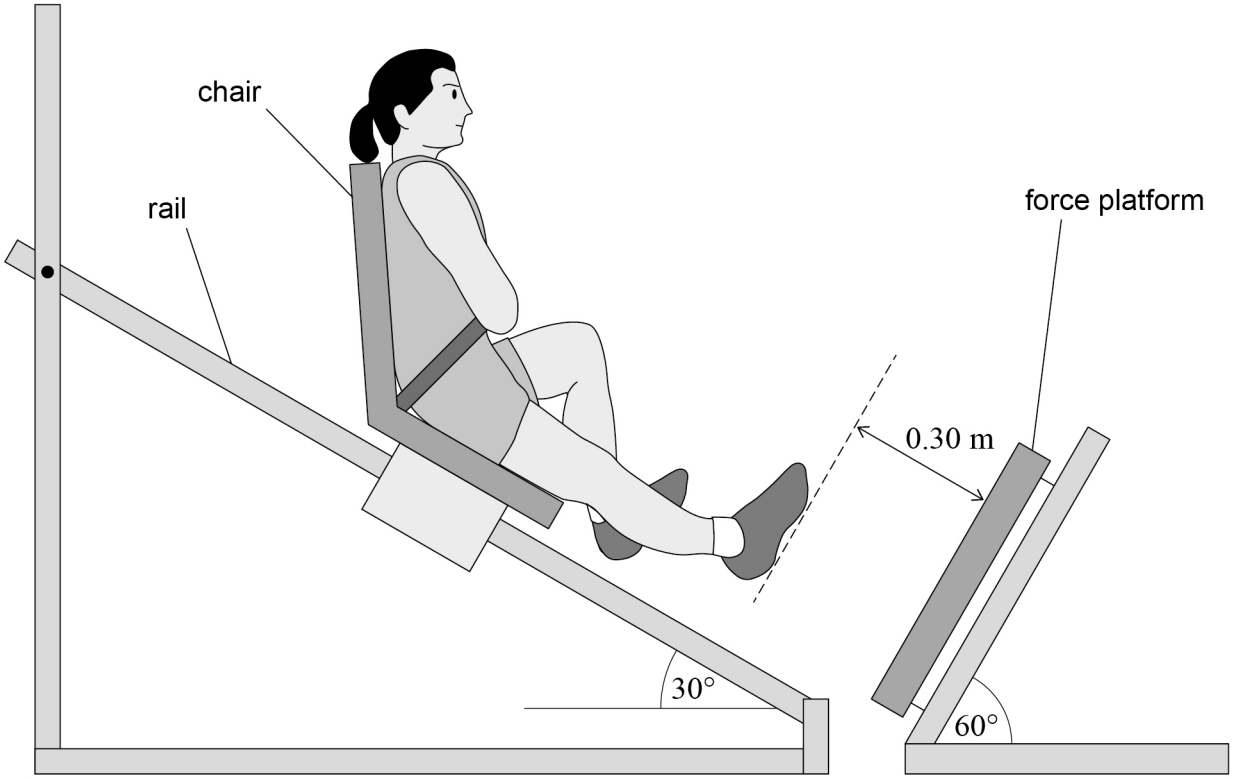
Question	Answers	Additional comments/Guidelines	Mark	AO
05.4	States block is (constantly) changing direction ✓ Uses appropriate Newton law of motion to link evidence (to show that a force acts) ✓ *Alternative 1* Block constantly changing direction (at constant speed) ✓ Uses N1 to show that a force must apply ✓ *Alternative 2* Changing direction shows (centripetal) acceleration ✓ Uses N2 to show that a force must apply ✓	Reference can be to the name of the law or to a description of what the law says. Condone lack of "resultant force" in N1 and N2. Use of "changing velocity" without reference to direction is not enough for MP1.	2	2 x AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
05.5	Use of pendulum equation by substitution or manipulation ✓ To give 1.55 m ✓	Allow 2+ sf Allow answer that rounds to 1.55 Use of $g = 10$ N kg^{-1} gives 1.58 – do not allow for MP2	2	2 x AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
05.6	*Amplitude* – the pendulum shadow amplitude becomes less than the block shadow amplitude ✓ *Phase* – time period decreases/changes OR frequency increases/changes (as pendulum amplitude gets less) therefore phase changes ✓	Must see a comparison for MP1 Condone: the time periods/ frequencies remain identical therefore the shadows remain in phase	2	2 x AO3
Total			**11**	

0 4 **Figure 6** shows apparatus used to measure the force exerted by an athlete during a single-leg jump.

Figure 6



In **Figure 6**, the athlete is strapped into a chair and held at rest halfway along a rail. The chair is then released to slide down the rail. The athlete keeps her right leg extended until her right foot makes contact with a force platform.
Friction between the rail and the chair is negligible.

initial distance between right foot and platform = 0.30 m
angle between rail and floor = 30°
angle between platform and floor = 60°

0 4 . 1 Show that the athlete and chair accelerate towards the platform at approximately $5\ \text{m s}^{-2}$.

[1 mark]

Do not write outside the box

0 4 . 2 Calculate the speed of the athlete when her right foot makes initial contact with the platform.

[2 marks]

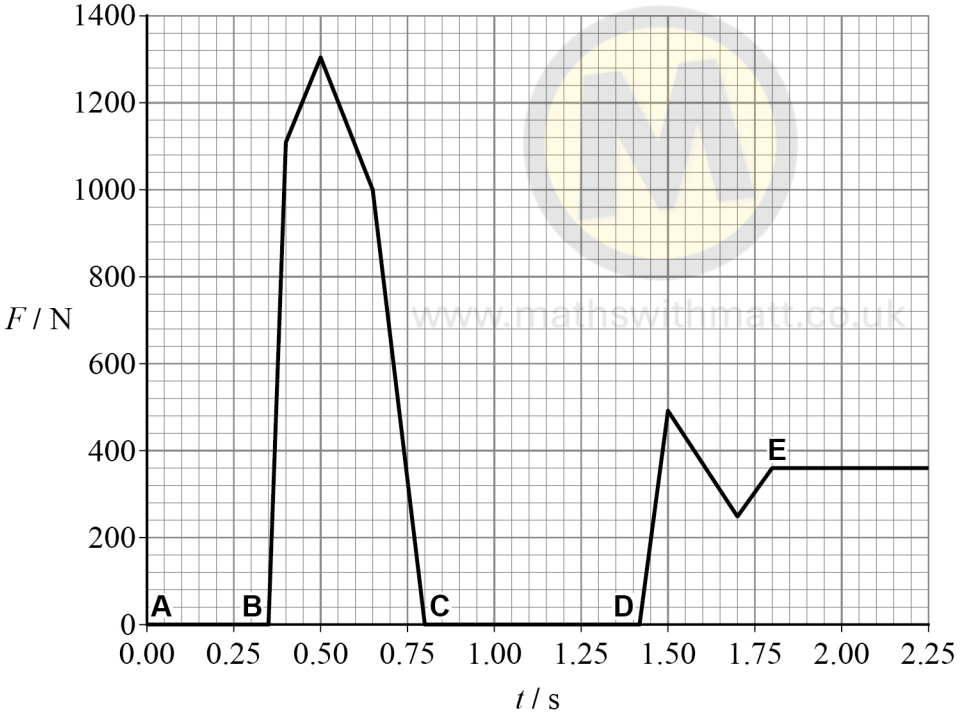
speed = _____ $\mathrm{m\ s^{-1}}$

Do not write outside the box

After her right foot makes contact with the platform, she uses her right leg to stop moving and then push herself back up the rail. She slides down the rail again, lands on the platform with both feet and comes to rest.

Figure 7 shows the variation of force F on the platform with time t during the full motion.

Figure 7



The sequence below describes what happens at the five instances **A**, **B**, **C**, **D** and **E** shown in **Figure 7**.

A: athlete and chair are released at $t = 0.00$ s
B: right foot of athlete contacts the platform with leg fully extended
C: right foot loses contact with the platform
D: athlete lands on the platform with both feet
E: athlete and chair come to rest

0 4 . 3 Determine the impulse provided by the force platform between **B** and **C**.

[2 marks]

impulse = _____ N s

Do not write outside the box

0 4 . 4 Determine the distance travelled by the athlete between **C** and **D**.

[3 marks]

distance travelled = _____ m

0 4 . 5 Determine, using **Figure 7**, the combined mass of the athlete and chair.

[2 marks]

mass = _____ kg

10

END OF SECTION B

Question	Answers	Additional Comments/Guidance	Mark	AO
04.1	(a =) 9.81 sin30 = 4.9 (m s^{-2}) seen ✓	Allow g sin30 or 9.8sin30 Accept cos60	1	AO2

Question	Answers	Additional Comments/Guidance	Mark	AO
04.2	substitutes into $v^2 = u^2 + 2as$ e.g. $v^2 = 2 \times 5 \times 0.3$ **OR** uses $\frac{v^2}{2} = g\ 0.3 \cos 60$ ✓ 1.7 (m s^{-1}) ✓	Do not allow 9.81 for a in suvat equation.	2	2 × AO2

Question	Answers	Additional Comments/Guidance	Mark	AO
04.3	attempt to find area between 0.35 s (**B**) and 0.80 s (**C**) $_1$✓	Max 1 for counting (small) squares **AND** a conversion factor of 2 N s stated Do not allow use of approximated shapes. For $_1$✓ need to see working for at least one part of the area under the graph. May see: Triangle: $0.5\times0.05\times1100 = 27.5$ Trapezium: $0.5\times(1100+1300)\times0.10 = 120$ Trapezium: $0.5\times(1000+1300)\times0.15 = 172.5$ Triangle: $0.5\times0.15\times1000 = 75$	2	1 x AO3 1 x AO2
	answer in range 390 to 400 (N s) $_2$✓	Treat “400” as a 2 sf answer.		

Question	Answers	Additional Comments/Guidance	Mark	AO
04.4	uses a relevant time in suvat equation(s) to get s $_1$✓	For $_1$✓ condone 9.81 for a. Do not allow $_1$✓ or $_3$✓ for solutions that use u=1.7 m s^{-1} For $_1$✓ allow 0.60 to 0.63 s for duration **C** to **D.** 1. Direct method: $s = \frac{1}{2}at^2$ 2. a) Obtains u first using $v = u + at$ **OR** $s = ut + \frac{1}{2}at^2$ 2. b) Then s using $s = \frac{1}{2}(u + v)t$ **OR** $v^2 = u^2 + 2as$ Expect to see $u = 1.5$ (m s^{-1})	3	2 × AO3 1 x AO2
	doubles their s **OR** halves their **C** to **D** duration $_2$✓			
	answer that rounds to 0.5 (m) $_3$✓	For $_3$✓ accept 0.44 (m).		

Question	Answers	Additional Comments/Guidance	Mark	AO
04.5	reads resting force from graph = 360 N **OR** divides an incorrect reading by 5 (4.91 N/kg) $_1$✓ 72 or 73 (kg) $_2$✓	for $_1$✓ allow use of their **04.3** with Δv = 3.2 m s^{-1}	2	1 x AO3 1 x AO2

Total			10

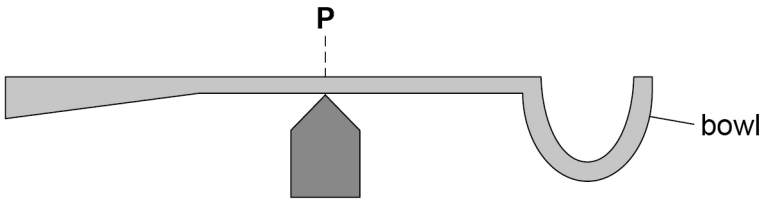
Section B

Answer **all** questions in this section.

0 3 **Figure 9** shows a spoon used to measure the mass of food.

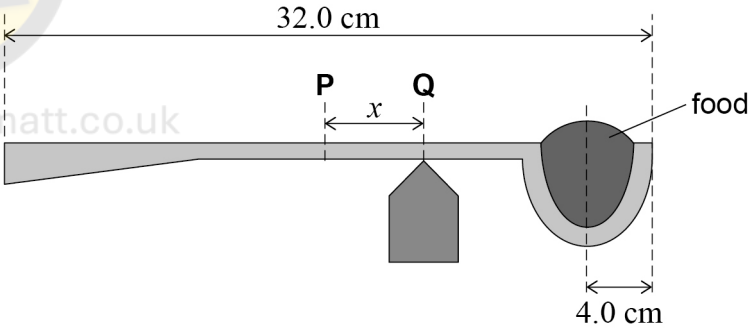
The empty spoon balances when a pivot is placed under a point **P** halfway along the spoon.

Figure 9



The spoon tilts when food of mass M is placed in the bowl. The spoon is rebalanced by moving the pivot a distance x to the right of **P**. The new position of the pivot is under point **Q** in **Figure 10**.

Figure 10



The total length of the spoon is $32.0\ \text{cm}$. The weight of the food acts through a line at a distance of $4.0\ \text{cm}$ from the right-hand edge of the spoon.

0 3 . 1 Explain why the spoon in **Figure 10** is balanced when the pivot is at **Q**.

[2 marks]

Do not write outside the box

0 3 . 2 The empty spoon has mass m.

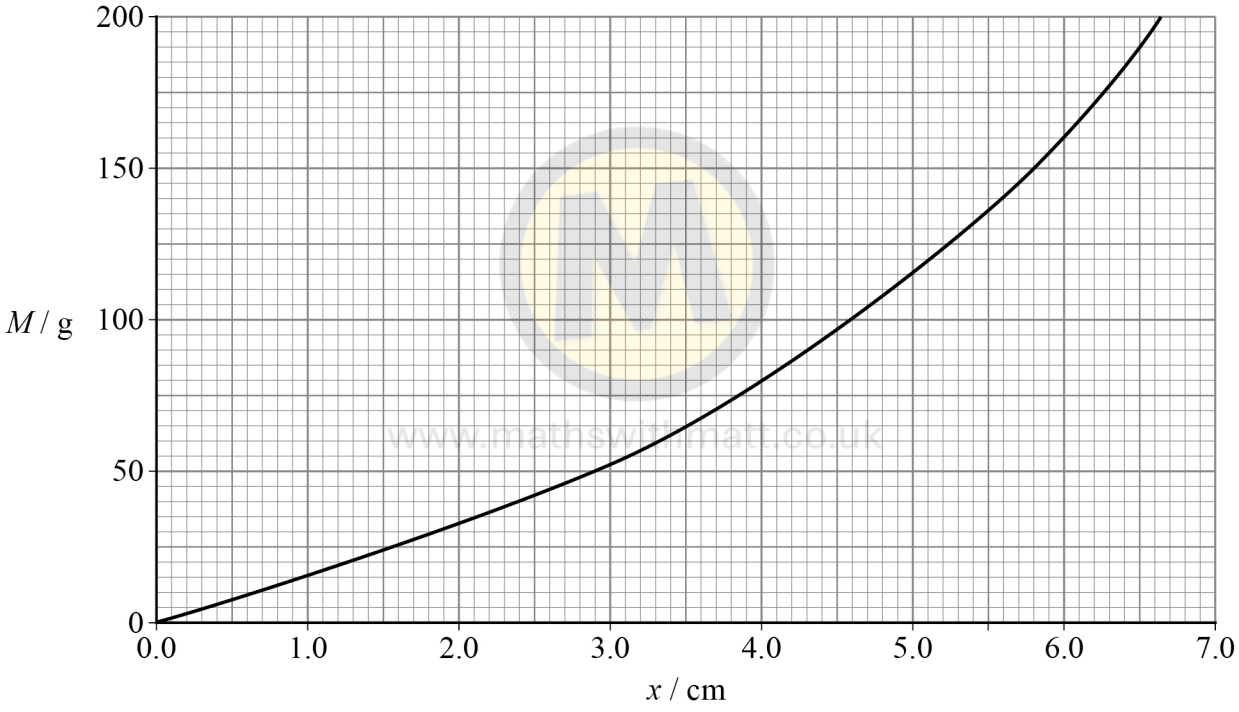
Show that, for the arrangement in **Figure 10**,

$$\frac{m}{M} = \frac{(12.0 - x)}{x}$$

[2 marks]

0 3 . 3 **Figure 11** shows how x varies with M.

Figure 11



Determine, using **Figure 11**, the weight of the empty spoon.

[3 marks]

weight = _____ N

Turn over ►

Do not write outside the box

0 3 . 4 A scale, in grams, is marked on the spoon between **P** and the bowl. **Figure 11** is used to calibrate this scale in intervals of $25\ \text{g}$.

M can be measured by balancing the spoon. The value is read from the point of the scale directly above the pivot.

State and explain how the uncertainty in the value read from the scale changes as M increases.

[3 marks]

10

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Question	Answers	Additional Comments/Guidance	Mark	AO
03.1	idea that moments are balanced or that there is no resultant moment ✓ (because) (overall) centre of mass is now beneath/at **Q** **OR** line of action of (overall) weight is through **Q** ✓	Answer must relate to the context e.g. reference to **Q** or weight of food/spoon Allow 'force × distance' or '$\mathrm{F} \times \mathrm{d}$' for 'moment'. 'Anticlockwise moment of weight of spoon about **Q** = clockwise moment of weight of M about **Q**' gains both marks.	2	AO1

Question	Answers	Additional Comments/Guidance	Mark	AO
03.2	statement of balanced moments seen e.g. $mgx = Mg(16 - 4 - x)$, leading to required formula ✓ ✓	For 1 mark: condone absent g if credible evidence for '$12 - x$' presented e.g. $mx = M(16 - 4 - x)$ or $mx = M(28 - 16 - x)$ **OR** condone lack of evidence for '$12 - x$' if g is shown e.g. $mgx = Mg(12 - x)$. Need to see g and evidence for '$12 - x$' for both marks. Evidence for '$12 - x$' need not be in an expression of a moment. Allow 9.81 or 9.8 instead of g.	2	AO2

Question	Answers	Additional Comments/Guidance	Mark	AO
03.3	max two from: ✓ ✓ • reads off a pair of values (e.g. 115 g, 5.0 cm) • substitutes into formula • multiplies their m by g answer that rounds to 1.5 or 1.6 (N) ✓	Allow correct conversion of M to kg and/or x to m for read offs or in the substitution. Expect to see 160 g for mass of spoon. Allow credit for an algebraic solution to get m: e.g. when $m = M$, $\frac{m}{M} = \frac{(12 - x)}{x} = 1$ So, $12 = 2x$, $x = 6.0$ cm. Reads off M at 6.0 cm to get 160 g.	3	AO1

Question	Answers	Additional Comments/Guidance	Mark	AO
03.4	(absolute) uncertainty in M increases as M increases ✓ (because) as M increases: marks on the scale get closer **OR** range of values of M for a fixed range of x increases (or vice versa) ✓ the gradient (in Figure 11) increases so the scale markings are unequal owtte ✓	MP1 only awarded supported by some relevant explanation. Treat 'percentage' uncertainty as neutral. Allow MP2 and MP3 for quantitative evidence given using Figure 11 e.g. from 0 g to 25 g, $\Delta x \sim 1.5$ cm; from 175 g to 200 g, $\Delta x \sim 0.4$ cm **OR** calculates gradients at low and high M.	3	AO3
Total			**10**	

Do not write outside the box

0 2 In 2021 the world land speed record was $1230\ \text{km h}^{-1}$.
This was the average speed achieved by a jet-powered car in two runs. Each run was measured over a distance of $1.61\ \text{km}$.

0 2 . 1 The average speed for one of these runs was $343\ \text{m s}^{-1}$.

Calculate, in s, the time taken for the car to complete the other run.

[2 marks]

time = _____ s

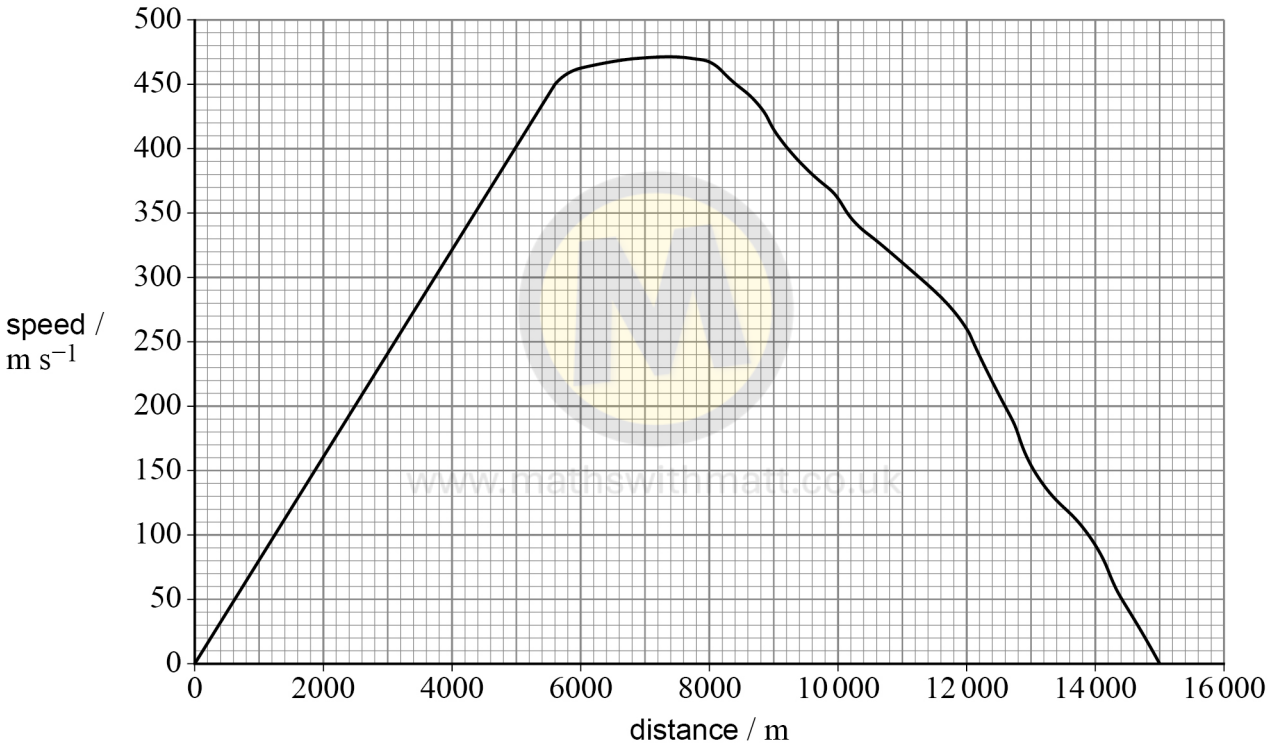
Question 2 continues on the next page

Do not write outside the box

0 2 . 2 Engineers are designing a new jet-powered car to break this record.

Figure 1 shows the variation of speed with distance for the car, as predicted by the engineers.

Figure 1



The car reaches its maximum acceleration when it is $5600\ \text{m}$ from the start.
At this point the mass of the car is $6.50 \times 10^3\ \text{kg}$.

Determine the kinetic energy of the car at its maximum acceleration.

[2 marks]

kinetic energy = _____ J

Do not write outside the box

0 2 . 3 At any point on the graph in **Figure 1**, the acceleration is given by:

acceleration = speed × gradient of line

When the car is at its maximum acceleration, the power input to the jet engines is 640 MW.

Calculate the percentage of the input power used to accelerate the car at its maximum acceleration.

[4 marks]

percentage of input power = _____ %

0 2 . 4 Scientists recommend that the average deceleration of the driver of the car should be less than $3g$.

Deduce whether the average deceleration is less than $3g$.

[2 marks]

_____

_____

10

Question	Answers	Additional comments/Guidelines	Mark	AO
02.1	Conversion of $1230\ \text{km h}^{-1}$ to m s^{-1} OR Calculates time for $343\ \text{m s}^{-1}$ run OR Calculates total time (using total distance, $3.22\ \text{km}$, and speed record) OR Calculates unknown speed ✓ Answer that rounds to $4.73\ (\text{s})$ ✓	Expect to see $342\ \text{m s}^{-1}$ (341.7) Expect to see $4.69\ \text{s}$ Expect to see $9.42\ \text{s}$ Expect to see $340.3\ \text{m s}^{-1}$ Do not accept 2sf for final answer.	2	AO1 AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
02.2	speed from graph: $450\ \text{m s}^{-1}$ ✓ Use of their speed and KE equation to give consistent answer ✓	Accept 445 – 455 m s^{-1} Expect to see 6.6×10^{8} (J)	2	AO3 AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
02.3	**MAX three** from: ✓✓✓ • Use of graph to determine gradient • Uses (their) speed and (their) gradient to give acceleration • Use of $F = m \times (\text{their } a)$ to give resultant force • Use of $P = (\text{their } F) \times (\text{their speed})$ Final answer between 16% and 17%✓	Expect to see 450 m s^{-1} for their speed Evidence for gradient may be on figure Allow ECF from **02.2** • $\frac{450}{5600} = 0.080(4)$ • Expect to see $450 \times 0.08 = 36(.2) \text{ m s}^{-2}$ • Expect to see $2.35 \times 10^5 \text{ N}$ • Expect to see $450 \times 2.35 \times 10^5 = 106 \text{ MW}$ Reject power that is calculated assuming a constant speed.	4	AO1 AO2 2× AO3

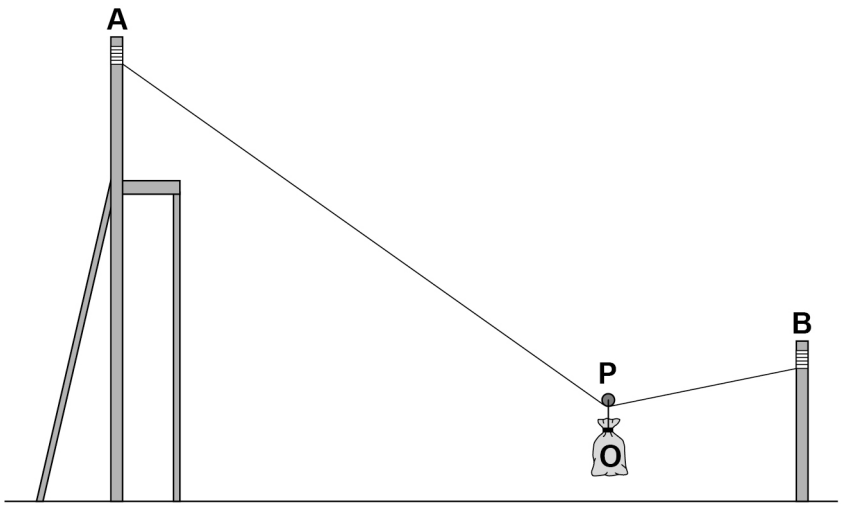
Question	Answers	Additional comments/Guidelines	Mark	AO
02.4	Identifies distance decelerating **AND** max velocity = (470 ± 5) m s^{-1} ✓ Uses *suvat* equation(s) to get $a = (-)\ 15$ m s^{-2} which is less than $3g$ (so yes). ✓	allow 7000 m to 7600 m allow answer consistent with their distance that rounds to 15 or 16 give full credit to calculations that show that an acceleration of $3g$ would stop the car in a (much) shorter distance, with a statement that this means that the actual acceleration must be (much) less than $3g$. For MP2 allow calculation of gradient × average speed to give $a = (-)\ 15$ m s^{-2} which is less than $3g$ (so yes)	2	AO3
Total			**10**	

0 5 A cable system is to be used to transfer supplies across a river. A model of the proposed system is built in order to test its performance.

The model consists of a cable attached to two vertical posts **A** and **B**, as shown in **Figure 3**.
A pulley **P** of negligible mass is attached to the cable.

In this question the length of the cable does not change and the weight of the cable can be ignored.

Figure 3



An object **O** is attached to **P**. In one test, **O** and **P** are at rest in the position shown in **Figure 3**.
The weight of **O** is 350 N.

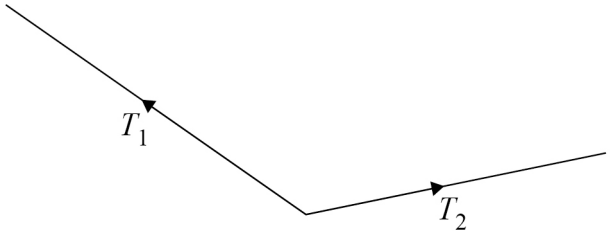
Do not write outside the box

0 5 . 1 **Figure 4** is a force diagram drawn to scale. It represents the magnitudes and directions of the tensions T_1 and T_2 in the cable when **O** is at rest in the position shown in **Figure 3**. At this position, resistive forces are zero.

Complete the force diagram.
Go on to determine, using your diagram, the magnitudes of T_1 and T_2.

[4 marks]

Figure 4



$T_1 =$ _____ N

$T_2 =$ _____ N

Do not write outside the box

0 5 . 2 In a second test, pulley **P** with **O** attached is released from **A**.
P and **O** move along the cable to **B**.

The change in height of the centre of mass of **O** between **A** and **B** is $4.5\ \text{m}$.
The distance travelled along the cable is $18\ \text{m}$.

The speed of **O** when it reaches **B** is $6.5\ \text{m s}^{-1}$.

Calculate the average resistive force on **O** and **P** as they move from **A** to **B**.

[5 marks]

average resistive force = _____ N

Question 5 continues on the next page

Do not write outside the box

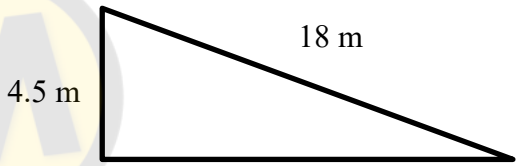
0 5 . 3 **O** contains a fragile item packed in suitable material.

Explain how the material can prevent damage to the fragile item when **O** stops suddenly at **B**.

[3 marks]

12

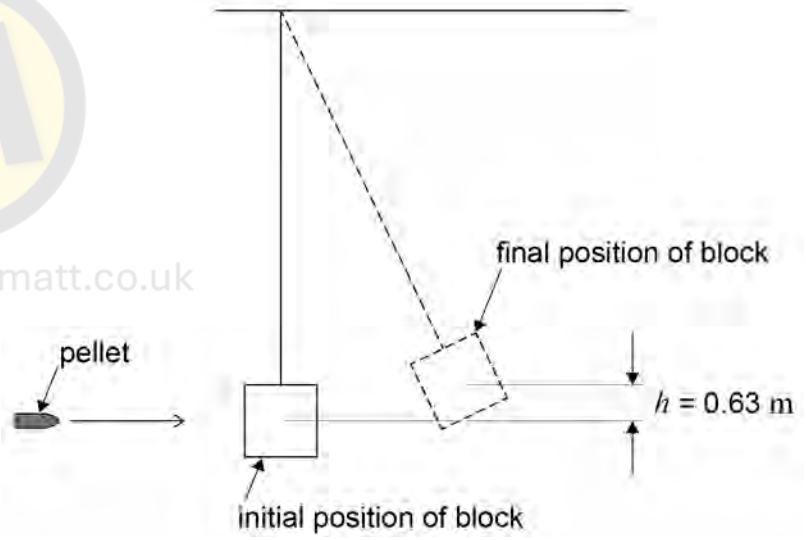
Question	Answers	Additional comments/Guidelines	Mark	AO
05.1	Formation of a parallelogram OR triangle to draw W 1✓ Use of their W to obtain the scale at which force diagram is drawn 2✓ Use of their scale to obtain T_1 and T_2 3✓ $T_1 = 480$ N AND $T_2 = 400$ N 4✓ **Alternative Approach 1** Formation of a parallelogram OR triangle to draw W 1✓ Both angles measured correctly/evaluated to be (34 — 35)° and (11 — 12)° 2✓ $T_1 \sin 34 + T_2 \sin 11 = 350$ AND $T_1 \cos 34 = T_2 \cos 11$ 3✓ $T_1 = 480$ N AND $T_2 = 400$ N 4✓	Correct by eye. If a hybrid approach is used, note that MP2 is given for a measurement of their W used to determine a scale OR for the measurement of the two angles within range. If correct values in range seen for MP4, then it can be assumed that a scale was used to obtain T_1 and T_2, MP3 can be awarded Expect to see: $\frac{350}{35}$ mm = 10 N mm^{-1} $T_1 = 48$ mm × 10 $T_2 = 40$ mm × 10 Range: allow T_1 470 – 490 N and T_2 390 – 410 N Allow complementary angles where quoted. In MP3 allow their angle values OR angle symbols consistent with labels on their diagram. Allow correct application of sine or cosine rules. Range: allow T_1 470 – 490 N and T_2 390 – 410 N	4	AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
05.2	Max 4 from: • $m = \frac{350}{g}$ ✓ • their m to give KE with v = 6.5 m s^{-1} at B ✓ • 350 N and 4.5 m in GPE equation✓ • evidence of *their* Δ*GPE* – *their* Δ*KE* to give work done against friction ✓ • evidence of friction force $= \frac{\text{their work done}}{18}$ ✓ Calculates average force = 46 N ✓	Expect to see 36 kg Expect to see 754 J Expect to see 1575 J Expect to see 821 J Alternative for first **four** marks. Must see a labelled diagram indicating use of this approach:  If the diagram is not seen, mark according to the main scheme (in the 'Answers' column). Max 4 from: • $m = \frac{350}{g}$ ✓ • Use of suvat to obtain a = 1.17 m s^{-2}✓ • Uses $F = ma$ to obtain their effective resultant force✓ • Uses 350 × (4.5÷18) or equivalent to obtain their effective component of weight✓ • Subtracts their resultant force from their component of weight✓ Accept answers that round to 46 N.	5	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
05.3	Idea that contact time or distance travelled during contact is increased ✓ Generic mark scheme for MP2 and MP3 • reference to physical principle ✓ • application of principle to explain why force is reduced ✓	**Momentum approach (time increased)** • reference to Force is rate of change of momentum • change in momentum/impulse/ $F \times \Delta t$ constant therefore force decreased **Energy approach (distance increased)** • reference to force × distance = change in KE/work done • change in KE/work done/$F \times s$ constant so force reduced **Newton 2 approach (time/distance increased)** • reference to Force = mass × acceleration • change in velocity constant, so acceleration reduced so force reduced	3	AO3
Total			**12**	

0 4 The speed of an air rifle pellet is measured by firing it into a wooden block suspended from a rigid support.
The wooden block can swing freely at the end of a light inextensible string as shown in **Figure 3**.

Figure 3



A pellet of mass 8.80 g strikes a stationary wooden block and is completely embedded in it. The centre of mass of the block rises by 0.63 m. The wooden block has a mass of 450 g.

0 4 . 1 Determine the speed of the pellet when it strikes the wooden block.

[4 marks]

speed = _____ m s^{-1}

0 4 . 2 The wooden block is replaced by a steel block of the same mass.
The experiment is repeated with the steel block and an identical pellet. The pellet rebounds after striking the block.

Discuss how the height the steel block reaches compares with the height of 0.63 m reached by the wooden block. In your answer compare the energy and momentum changes that occur in the two experiments.

[4 marks]

0 4 . 3 Discuss which experiment is likely to give the more accurate value for the velocity of the pellet.

[2 marks]

04.1	Max GPE of block = Mgh = 0.46 x 9.81 x 0.63 = 2.84 J ✓ Initial KE of block = ½ Mv^2 = 2.84 J Initial speed of block v^2 = (2 × 2.84)/0.46 v = 3.51 ms^{-1}✓	The first mark is for working out the GPE of the block The second mark is for working out the speed of the block initially The third mark is for working out the momentum of the block (and therefore pellet)	1 1

	momentum lost by pellet = momentum gained by block = Mv = 0.46 x 3.51 = 1.61 $kg\ m\ s^{-1}$ ✓ Speed of pellet = 1.58 / m = 1.58 / 8.8 x 10^{-3} = 180 ms^{-1} (183) ✓	The final mark is for the speed of the pellet At each step the mark is for the method rather than the calculated answer Allow one consequential error in the final answer	1 1

04.2	As pellet rebounds, change in momentum of pellet greater and therefore the change in momentum of the block is greater ✓ Initial speed of block is greater ✓ (Mass stays the same) Initial KE of block greater ✓ Therefore height reached by steel block is greater than with wooden block ✓	Ignore any discussion of air resistance	1 1 1 1

04.3	Calculation of steel method will need to assume that collision is elastic so that change of momentum can be calculated ✓ This is unlikely due to deformation of bullet, production of sound etc.✓ And therefore steel method unlikely to produce accurate results.		1 1